Obsidian Tool Function and Settlement Pattern during the Middle – Late Holocene on Garua Island, West New Britain, Papua New Guinea

Volume 1 – Text

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Statement of Originality

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text.

Statement of Contribution by Others

To the best of my knowledge and belief, the "Acknowledgements" section of this thesis outlines the contribution of others to the intellectual, physical and written work presented in this thesis.

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The background to this thesis extends over many years and many people have contributed to my interest in use-wear on stone tools by sharing their knowledge of lithic technology. I would like to express my gratitude to my Australian, Russian, American, Korean and Japanese colleagues who have helped me to develop my knowledge of lithic technology.

Before undertaking this doctoral thesis, I spent more than thirty years in the study of Archaeology, having started my scientific career at the Institute of History, Archaeology and Ethnography of the People of the Far East, Far Eastern Branch of Russian Academy of Sciences, in 1974. From 1978 to 1981, I undertook post-graduate studies at the Leningrad Branch of the Institute of Archaeology, Academy of Sciences of the USSR, Saint Petersburg, and I would like to express my gratitude to my teachers, Dr Sergei Alexandrovich Semenov and Dr Gallina Fedorovna Korobkova, who both personally introduced me to use-wear methodology at that time. My dissertation was entitled "The Technology of Stone Tools and the Economy of Tribes in the Maritime Region of the Far East: 3,000 – 2,000 BC". In Australia, from 2002, Dr Richard Fullagar assisted me to expand my knowledge of use-wear/residue analysis and my association and collaboration with him has been extremely valuable in exploring the value of the microscopic examination of artefacts to use-wear analysis and to Archaeology. I offer my special thanks to Dr Richard Fullagar for his productive comments on my final draft.

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List of Publications

Publications by the Candidate Relevant to the Thesis

Kononenko, N.A.

Kononenko, N. and R. Fullagar.

Hong, M. and Kononenko, N. A.

Torrence, R., Swadling, P., Ambrose, W., Kononenko, N., Rath, P. and Glascock, M.

Kononenko, N., R. Torrence and T. Doelman.
In prep. Functional Analysis of Stemmed Tools from Garua Island, West New Britain.

Additional Publications by the Candidate Relevant to the Thesis but not Forming Part of It


In press. Raman spectroscopy applied to understanding prehistoric obsidian trade in Melanesia. Vibrational Spectroscopy. Accepted 03.02.08.

Kononenko, N. and J. Specht.
In prep. Late Holocene stemmed tools in New Britain, Papua New Guinea.

Total of 122 other publications including 7 cooperative monographs.
Abstract

This thesis tests hypotheses previously proposed by scholars about the function of obsidian tools and their relationship with various aspects of human behaviour in the middle and late Holocene. Based on the functional analysis of a large sample of obsidian artefacts recovered from the FAO site on Garua Island, West New Britain, Papua New Guinea, this research has made significant contributions to both (1) use-wear methodology in the study of lithic assemblages and (2) new interpretations for subsistence, settlement patterns and mobility of the middle and late Holocene populations on Garua Island, with implications for the Bismarck Archipelago generally.

A comparative approach was developed in order to understand how use-wear is formed and the potential impact of taphonomic factors. This approach involved comparisons of (1) extensive replication experiments and (2) studies of archaeological assemblages of obsidian artefacts from Vanuatu, Korea and Russia to reconstruct tool use on the basis of a microscopic study of artefact edges viewed at high magnification. Task-oriented experiments involving 292 obsidian tools were conducted. Some materials not previously incorporated into obsidian use-wear experiments were included to broaden the range of use-wear patterns. The extensive and detailed photographic documentation of wear patterns observed on artefacts and experimental tools has generated an important resource for future comparative studies of obsidian assemblages both in the Pacific region and elsewhere.

My integrated use-wear/residue study of 190 obsidian tools from FAO on Garua Island has significantly extended the documented range of functions of obsidian tools used for subsistence, craft and social activities, some of which had not been previously recognised as occurring in the middle and late Holocene periods in Papua New Guinea. Most of the tools had been used in craft activities, notwithstanding their chronological origin. Plant and non-plant materials were worked with obsidian tools using various modes of use and a range of materials. The working of skin, particularly piercing, is probably related to tattooing and scarification of the human body in both Papua New Guinea and Korea, and suggests a social function of stone tools not previously recognised within lithic assemblages. With rare exceptions, flakes were used for short periods of time as single purpose tools in both chronological periods confirming an
expedient tool use strategy as a common technological feature in the Bismarck Archipelago throughout the Holocene.

For most of the middle and late Holocene assemblages in the Bismarck Archipelago, no previous attempt has been made to establish the structure and organisation of activities at a particular site through a systematic analysis of used tools and the pattern of their discard. My research provides evidence that the FAO site was re-occupied repeatedly during both periods, although a slightly different approach to the use of the space is apparent in the late Holocene. Moreover, my systematic study of obsidian tool use has revealed continuity in subsistence practices, settlement strategies and tool use patterns on Garua Island, during both the middle and late Holocene. This significant result suggests that the human populations had a low level of mobility and that gardening practices were developed in West New Britain before the Lapita pottery tradition was introduced into the region following the W-K2 catastrophic eruption. This conclusion is consistent with hypotheses of other scholars.

Furthermore, the absence of obvious changes in the strategy of tool use, settlement organisation and subsistence activities coinciding with the appearance of new social groups with Lapita pottery, new lithic technology, advanced agricultural practices and domesticated animals, raises a number of important issues. These issues need to be resolved through further investigation of the relationship between the function of tools and available environmental resources and the cultural and social activities of the middle and late Holocene populations in the Bismarck Archipelago. These new issues emerged from use-wear/residue studies of stone tools and are critical for understanding the processes involved in the development and spread of the Lapita Cultural Complex in the Pacific region.
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</table>
The middle and late Holocene in the Bismarck Archipelago represent the most intriguing chronological periods because of the dramatic changes in human behaviour which occurred 6000 – 2000 years ago. The archaeological record demonstrates an intensive movement of people into new landscapes, the development of complex patterns of maritime transportation and the establishment of new economic and social networks (Kirch 1997:39-42; Spriggs 1997:43-66). Crucial changes occurred in subsistence and settlement patterns about 3,300 years ago with the advent of the Lapita Cultural Complex and the associated development of pottery, agriculture and the introduction of domesticated pigs, dogs and chickens to the region.

There is continuing debate among Pacific scholars about the origin of the Lapita culture. For many scholars, Lapita is thought to signify the arrival of a new people and new technologies (e.g. Green 2003; Kirch 1997:45-52; Spriggs 1997:67-106). Alternatively, some scholars suggest that the Lapita culture originated in the Bismarck Archipelago from local traditions with the intrusion and influence of some new groups of people with a pottery tradition (Allen 1991, 2003; Allen and White 1989; Green 1991, 2002, 2003; Gosden 1992; Specht, Fullagar and Torrence 1991; Torrence 1992, 2002a; Torrence, Pavlides, Jackson and Webb 2000) or as a result of information exchange which must have involved the movement of people (Summerhayes 2000:233; 2001b:130; 2007:24). Both these explanations are based on comparisons of archaeological records during the key time periods but both positions must be qualified because there is relatively little data available for the middle Holocene. Consequently, the middle Holocene is thought to be a phase of largely non-intensive and unsystematic patterns of resource use and limited economic organisation.

Torrence (1992, 2002a, 2003; Torrence et al. 2000) and Pavlides (2006) propose that the changes in technology, subsistence and settlement patterns observed over time in West New Britain are more complex than simply being attributable to the arrival of a new group. According to these authors, the changes which occurred in the late Holocene demonstrate continuity with the previous pattern of occupation (Pavlides 2006; Torrence 2002a; Torrence et al. 2000). This view of a continuing gradual change in subsistence and settlement patterns and slow decrease in mobility at the end of middle Holocene period, when combined with some trends indicating an intensification of plant exploitation, from gathering to gardening, and an increase of sedentism in the late
Holocene has been supported by preliminary data from use-wear/residue studies of stone tools (Fullagar 1992, 1993a, Fullagar, Loy and Cox 1998; Kealhofer, Torrence and Fullagar 1999). However, the concept of tool use and its link to the overall subsistence strategies needs a more systematic analysis of a range of tools within the wider environmental and archaeological context. The purpose of my research is to assess the strategy of obsidian tool use at an important site, FAO on Garua Island, West New Britain, in order to investigate a number of hypotheses concerning the transition from highly mobile settlement and subsistence patterns to a more sedentary way of life involving an intensified land use pattern in West New Britain, Papua New Guinea.

1.1 History of Research and Current Interpretation

In contrast to other areas of the Bismarck Archipelago, intensive research on the Willaumez Peninsula in West New Britain, Papua New Guinea, by Specht and Torrence, has identified a number of sites containing evidence of both the middle and late Holocene periods of occupation (e.g. Specht 1974; Specht and Torrence, 2007; Specht, Fullagar, Torrence and Baker 1988; Torrence 1992, 2002a, 2004a, 2004b; Lentfer and Torrence 2007; Torrence and Stevenson 2000; Torrence et al. 2000). Furthermore, long-term research on Garua Island, conducted by Torrence and her team (Torrence 1992; 2002; Torrence and Summerhayes 1997; Torrence and Stevenson 2000; Torrence et al. 2000) covered different aspects of human behaviour within the unstable volcanic landscape during the middle and late Holocene. Specific attention was drawn to the organisation of obsidian raw material procurement, technology of production, use and discard of tools across the landscape (Torrence 1992, 2002a; Torrence and Summerhayes 1997; Summerhayes 2000, 2001a, 2001b, 2003, 2004; White 1996). Torrence (1992:121) has proposed that the main limitations on the form of tools, the strategy of their manufacture, the pattern of use and discard was the extent of residential mobility and the intensity of the food production system. Chronological analysis of settlement patterns, reconstructions of cultural landscapes through distributional patterning of artefacts, technological and obsidian characterisation studies and preliminary use-wear/residue examination of selected artefacts have all been used to support a hypothesis of gradual change and cultural continuity in human behaviour from the middle to the late Holocene in West New Britain (Torrence 2002a, Torrence et al. 2000).
1.2 Previous Use-Wear and Residue Analyses

Lithic use-wear/residue research can contribute significant data and address important questions relevant to general patterns of human behaviour: e.g. how were artefacts used; what materials were processed; what activities took place; how settlements functioned within particular socio-cultural systems; and, how and what may have caused change within these systems (e.g. Ahler 1979; Aldenderfer 1991a, 1991b, 1998; Aldenderfer, Kimbal and Sievert 1989; Anderson-Gerfaud 1990; Dillehay 1997:507; Fullagar 1994; Hayden and Kammenga 1979; Hurcombe 1992:64-66; Ibáñez and González 2003; Odell 1996b; Odell, Hayden, Johnson, Kay, Morrow, Nash, Nassaney, Risk, Rondeau, Rosen, Shott and Thacker 1996; Schiffer 1972, 1979).

The change in both subsistence strategy and lithic technology during the middle and late Holocene in West New Britain, and on Garua Island particularly, suggests some differences in the organization of tool use between these periods. This assumption was supported by Fullagar's (1992, 1993b, Fullagar et al. 1998) use-wear/residue examination of selected artefacts from middle and late Holocene sites located in the Kandrian region, on the Arawe Islands, in the Talasea area and on Garua Island. On the basis of use-wear and residue analysis, Fullagar (1992, 1993a, 1993b) came to the conclusion that, firstly, middle Holocene stone assemblages are mainly characterized by both multi-functional and single purpose tools which were used primarily for processing plant materials and, moreover, that the presence of only a few tool-using activities and a limited range of tasks performed at individual sites, indicate a high level of mobility during this period. Secondly, during the late Holocene nearly all activities were performed at the sites he studied, suggesting a decline in mobility over time. Late Holocene tools indicate more expedient manner of use: after the performance of only one task, they were usually discarded (Fullagar 1992:139-140).

These preliminary results were further tested by more detailed residue studies observed on obsidian artefacts, including phytoliths and starch grains (Barton, Torrence and Fullagar 1998; Fullagar 1993b; Kealhofer et al. 1999). Such an integrated approach to the study of tool function is able to provide a new perspective for a more comprehensive reconstruction of subsistence and settlement history in the Bismarck Archipelago (Fullagar 1994, 1998, 2006a, Fullagar, Field, Denham and Lentfer 2006). However, despite the significant contribution made by integrated studies of use-wear and residues on stone tools from sites in the Pacific region (e.g. Barton and Fullagar 2006; Barton and Matthews 2006; Barton and White 1993; Barton et al. 1998; Fullagar
current interpretations of subsistence and settlement patterns in the Bismarck Archipelago leave many questions under-resolved and require more complete use-wear information about the lithic assemblages. This is an especially important subject for further research into those archaeological assemblages of the middle and late Holocene which consist of mainly stone artefacts. Garua Island with obsidian sources and an abundance of prehistoric stone artefacts widely spread across the landscape and over long time scales is one of the local areas within the Bismarck Archipelago about which more needs to be known. The prehistory of this island is closely connected to the unique history and experience of people who colonised the vast region of the Pacific during the Holocene.

A systematic use-wear/residue analysis of obsidian artefacts recovered from FAO, which is located on Garua Island, West New Britain, provides the opportunity of improving knowledge of the strategy of tool use and day-by-day activities of the people who inhabited the island's landscape during the middle and late Holocene. FAO contains well stratified deposits with an abundance of obsidian artefacts associated with both the middle and late Holocene periods. Use-wear/residue examination of these artefacts makes it is possible to further examine the extent to which the pattern of tool use can differ between these two periods and allows an assessment of the impact of the advent of a society, represented by the Lapita pottery tradition in the archaeological record, on subsistence and settlement patterns on Garua Island.

1.3 Aims and Scope of Research

The aims of this research project are: (1) to examine the patterns of obsidian tool use in both the middle and late Holocene periods at FAO; (2) to investigate the relationship between tool assemblages and various aspects of subsistence activities, settlement organisation and residential mobility; and, (3) to examine the impact of the Lapita pottery society on subsistence and settlement patterns of the inhabitants of this particular site and on Garua Island generally.

The obsidian assemblages recovered from FAO provide evidence of strategies for the procurement and processing of food and non-food resources by prehistoric people utilising the environment in which they lived. Use-wear/residue analysis identifies tool kits and therefore suggests the range of activities that took place at the site. The guiding
hypotheses of this project are that tool use patterns and the structure of associated activities will be similar within societies with either mobile or semi-sedentary styles of life because of three interrelated factors: (1) common physical needs of human beings in the use of food and non-food resources; (2) similarities in ecological conditions over time providing a relatively stable set of available environmental resources required to maintain human communities; and, (3) specific physical properties of obsidian raw material which restricts the number of possible technical solutions to the performance of particular tasks and inevitably creates similarities in the mode of use of prehistoric tools.

The alternative hypothesis is that a high level of mobility in human society during the middle Holocene on Garua Island was associated with selective approaches to the procurement of particular food or non-food resources within a similar environment and this produces the specific range of tool function and associated activities and, consequently, the change in patterns of tool use.

To test these hypotheses, a number of related predictions will be examined using data obtained through use-wear/residue analysis of obsidian artefacts and considered in association with their archaeological context. The predictions are that:

- Relatively fewer stone artefacts with intensive use-wear patterns would have been discarded if the site was occupied by mobile people for a short time period during the middle Holocene. In contrast, during the Late Holocene, a relatively long-term period of occupation of sites would produce a significant increase in finds of used and discarded flakes with an uncertain or low intensity of use-wear on the working edge reflecting the short-term use of tools used for a variety of tasks.

- Intermittent and short-term use of the site for particular tasks during the middle Holocene should result in a relatively equal distribution of discarded artefacts with no spatial definition of the organisation of activities. In contrast, a relatively long-term period of occupation of the site during the Late Holocene would create concentrations of used and discarded artefacts and identifiable areas of activities. The identification of the spatial distribution of these concentrations at the site may describe the pattern of organisation of activities within a single settlement.

- Changes in the pattern of tool use and in the structure and organisation of activities over time become evident then these changes should correlate with shifts in patterns of mobility as proposed by Fullagar (1992) and Torrence (1992). However, if tool use patterns and activities are similar for both middle
and late Holocene occupations, then the same model of settlement patterns should be inferred: either high mobility or semi-sedentary way of life for both periods.

In addition, many other questions will also be addressed in this study. For instance, to what extent is use-wear/residue analysis of artefacts able to indicate chronological differences in subsistence and stone tool technology? What is the relationship between the function of stemmed tools and their morphological and technological attributes, and how are they able to be considered as the signature of curated technology? Do the distinctive use-wear characteristics on obsidian artefacts alter over time and in what way? Are there changes in surface alteration and how do these influence the functional interpretation of tools? My research is intended to provide important information on issues that are related to the middle and late Holocene cultural sequences on Garua Island particularly and to the broader context of the Bismarck Archipelago prehistory generally. This approach will also assist in evaluating the roles played by environmental and social factors in long-term changes that occurred in prehistoric cultures of the Pacific region.

1.4 Research Design and Methods

I have chosen integrated use-wear and residue analysis as the most appropriate method to investigate the function of obsidian artefacts. This method was first applied to Pacific obsidian tools by Fullagar (1986, 1991, 1992). In this research project, I have applied use-wear analysis and have used supplementary residue studies with the intention of determining links between the way in which stone artefacts were made, used, and discarded and some more fundamental aspects of behaviour such as subsistence, technology and settlement strategy. My research was organised to provide a systematic, functional analysis of a wide range of obsidian artefacts found at FAO on Garua Island, West New Britain, Papua New Guinea. In addition, comparative use-wear/residue data obtained from a number of obsidian artefacts from late Holocene sites on Aore Island, Vanuatu, the Zara site in Primorye, Russia and the Hopyeong-dong Upper Paleolithic site enhanced the reliability of my functional interpretation of tools from Garua Island. This approach involved the examination of use-wear/residue characteristics within the context of broader behavioural systems identified by changes in the nature of assemblages.
The FAO site was chosen because it has good stratigraphic and temporal control and sufficient chronological depth to allow the observation of changes over time during the middle and late Holocene. As a result of volcanic eruptions, tephras have preserved a series of ancient ground surfaces at the site (Torrence 2002a; Torrence and Stevenson 2000; Torrence et al. 2000). Chronologically well-defined cultural deposits, with an abundance of obsidian artefacts belonging to the middle and late Holocene periods, provide unique opportunities for full-scale, on-site use-wear and residue analysis which has not yet been practicable in Pacific archaeology (Fullagar 1989).

My project involved a total sample of 1381 obsidian artefacts selected from seven test pits at FAO of which 549 artefacts are from the middle Holocene deposit and 832 artefacts from the late Holocene deposit. Microscopic identification of use-wear features and remnant residues required the compilation of a comprehensive image database of the types of use-wear and residues found. This comparative database was the initial focus of my analysis and was achieved through the imaging of relevant use-wear and residues patterns. Experimental replication of a range of activities, relevant to use-wear/residue studies, was conducted during fieldwork at the obsidian sources in West New Britain, as well as in the Laboratory of the Australian Museum. An examination of available literature related to use-wear and, to a lesser extent, residue studies was a necessary part of my research.

The interpretation of the data obtained through microscopic identification required comparative analysis with experimental database in order to distinguish characteristic patterns of observed use-wear generated by specific tasks and functions. Tables of use-wear features and associated residues which occurred concurrently pertained to a particular task or function were constructed and these were employed during analysis to infer individual artefact use. These results were extrapolated to reconstruct activities involving artefact use in each chronological period.

1.5 Thesis Organisation

I begin the thesis by defining the aims and scope of my research within the framework of middle and late Holocene archaeology on Garua Island and the wider context of prehistory in the Bismarck Archipelago. Models explaining these periods are briefly outlined and I propose use-wear and residue analyses of stone tools as being reliable approaches for the reconstruction of human behaviour during both the middle and late Holocene in the Pacific region.
Prior to outlining the methodology used in this research, a brief review of current hypotheses about settlement patterns, subsistence and stone technology during the middle and late Holocene periods in the Bismarck Archipelago and Garua Island are reviewed in Chapter 2. The main aim of this chapter is to examine what is known about tool use behaviour of human populations during these key periods and to investigate the extent to which changes in subsistence and settlement strategies may be recognised through tool function.

The next part of the thesis is devoted to establishing an appropriate methodology for functional analysis of obsidian artefacts (Chapters 3 and 4) and then archaeological application of this methodology is considered (Chapter 7 and 8).

Chapter 3, therefore, describes the analytical methods and approaches employed in the study of function of stone artefacts and particularly of obsidian tools. Functional studies of prehistoric artefacts generally aim to provide at least two types of information: (1) the way in which the tool was manipulated (use-action) and (2) the material on which it was used (use-material). The level of definition of these basic aspects of functions differs according to the analytical methods employed. Several approaches have been developed for flint artefacts, but there is little published work employing the functional approach for obsidian tools. The first use-wear study of obsidian tools was initiated by Semenov (1964) who emphasized that wear on obsidian will be quicker to appear than on flint, and the form of wear will be slightly different on obsidian. Hurcombe (1992) shows that differing physical and chemical properties of flint and obsidian mean that approaches devised for flint tools are not necessarily relevant to obsidian assemblages. There are two important recent developments in the approaches adopted for obsidian use-wear analysis. The first concentrates on the study of distinctive polishes and other use-wear features observed on tools under high magnifications (e.g. Fullagar 1986; Hay 1977; Hurcombe 1992; Kamminga 1982; Kazarjan 1990; Keeley 1980; Mansur-Franchomme 1983; Vaughan 1985). The second recently developed approach is the investigation of residues on stone tools, including phytoliths, blood and starch residues (e.g. Anderson-Gerfaud 1988; Barton et al. 1998; Fullagar 1998, 2006a, 2006b; Kealhofer et al. 1998; Loy 1983, 1993; Robertson 2005). I have used previous theoretical and experimental work on obsidian tools to determine those use-wear variables which are important in an examination of artefacts. I have undertaken the integrated use-wear/residue study of prehistoric obsidian tools in my research project.
An important methodological component of the functional study of stone tools is replication experiments. Chapter 4 is devoted to my experimental program. My study addresses three interrelated problems that were examined through 292 task-oriented and controlled experiments involving the replication and use of obsidian tools similar to the archaeological samples found at the site. The first problem that I encountered arises from theories about the formation of use-wear and residues on obsidian because this process is not well understood (Hurcombe 1992:57-61; Fullagar 1991). My experimental study of the formation of wear features, including scarring, striations, edge rounding, polish and residues, together with a systematic recording procedure for microscopic wear provides an essential and reliable database for the interpretation of use-action and the identification of use-material on prehistoric obsidian artefacts.

The second theme of my experimental program is the determination of the relationship between wear patterns, tool efficiency and use duration in respect of tools involved in the processing of a wide range of tropical plants as well as non-plant materials which were, and are, used by indigenous people in West New Britain and can be suggested to have been used by prehistoric populations. Finally, the design of my experiments focused on obtaining functional data comparable with archaeological tools to allow the function of artefacts to be identified. These data are used to answer wider questions about past human behaviour, such as subsistence, craft activities and settlement pattern.

The environment in which the middle and late Holocene population used the tools is an important source of information about the nature of resources which were available to humans on Garua Island during the middle and late Holocene. The processing activities associated with these resources involved the use of stone tools and created use-wear on the working edges of those tools. Chapter 5 introduces the environmental and historical background of the study area including a brief geological and volcanic history of the region, sea level change, the geographical setting of the site, the ecological structure and the dynamics of local landscapes in the context of the marine environment surrounding Garua Island.

The archaeological context of the artefacts studied in this project is detailed in Chapter 6 which describes the excavation of the FAO site, the stratigraphical sequence of deposits and the chronology and spatial distribution of the obsidian artefacts recovered by the excavation.

Based on the environmental and archaeological contexts of the lithic assemblages and the methodological approaches for the study of obsidian artefacts, the next step of
this research involved the application of integrated use-wear/residue study of archaeological stone material from FAO. The results of use-wear/residue analysis of obsidian artefacts from the middle and late Holocene periods are presented in Chapter 7. The range of identified tools used to process a variety of plant and non-plant materials at FAO, is summarised. Similarities and differences in the functional and morphological characteristics of tools and their relationship with particular activities in each chronological period are discussed together with my interpretation of a range of tools and activities.

Data derived from my use-wear/residue examination of obsidian artefacts together with available archaeological information from neighbouring regions, ecological evidence and ethnographic materials provide the basis for new explanations of middle and late Holocene human behaviour which are outlined in Chapter 8. By interpreting tool function, I make inferences about various categories of daily activities which occurred at the site, intra site structure, settlement pattern, technological organisation and mobility for each particular chronological period under investigation.

Chapter 9 summarises my conclusions in relation to the various hypotheses on tool use behaviour, subsistence, settlement patterns and the mobility (or otherwise) of human populations in the middle and late Holocene. The broader implications of my research into the function of obsidian artefacts are also discussed.

In summary, this thesis sets out to tests hypotheses proposed by previous scholars about the function of obsidian tools and their relationship with various aspects of subsistence, settlement and mobility patterns in the middle and late Holocene and is based on the functional analysis of a large sample of obsidian artefacts recovered from the FAO site on Garua Island.
Chapter 2

Middle and Late Holocene Prehistory in the Bismarck Archipelago and Garua Island.

2.1 Introduction

The task of this chapter is to briefly review previous research on middle and late Holocene settlement patterns and subsistence in the Bismarck Archipelago with specific reference to the information derived from lithic assemblages. I will examine archaeological data which has been used to reconstruct human behaviour and assess the extent to which flaked artefacts have been used by scholars to support hypotheses and explanations related to the economic and cultural changes and residential mobility of the societies that inhabited the Bismarck Archipelago during the middle and late Holocene.

The development of subsistence practices and settlement patterns in both periods has been the subject of discussion and speculation among scholars because of variation in the degree of organic preservation from different sites. Organic remains of resources used by prehistoric people have only been preserved on a few open sites. Much more information is available from rock shelters and cave sites, although these types of sites were rarely used by people in the middle and late Holocene. Despite these limitations, available data provide significant proxies for the interpretation of changes in environments, settlement and subsistence strategy over the long period of human occupation of the Bismarck Archipelago. A review of information regarding past resource use derived from excavations in which organic material was found is especially relevant and useful for gaining an understanding of settlement patterns and subsistence on Garua Island, where material remains, other than tool residues, are only represented by obsidian artefacts in middle Holocene deposits and obsidian artefacts and pottery sherds in late Holocene contexts.

Stone artefacts have been used in different ways to explain past human behaviour in the Pacific region. Previous specific archaeological research and ethnoarchaeological data that refer the use of stone tools is particularly relevant to my interpretation of the function of obsidian tools from FAO. An analysis of both the research approaches involved in the study of stone artefacts and the knowledge as to the way in which stone tools were used, assists in building models about subsistence, settlement pattern and mobility in the behaviour of the inhabitants of Garua Island and the Bismarck Archipelago in the middle and late Holocene.
In the next section, the chronological sequence within the Holocene is outlined with specific reference to the dating of the middle and late Holocene periods in West New Britain. I then describe middle and late Holocene prehistory as it has been established by archaeological data. Finally, the results of previous use-wear/residue studies are briefly described.

2.2 Holocene Chronology

The Bismarck Archipelago played a significant role in the history of human colonisation of the Pacific region. People occupied a variety of ecological zones on the immediate coast and within the interior of large and small islands since the late Pleistocene. This indicates both the technical and cultural ability to overcome sea barriers as well as the ability to cope with interior rain forest environments. Late Pleistocene history is considered as a distinctive phase in human behaviour that is different in some respects from the following Holocene period (e.g. Allen 2000, 2003; Anderson 2000, 2002; Gosden and Robertson 1991; Gosden and Pavlides 1994; Irwin 1992:4-7; O’Connor and Veth 2000; Pavlides 2006; Spriggs 1997:27-30; Torrence, Neall, Doelman, Rhodes, McKee, Davies, Bonetti, Gugliemetti, Manzoni, Oddone, Parr and Wallace 2004).

The Holocene sequence in the Bismarck Archipelago is divided into the Early, Middle and Late Holocene periods, although criteria for each period are not well defined (e.g. Allen 2000; Spriggs 1997:43, 2003; Kirch 2000:78-83; Pavlides 2006; Torrence et al. 2000). The island of New Britain is the only region where chronological definition has been possible on the basis of volcanic tephras that separate deposits within stratigraphical sections at archaeological sites thus providing temporal division. The correlation of the Holocene sequence with the Witori and Dakataua volcanic eruptions have been outlined as consisting of the five following phases (Torrence et al. 2000):

- Phase 1 – c.10,000 – 5900 BP (pre W-K1);
- Phase 2 – 5900 – 3600 BP (W-K1 to W-K2);
- Phase 3 – 3600 – 1700 BP (W-K2 to W-K3-4);
- Phase 4 – 1700 -1100 BP (W-K3-4 to Dk); and,
- Phase 5 – 1000 – present (after Dk).

Recently refined dates for eruptions of both Witori and Dakataua volcanos in the Willaumez Peninsula are proposed by Petrie and Torrence (in press) on the basis of
Bayesian calibration techniques. Using 115 radiocarbon determinations obtained mostly from archaeological sites together with a few dates derived directly from carbonised material preserved within deposits of airfall tephras (Dk and W-K4 eruptions), the authors calculate the modal dates for these volcanic events in West New Britain. It has been emphasised by these authors (Petrie and Torrence, in press) that the modal dates for the W-K1 (5920 cal. BP) and W-K3 (1615 cal. BP) are close to the previously proposed dates.

However, the modal dates for the W-K2 and Dk are essentially different from previously published data: 3315 cal. BP for the W-K2 eruption and 1300 cal. BP for the Dk event (Petrie and Torrence, in press). Consequently, the length of earlier proposed Phases 2-5 would change. For example, the length of Phase 2 (the middle Holocene) increases up to 285 years while Phase 3 (the late Holocene) becomes shorter by to the same number of years. Moreover, Petrie and Torrence (in press) particularly stress that both Interval (3480 – 3150 cal. BP) and modal (3315 cal. BP) dates for the W-K2 eruption are close to the earliest dates associated with the spread of Lapita pottery sites in the Bismarck Archipelago (3350 BP) (Anderson, Bedford, Lilley, Sand, Summerhayes and Torrence 2001; Kirch 1997: 58; Petrie and Torrence, in press; Specht and Gosden 1997; Summerhayes 2001a, 2003, 2007).

It is unclear as to what extent the new dates proposed by Petrie and Torrence (in press) will effect the widely recognised middle and late Holocene sequences with the chronological boundary being between 3600 and 3500 BP based on a series of radiocarbon dates obtained from the sites in the Bismarck Archipelago (Anderson et al. 2001; Kirch 1997:58; Lilley 2004; Pavlides 1999:25, 2006). In relation to Garua Island, the adoption of the new date for the W-K2 eruption would inherently suggest human abandonment of the island some hundreds years prior to the catastrophic W-K2 eruption. This follows from an analysis of dates obtained from sites which were buried by volcanic ash (Petrie and Torrence, Table III, in press). The latest dates for these sites are 3990-3640 cal. BP (FAO), 3830-3460 cal. BP (FAAK) and 3640-3440 cal. BP while the modal date for W-K2 eruption is 3315 cal. BP (Petrie and Torrence, Table V, in press). This contradicts the existing archaeological record (Torrence 2002a; Torrence and Stevenson 2000; Torrence et al. 2000) and is also not supported by some Bayesian modelling dates obtained from a number of middle Holocene sites in the Isthmus region of the Willaumez Peninsula (Petrie and Torrence, in press).

Phases 2 and 3 are associated with the middle and late Holocene history of the Bismarck Archipelago. These phases on Garua Island and in the Isthmus region are
named by scholars differently using terms: "stage", "phase" and "period" that are also often associated the use of terms "pre-Lapita period", "Lapita period" and "post-Lapita period" as well as "Lapita pottery site" (Fullagar 1992:136; Kealhofer, et al. 1999:529; Lilley 2004:92-95; Specht and Torrence 2007; Specht et al. 1991:281-282; Summerhayes 2003, 2007; Torrence 1992, 2002a:769; Torrence and Stevenson 200:335-337; Torrence et al. 2000:235; Torrence et al. 2004:123). In order to avoid confusion with the variety of terms used for the same chronological divisions, I prefer to organize my data within the framework of Pavlides's (1999:133) broader Holocene scheme using the following terms:

1. The middle Holocene period which is associated with Phase 2 (W-K1 to W-K2) and the term "pre-Lapita period"; and,
2. The late Holocene period that comprises Phase 3 (W-K2 to W-K3-4) and is related to the term "Lapita period"

2.3 Middle Holocene Settlement Patterns, Subsistence and Stone Technology in the Bismarck Archipelago

By the middle Holocene, many cave sites initially used by humans in the late Pleistocene and early Holocene had been abandoned or were only intermittently used and new sites started to appear within different landscapes on islands in the Bismarck Archipelago. This change in the way in which people interacted with their environment indicates changes in settlement pattern (O'Connor and Chappell 2003). Human populations were scattered across landscapes and no large permanent sites are known at this time. Settlement patterns had an inland orientation although coastal resources were regularly exploited (Kirch 2000:86-87).

Some rock shelter and cave sites dated to the middle Holocene period are known on Manus Island (Kennedy 1983; Spriggs 1997:73), Nissan Islands and Buka Island (Spriggs 1991; Spriggs 1997:80-81). Middle Holocene assemblages are absent from some islands or are often represented only by ephemeral scatters of material (Gosden 1991a, 1991b; Gosden and Webb 1994).

New Britain and its near islands provide archaeological evidence of relatively intensive patterns of use of three regions during the mid-Holocene: Arawe Islands, the Kandrian area and the Willaumez Peninsula including Garua Island. Sites in the Arawe Islands, off the south-west coast of New Britain, are located immediately adjacent to the
beaches. The Apalo site on Kumbun Island contains waterlogged deposits with wooden structures and concentrations of obsidian flakes and other artefacts (Gosden 1991; Spriggs 1997:77-79). Deposits at Lolmo Cave on Kumbun Island contain hearth stones, in addition to obsidian artefacts (Gosden 1991:210; Gosden, Webb, Marshall and Summerhayes 1994).

In the Kandrian area on the south coast of New Britain, both the coast and inland areas were used by middle Holocene populations. The coastal shelter, Alanglong, initially was a burial site which was probably used c. 6500-8500 BP. The later cultural deposits are dated c. 3850 BP (Specht, Lilley and Normu 1981). The inland rainforest Yombon region was re-occupied between 5900 and 3600 BP and is characterized by an abundance and wide distribution of artefacts within the landscape and there is evidence of the re-use of locations as well as evidence of initial occupation of new settings (Pavlides 1999:261-313). The middle Holocene deposits at Misisil cave, which is located in the rainforest Yombon region, include many compacted hearths separated from each other by thin bands of clay (Pain and Specht 1985).

Middle Holocene sites on the Willaumez Peninsula are generally located on hills or ridge tops close to the shore. Some sites on Garua Island and on the coastal mainland near Talasea are located near obsidian sources (Specht et al. 1991; Torrence 2002a; Torrence et al. 2004). There is no organic material, other than residues on stone tools, preserved at the sites, however, the relatively homogenous spread of obsidian artefacts across the landscape on Garua Island, including FAO, in association with patterned raw material procurement and lithic technology is interpreted as an indicator of multiple, short-term activities which were undertaken by highly mobile middle Holocene inhabitants (Torrence 1992, 2002a).

Subsistence and strategies of resource use in different parts of the Bismarck Archipelago during the middle Holocene are well documented by data from caves and waterlogged sites. For example, the inland rock shelter, Peli Louson, on Manus Island contains a high density of marine shells indicating intermittent use of this site by mobile groups for short periods. A concentration of marine shells and bone, including reef and estuarine fish, is found on the coastal open site, Father's Water, on Manus Island (Kennedy 1983). The middle Holocene deposit of the Takori and Halika phases on the Nissan Islands contains nuts from various species such as Canarium, coconut, Areca palm and 5 other species as well as evidence for sago, tree fern and possibly taro or yam (Spriggs 1991:233; 1997:80-81). An abundance of shell and animal bone was also found and included phalanger, bats, rats, pig and reef fish (Spriggs 1991; Spriggs
1997:80-81). In New Britain significant information was obtained from waterlogged deposits at the Apalo site. These deposits include wooden structures and a large quantity of plant remains similar to those represented by the most important trees of arboriculture used in modern gardening on the Arawe Islands (Gosden 1991b; Gosden, et al. 1989). Within the mid Holocene deposit at Misisil cave, land snail and freshwater shells, bones of phalanger or wallaby, reptiles and cassowary eggshell have all been recovered (Spriggs 1997:77).

The reconstruction of subsistence practices on open sites in the Willaumez Peninsula and on Garua Island is mainly based on phytoliths and starch analysis of the sediments and residues found on stone tools (Barton et al. 1998; Boyd, Lentfer and Parr 2005; Kealhofer et al. 1999; Fullagar 1992, 1993b; Lentfer 2003:301-303; Lentfer and Torrence 2007; Parr, Lentfer and Boyd 2001; Therin, Fullagar and Torrence 1999). The data obtained through these analyses indicate the coincidence of forest clearance and burning with the concentration of stone artefacts, some of which were used for processing plants. These provide the basis for the suggestion of gardening by the inhabitants of FAO during the middle Holocene (Boyd et al. 2005; Lentfer and Torrence 2007).

Early plant domestication and horticultural development first occurred in the New Guinea Highlands at Kuk swamp site during the Early Holocene (Denham 2004, 2006; Denham, Haberle and Lentfer 2004; Fullagar et al. 2006; Golson 1976). Although it is not known whether taro and other root crops were cultivated in the Bismarck Archipelago during the middle Holocene, the presence of remains of fruits, seeds and nuts within archaeological deposits in cave sites and in waterlogged sediments provides evidence for the domestication of tree crops, or arboriculture, by the middle Holocene (Kirch 2000:80-83; Spriggs 1997:79-82). The appearance of new subsistence strategies related to food production, together with the continuing development of techniques for the exploitation of marine resources, collecting forest products and hunting all stimulated the change in technological behaviour of humans and the manufacture of implements made of shell, bamboo and other organic materials, in addition to the use of stone raw material (Allen 2003; Boyd et al. 2005:388; Kirch 2000:82-83; Smith 2001:152-153; Spriggs 1991:239; Spriggs 1997:80-81; White, Flannery, O’Brian, Hancock and Pavlish 1991).

Stone assemblages from middle Holocene sites in the Bismarck Archipelago generally demonstrate the use of simple flake technology and little secondary modification. Formal types of retouched tools are exceptionally rare. The uniformity of
lithic assemblages essentially limits their use for the reconstruction of the middle Holocene activities. This is especially relevant to the material obtained from caves and rock shelters which is characterized by a low number of stone artefacts produced from local lithic resources (Gosden 1991; Gosden and Webb 1994; Kennedy 1983; Spriggs 1991, 1997:73). The organization of lithic procurement was based on the selection of appropriate river and stream cobbles followed by initial knapping at these secondary sources. Flakes were transported over some distance to sites where they were used and discarded without any modification of the edges. This strategy of procurement was embedded within broader subsistence activities. (Gosden 1991; Kennedy 1983; Specht, Lilley and Normu 1981; Spriggs 1991, 1997:80-81).

In contrast, assemblages from those areas in New Britain which had abundant lithic raw material sources, such as the Yombon rainforest area in the Kandrian region, the Talasea region and Garua Island, demonstrate more complicated technological behaviour. The nature of the assemblages suggests structured and spatially organized procurement, staged reduction and increased planning in the production of formally shaped stemmed artefacts which were used as multipurpose tools within the curated technological strategy (Pavlides 1999, 2006; Torrence 1992, 2002a; Torrence et al. 2000). On the basis of technological analysis and a distributional approach to flaked artefact assemblages, Pavlides (1999, 2006) and Torrence (Torrence 1992, 2002a; Torrence et al. 2000) propose certain patterns of middle Holocene subsistence activities and land use in both the inland rainforest region and on the coastal areas of New Britain.

Pavlides (2006:207) proposes that the organisation of technology and, by inference, settlement patterns, resource use and economy of the inhabitants of the Yombon rainforest region, does not indicate continuity with the patterns of human behaviour observed in the early Holocene period. Instead, she considers that the change in technology was as a result of a more intensive system of land management and decreased settlement mobility which occurred during this period. These changes in subsistence and settlement patterns continued into the late Holocene although formal tools disappeared in this later period (Pavlides 2006:221).

In contrast, Torrence (1992, 2002a; Torrence, Boyd, Doelman, Neall, Specht and White 2002) stresses that middle Holocene obsidian assemblages on Garua Island and in the Talasea region on the Willaumez Peninsula indicate a continuity with the early Holocene technological organisation of raw material procurement, production, use and discard of tools. The manufacture of retouched stemmed tools during the early and middle Holocene and their disappearance in the Late Holocene is explained by Torrence
(1992, 2002a:773; Torrence et al. 2000:232) as a consequence of gradual changes in patterns of subsistence and patterns of mobility. This proposal is supported by the spatial distribution of artefacts across the landscape on Garua Island (Torrence 2002a) and by the result of use-wear/residue analysis of some selected tools (Fullagar 1992, 1993b; Kealhofer et al. 1999). On the basis of these data, it has been assumed that multipurpose stemmed tools and associated curated technology are closely related with the highly mobile style of life of the middle Holocene inhabitants who "were competent forest managers of roots and nut-bearing trees and were moving among various places where they had made clearings to encourage growth or were tending plants" (Torrence 2003:297).

The concept of multipurpose formal tools functioning within a curated technology, however, is built on the basis of a single category of retouched finds: stemmed tools. This concept does not consider the use of a numerous flaked artefacts which comprise most of the stone assemblages at open sites in the Bismarck Archipelago, and on Garua Island particularly. As a result, many aspects of human activities, especially those that are associated with flaked tool use and discard behaviour remain unstudied. Preliminary use-wear/residue study of middle Holocene artefacts by Fullagar (1992, 1993a, 1993b) reveals a number of flakes which were used as tools in a variety of activities. These results indicate that use-wear/residue analysis provides a suitable methodology for investigating subsistence, settlement patterns and mobility in situations where the archaeological record is represented by flaked artefacts only.

2.4 Late Holocene Settlement Patterns, Subsistence and Stone Technology in the Bismarck Archipelago

The Late Holocene in the Bismarck Archipelago is associated with the spread of the cultural phenomenon referred to by scholars variously as an "archaeological horizon", "archaeological tradition" or "Lapita Cultural Complex" (e.g. Anderson et al. 2001; Green 2002). The Lapita phenomenon is complicated and under constant debate in Pacific Archaeology (e.g. Allen 2000; Allen and Gosden 1996; Ambrose 1991; Anderson 2001, 2002; Gosden 1991b; Green 1991, 2003; Kirch 1997:45-52; Spriggs 1997:67-106; Summerhayes 2000, 2001a, 2001b, 2003, 2007; Terrell 2002, 2003).

There are four main models for interpreting the origins of the Lapita Cultural Complex and its colonization of the Pacific. The first, the "Fast Train Model" involves a movement of Austronesian-speaking people with their material-culture complex (the
Lapita Cultural Complex) out of Southeast Asia into Oceania through the Bismarck Archipelago (e.g. Green 2003; Kirch and Hunt 1988; Kirch, Hunt, Weisler, Butler and Allen 1991; Summerhayes 2001a). The second is the "Indigenous Bismarck Archipelago Model" that proposes cultural continuity among indigenous inhabitants and suggests the development of the Lapita Cultural Complex within the Bismarck Archipelago (e.g. Allen 1991; Allen and White 1989; Green 2003; Kennedy 1983; Specht et al. 1991; Summerhayes 2001a, 2001b, 2007; Torrence 1992; White and Allen 1980). The third model, named "The Slow Train Model" although accepting the origin of the Lapita Complex from Southeast Asia, considers the possibility that Lapita may have been in the Bismarcks for 300 years before its spread into Remote Oceania (e.g. Green 2003; Summerhayes 2001a, 2001b, 2007). Finally, the concept of the "Triple I model", Intrusion, Innovation and Integration, has been developed by Green (1991). Intrusion is interpreted as the moving of Austronesian speakers into the area from Southeast Asia. Innovation suggests new development within the Bismarck Archipelago, and Integration is associated with adopting elements of material culture from the original inhabitants (e.g. Green 1991, 2002, 2003; Summerhayes 2001a, 2001b, 2007).

One of the important aspects in the interpretation of the Lapita Cultural Complex is its chronology which is also the subject of continuing debate among Pacific scholars. Recently Summerhayes (2001a, 2003) suggested a detailed chronological sequence of Lapita sites in the Bismarck Archipelago on the basis of known radiocarbon dates. His sequence includes four phases:

1. Early Lapita phase (3300 – 3000/2900 BP);
2. Middle Lapita phase (3000/2900 - 2700/2600 BP);
3. Late Lapita phase (2700/2600 – c. 2200 BP); and,
4. Post Lapita transition (2200 -1600 BP).

Within this temporal framework, the earliest Lapita sites with dates around 3500 BP are found on Mussau Islands (Kirch 1997:60-61; Kirch et al. 1991) and are evidence of the Early Lapita phase which is also suggested for the Kamgot site in New Ireland, Magekur and Apalo sites on the Arawe Islands (Anderson et al. 2001; Specht and Gosden 1997; Summerhayes 2001a, 2003, 2007).

In the regional context, re-occupation of Garua Island following the W-K2 eruption occurred about 3340-3000 cal. BP (Petrie and Torrence, in press). These dates obtained from the FYS site and correspond with the Early Lapita Phase (Summerhayes...

The Early Lapita phase is characterised by a higher level of movement of people between settlements in comparison with the reduced mobility of people during the Middle Lapita phase (Summerhayes 2000:234-235, 2003). Settlement patterns associated with the Lapita Cultural Complex in the Bismarck Archipelago are interpreted by most scholars as mostly a coastal phenomenon with sites occurring on beach terraces opposite reef passages, or on small offshore islands. A number of common traits are observed in the Lapita settlement strategy oriented towards those environmental settings which allows the exploitation of both rich marine and terrestrial resources (Lepofsky 1988). Many Lapita sites were stable villages or hamlet-sized settlements often with stilt-houses built over shallow water (Ambrose and Gosden 1991; Golson 1991; Gosden, Allen, Ambrose, Anson, Golson, Green, Kirch, Lilley, Specht and Spriggs 1989; Green and Anson 1991; Kirch 1997:167; Kirch et al. 1991; Spriggs 1997:127). Although small sites with repeated re-occupation by mobile groups are widely known (Gosden 1991b, 1992; Gosden and Pavlides 1994:169; Gosden and Webb 1994).

The total of 47 localities containing sherds representing the Lapita pottery style have been found at the central part Willaumez Peninsula and its adjacent islands and material recovered from survey and test pit excavations by Specht (Specht 1974; Specht et al. 1988; Specht and Torrence 2007:136) and Torrence (Torrence 1993; Torrence and Stevenson 2000; Torrence, Boyd, Doelman, Neall, Specht and White 2002). Most of the earliest sites are situated at the beach level of the mainland coast and nearby islands. During the Middle and Late Lapita phases, however, site locations were not restricted to the shoreline of the coast and, to varying degrees, were distributed on inland hills and ridge tops (Specht, et al. 1991). This is evidence by recent research at Numundo, Garu, Kulu-Dagi and Haella inland areas (Anderson et al. 2001; Torrence et al. 2004; Torrence and Stevenson 2000; Torrence et al. 2002). These inland areas, however, were quite close to the coast. Specht et al. (1991) argues that the distribution of sites on the beaches is the result of the occupation of newly-formed land rather than evidence of a dramatic change in the late Holocene settlement patterns in comparison with the middle Holocene settlement strategies. The continuous use of the same site locations during both middle and late Holocene are noted on Garua Island including at FAO (Torrence and Stevenson 2000; Torrence 2002a).
Many sites with Lapita style pottery on Garua Island and the Talasea mainland are located within a few minutes walk of obsidian sources or only short canoe trips although sites on the Isthmus are not associated with these sources (Specht, et al. 1991; Torrence and Doelman, 2007). Specht et al. (1991) identified two types of sites on the basis of the distribution of pottery sherds. The first group includes FEA (Boduna Island) and FCR/FCS (Lagenda) where large amounts of sherds were recovered, suggesting that these sites probably represent major settlements and/or pottery production centres. The second group comprises sites which yield less than 10 sherds each. These sites may represent small hamlets which were used by groups who imported pottery from the production centres (Specht, et al. 1991; Summerhayes, Gosden, Fullagar, Specht, Torrence, Bird, Shahgholi and Katsaros 1993).

The distribution of obsidian artefacts and pottery sherds which were found within 69 test pits on Garua Island reveals a significant shift in human behaviour during the Late Holocene (Torrence 2002a; Torrence and Stevenson 2000). The material recovered by excavation shows a more clustered pattern of artefact distribution than in previous chronological periods. On the basis of these data, and a series of radiocarbon dates from 21 test pits, as well as obsidian hydration dates obtained from 10 test pits, Torrence and her colleagues (Lentfer and Torrence 2007; Torrence 2002a, 2003; Torrence and Stevenson 2000; Torrence et. al. 2000) have proposed that human activities during the late Holocene on the island were more focused on a few particular places in the landscape. These places might signify villages with long-term occupation based on intensified forms of land use and cultivation.

Subsistence activities of the inhabitants of the Bismarck Archipelago in the late Holocene are reconstructed thanks to waterlogged deposits of cultural remains at sites from Mussau Islands (Kirch 1997: 203-217; Kirch, Hunt, Weisler, Butler and Allen 1991), Arawe Islands (Gosden 1991b; Gosden and Pavlides 1994; Gosden et al. 1989) and Watom Island (Specht 2003), as well as organic material preserved in cave sites, rock shelters and some open sites in New Ireland, Nissan Islands and Buka Island (Golson 1991; Spriggs 1991, 1997:80-81, 128; Summerhayes 2007:26; White et al. 1991).

The rich archaeological record indicates that a diverse range of species of fish and shells, as well as species of shark, tuna, dolphin, barracuda, green turtle, dugong and crocodile were procured from the sea by people from the late Holocene who developed relatively sophisticated fishing technology (Allen 2002; Golson 1991; Gosden et al. 1989; Kirch 2000:56; Kirch et al. 1991; Ono 2003; Spriggs 1997:80-81; Summerhayes
2007:26; White et al. 1991). The land provided wild animal resources including phalangers, wallaby, bandicoot, rats, bats, reptiles and birds which were hunted by humans in the region (Golson 1991; Gosden et al. 1989; Kirch et al. 1991; Specht 2003; Spriggs 1997:125; White et al. 1991). Domesticated pigs, chickens and dogs were also known to the late Holocene populations (Gosden et al. 1989; Kirch et al. 1991; Specht 2003; Spriggs 1997:124-126).

Archaeobotanical remains of 15 species of crop plants including coconut, bananas, nuts, breadfruit, taro and yams are associated with cultivation practices of the late Holocene populations of the Bismarck Archipelago (Kirch 2000:109). Horticulture was apparently "based on a combination of permanent orchard gardens of tree crops (quite likely situated in and around villages themselves) and swiddens or shifting cultivations cut annually in the rainforest (or from second-growth forest once this was established) for the root and tuber crops" (Kirch 2000:110).

This general model of late Holocene subsistence is associated with the spread of the Lapita Cultural Complex and the concept of "transported landscapes" (Kirch 1997:217-218). The model indicates the dynamic and complicated history of the Pacific region with regional peculiarities observed in the archaeological record. For example, Spriggs (1997:121) pointed out that late Holocene open sites in the Arawe Islands "would usually be interpreted to present permanently occupied villages, belonging to agricultural communities who kept domestic animals and engaged in swidden agriculture on the various islands and presumably also the adjacent mainland". However, Gosden (1991b; Gosden and Pavlides 1994) argues that Lapita sites in the Arawe Islands were not permanently occupied but represented a continuation of the high mobility of the Pleistocene. The presence of some special features within the landscape, such as stands of nut bearing trees and areas of cleared land for gardens would encourage people to return regularly to these locations. This way of life, based on impermanent hamlets on the coast, is associated with a form of low intensity agriculture. This settlement pattern and associated subsistence practices continued until at least the establishment of intensive forms of agriculture involving new crops and tools resulting from contact with Europeans some 100 years ago (Gosden and Pavlides 1994:167).

Open sites from the late Holocene on the Willaumez Peninsula preserved only charred fragments of Canarium, coconut and other nutshells and several unidentified bone fragments and marine shells found at FEA on Boduna Island (Specht, et al. 1991). Phytoliths and starch analyses of the late Holocene sediment at FAO indicate that
gardening activities, associated with the cultivation of fishtail palm Caryota rumphiana, banana and probably tubers (Boyd et al. 2005; Kealhofer et al. 1999; Lentfer and Torrence 2007), were practiced by the inhabitants during this period. Torrence et al. (2000) suggest also that after the catastrophic W-K2 eruption, the first occupants of Garua Island were largely dependent on marine resources. This conclusion when considered together with the phytolith data and residues on the tools is consistent with model of the Lapita economy which was complex and based on marine resource exploitation, arboriculture, horticulture, domestication of pigs, dogs, chickens, collecting forest products and small scale terrestrial hunting (e.g. Green 2002; Gosden and Pavlides 1994; Gosden et al. 1989; Kirch 1997:195-226; Spriggs 1997:84-87; Summerhayes 2007).

The late Holocene sites in the Bismarck Archipelago exhibit a greater range of tools and implements made of shell and stone, although flaked assemblages are characterised by expedient technology of tool production and use (e.g. Allen 2003; Allen and Bell 1988; Gosden 1991b; Green and Anson 1991; Halsey 1995; Hanslip 2001; Kirch et al. 1991; Sheppard 1992, Swete-Kelly 2001, Summerhayes 2003, 2004; White and Harris 1997). Technological analyses of chert assemblages by Pavlides (1999) in the Yombon area and obsidian assemblages by Torrence (1992) on the Willaumez Peninsula lead those authors to the conclusion that there is continuity in the organisation of lithic procurement, tool production and tool use between the middle and late Holocene, and the appearance of sites with Lapita style pottery in these regions did not signal a major change in lithic technology (Pavlides 2006:221; Torrence 1992:124). However, the disappearance of formal stemmed and waisted tools in the late Holocene assemblages (Pavlides 2006; Torrence 1992, 2002a; Torrence et al. 2000) tends to suggest that the pattern of lithic procurement, tool production and tool use was not continuous and that lithic technology had changed. Moreover, as Torrence et al. (2000:241) has also emphasised, a major change in lithic technology occurred during the late Holocene, following the W-K2 event, when the disappearance of formal tools also coincided with the change in the pattern of artefact discard, the introduction of pottery and a new social system (Torrence et al. 2000:241-243).

These data, together with proposed changes in land use and settlement patterns from high mobility of the middle Holocene to localised settlement patterns of the late Holocene, which is associated with preferred coastal location and an intensification of gardening activities (Lentfer and Torrence 2007; Specht et al. 1991; Torrence 2002a; Torrence and Stevenson 2000) is more supportive of the explanation by Kirch
According to these authors, there is no cultural continuity between the inhabitants who were settled in West New Britain before the W-K2 eruption and those who occupied this region after the eruption and this also contradicts concepts of continuity proposed by Torrence (1992, 2002a, Torrence et al. 2000:241) and Pavlides (2006).

2.5 Potential of New Approaches

The prehistory of the Bismarck Archipelago demonstrates dramatic changes in settlement patterns, subsistence and stone technology throughout the middle and late Holocene. These changes are more obvious in hazardous environments created by catastrophic volcanic events and subsequent lengthy periods of human abandonment (as is the case in West New Britain) because the archaeological record is divided into different phases (Torrence et al. 2000). The reconstruction of subsistence activities during both the middle and late Holocene periods has been based mainly on the examination of technological organisation and distributional patterns of lithic artefacts (Pavlides 1999, 2006; Torrence 1992, 2002a; Torrence and Stevenson 2000) and very limited paleoenvironmental data (Boyd et al. 2005; Lentfer 2003; Lentfer and Torrence 2007; Parr 2003; Parr et al. 2001; Therin 1994; Therin et al. 1999).

Use-wear and residue analyses provide new opportunities for studying stone tools to reconstruct subsistence and settlement patterns. As discussed in Chapter 1, Fullagar's studies of flaked artefacts (e.g. Fullagar 1986, 1991, 1992, 1993a, 1993b, 1998, 2006a, 2006b; Fullagar et al. 1998, Fullagar et al. 2006; Kealhofer et al. 1999) has shown the value of these approaches. On the basis of microscopic examination of 140 artefacts from six sites located in the Kandrian region, on the Arawe Islands and in the Talasea area, Fullagar (1992, 1993b) proposed that a limited range of activities took place at the middle Holocene sites, reflecting a highly mobile pattern of subsistence. In addition, results of use-wear/residue and phytoliths analysis of 28 obsidian artefacts from FAO on Garua Island (Barton et al. 1998:1235; Kealhofer et al. 1999:530) and 35 artefacts from FRL in the Talasea (Fullagar 1992:137; Kealhofer et al. 1999:530) allowed Kealhofer et al. (1999) to make inferences about chronological changes in tool use patterns that were associated with a decline in mobility during the late Holocene. Despite unsuccessful use-wear analysis of obsidian artefacts by Hanslip (2001:216-222), studies by Fullagar provided a starting point for my study of middle and late Holocene obsidian assemblages from FAO. His research encouraged me to investigate the extent to which
detailed use-wear/residue analysis of stone tools can contribute valuable information about prehistoric human behaviour. This places greater emphasis on the flaked artefact analysis in terms of their function and associated activities through the middle and late Holocene sequence.

A comparative approach for the study of obsidian artefacts is developed in Chapters 3 and 4 in order to understand how use-wear is formed and residue retained on the working edges. The following chapter will introduce some methodological aspects of use-wear/residue analysis which form the basis of my research strategy for the functional interpretation of prehistoric obsidian artefacts.
Chapter 3


3.1 Introduction

Stone artefacts comprise the most abundant archaeological remains at prehistoric sites in West New Britain. These artefacts represent different stages of production, modification, use and discard and give different levels of information about past human behaviour. Scholars have assumed that the use of obsidian tools around the Talasea area and on Garua Island was a function of the range of activities which were carried out during the particular chronological period. Some suggestions about the function of these artefacts have been made by Fullagar (Fullagar 1992; also Barton et al. 1998; Kealhofer et al. 1999). The specific question arises which is the subject of my functional study: What kind of tools were being made and used at the FAO site and what was their purpose?

Functional analysis of stone tools utilises several sources of evidence including (1) properties of the raw material used, (2) manufacture and design characteristics of artefacts, (3) use-wear features, (4) tool residues, (5) tool-use experiments, and (6) ethnographic analogies (Fullagar 2006a:208-209). Undertaking a functional analysis means making an assessment of all the main forms of use-wear and the residues observed on any one artefact to determine how it was used. Residues can sometimes be firmly attached to, or absorbed within, a tool surface, although sometimes it can be difficult to distinguish additive residues on worn or polished surfaces (Kealhofer et al. 1999:527). Use-wear usually refers to surface modification that occurred during use, including hafting, handling, and sometimes storage (Fullagar 2006a:208; Hayden and Kamminga 1979:2-5; Keeley 1980:1-2; Lewenstein 1987:5-10; Vaughan 1985:4). The general principles of use-wear analysis are applicable to all classes of stone material, but specific methods and interpretative rules have been developed for particular raw materials such as obsidian (e.g. Aoyama 1999; Hurcombe 1992).

Determining the function of tools on the basis of macroscopic and microscopic wear evidence requires a variety of approaches. Of these approaches, the most reliable and productive are use-wear/residue analysis and experimental replication both of which demand a comparative assessment of the main functional variables on each stone tool. The focus of this chapter is, firstly, to outline the methodology used for obtaining
functional data from obsidian tools and, secondly, to describe the preparation procedures for use-wear analysis of the experimental tools and the prehistoric obsidian artefacts, laboratory equipment and recording systems which were employed in my study.

3.2 Limitations of Functional Analysis of Stone Artefacts

The functional study of stone tools is able to provide essential knowledge for the interpretation and reconstruction of human behaviour. On the basis of wear and residue evidence observed on stone tools, it is possible to determine details of their use-action, use-material and approximate duration of use. These data may indicate the purpose for which tools were made, the choice of raw material, the strategy of lithic procurement, the technology of tool manufacture, the range of activities and their relationship with resources available within the inhabited landscape (e.g. Aldenderfer 1991a, 1991b; Bamforth 1991; Fullagar 1986; Hayden 1979a, 1979b; Hayden and Kamminga 1979; Hurcombe 1992; Keeley 1980; Semenov 1964; Schiffer 1979; Odell 2004; Torrence 1989a, 1989b; Vaughan 1985).

However, there are some limitations to obtaining functional data. First, post-depositional effects can cause a high degree of surface alteration that may obscure or mask any wear traces, especially on fragile obsidian artefacts. Second, use-wear patterning itself depends upon a range of inter-related factors. The wear formation process requires varying time periods and is dependent on the types of worked materials and the mode of use of tools. For example, if the obsidian artefact has been used for a very short time, use-wear will not be observed (Hurcombe 1992:61). This means that any quantitative data related to the number of tools involved in different activities should be assessed as representing only a broad indicative trend. Thirdly, various types of worked materials might form use-wear on obsidian implements at different rates (Hurcombe 1992:22). For example, a tool used for processing hard wood will usually be exhausted much faster than will a knife used for butchering animals.

The fourth factor is related to the complex use-history of tools. As my analysis indicates, some obsidian tools have two, or sometimes, three sets of use-wear features. In most cases a single task involves more than one action, for example, processing soft wood. This could require three actions: whittling, sawing and cutting/slitting. In this case, it would be difficult to determine the dominant set of wear. However, in some situations the combination of wear features could be distinguished thanks to their
different distribution on the working edge. For example, if the tool had been used initially for processing a soft elastic material (skin, fish, or meat) and subsequently for whittling wood, then scars, striations and polish from whittling actions might be localized on particular parts of the edge. However, the last use-action might remove previous wear features formed by earlier actions. These limitations of functional analysis, in some respects, can be resolved on the basis of comparison with available experimental data and ethnographic material.

3.3 Use-Wear Variables

The main forms of use-wear on stone artefacts are scarring, striations, edge rounding, polish and residues. Patterning in these use-wear variables are determined mainly by tool material, edge morphology, mode and duration of use, and the nature of material worked: wood, bone, stone, skin, meat or shell (e.g. Ahler 1979; Dillehay 1977; Frison 1979; Fullagar 1986, 2006a; Hayden 1979; Hurcombe 1992; Kamminga 1982; Keeley 1980; Richter 1996; Semenov 1964; Vaughan 1985). These variables form the main focus of my study of obsidian artefacts.

3.3.1 Scarring

The formation of scars, or microchips, on stone tool edges as a result of use is very common, particularly on edges with an acute angle (Plates 3A-3C, figure 4.1 and plates 55-56). The nature of use scars is related to the force applied to the working edge; the direction of action in which the tool was involved; the type of worked material; and the morphology (in end-view, plan-view and cross-section or edge angle) of the tool edge. The initial edge morphology may affect the extent of scarring and also the size and shape of scars. A thin edge may be more easily damaged by an impact causing common bending scars.

On the basis of the type of fracture initiation, termination types and their shape and size, scars can be classified as feather, step, hinge or bending (Cotterell and Kamminga 1979). Types of scars used in this study were defined following Kamminga's definition (1982:5-7) under which bending scars are created by transverse snapping and do not have a floor. They contrast with feather scars which have a gently sloped floor. Step scars are characterised by two discrete fracture surfaces. In one case the first fracture surface "ends at the point where the second fracture surface begins"
(Kamminga 1982:7), in another situation the first fracture surface may continue "beyond the point at which the second fracture initiates" (Kamminga 1982:7). Most of the used obsidian artefacts have scars of a small to medium size which are visible to the naked eye, but, micro-scars, which can only be observed under magnification, are often also present. The different types of scars on artefacts and their distribution on the working edge were recorded in my study and were compared with experimental data in order to verify their relationship with the use-material, use-action and use-duration.

3.3.2 Striations

Striations are linear deformations of the surface caused by abrasive particles. On the working edge, striations represent the most important indication of the direction of tool use or "kinematics" (Semenov 1964:88). The smooth, fresh fracture surface, brittle and fragile nature of obsidian allows striations to be formed easily in both the use and non-use context. For example, sandy conditions can introduce abrasive particles into the use that might increase the incidence of striations on the surface of the tools. Abrasive particles that cause linear alteration may be blunt or sharp. They can come from different sources, including extraneous dust, sand, and particles from the materials being processed, small flakes resulting from edge damage or fine debris created during the manufacture of tools (Kamminga 1979:152-153). The number of striations on the working edge, their length, width, depth and morphology is affected by the presence of abrasive particles (Hurcombe 1992:16; Keeley 1980:23).

The type of striations identified in my study followed Hurcombe (1992:37): (1) sleeks or plastic modification of the surface by straight-sided fine striations with a smooth cross-section (Plates 37C); (2), rough-bottomed striations with slightly irregular or straight sides but an irregular bottom (Plates 23D and 26F); (3) intermittent striations that are related to a series of small, rounded and distinct points of damage arranged in a line on the surface (Plates 29C and 60); (4) fern-like striations which are characterised by a central line of damage with the scarred surface of short lines at right angles to the striation orientation; and (5) flaked striations that are associated with a line of fracture damage on the edge. In addition, some linear features, or alignment, in the form of shallow, wide, discontinuous and poorly defined striations (Fullagar 1986:80, Kamminga 1982:14) were also recorded.

These different types of striations do not correlate precisely with a specific function, but their orientation (e.g. parallel, transverse, diagonal and two-crossed
diagonal) in relation to the edge axis does indicate the mode of use (Hurcombe 1992: 57).

### 3.3.3 Edge Rounding

Edge rounding is an attrition process, associated with abrasive smoothing and dulling of the edge due to use. Abrasion is caused by free and fixed particles contacting the surface of the tool. Obsidian is particularly likely to become abraded. It shows clearly as a rough and darker surface area (Plates 33A and 33B). The potential sources of abrasive particles consist of the materials being processed, the tool itself through micro-chipping (auto-abrasion), passive sources (dirty hands or a wind-blown dust layer) and deliberately added abrasive material as part of a processing activity (Ahler 1979:308; Fullagar 2006a:225-226; Hurcombe 1992:25; Kamminga 1982:17; Vaughan 1985:26). Not all used edges display edge rounding (because of different task conditions), but the presence of sand and other grit in the local environment can greatly increase the extent of edge rounding. This process affects the prominent points of the surface and creates some variation in the profile of used edges (Plates 26C, 57B and 58B). Following Fullagar (1986:80), the degree of edge rounding on obsidian tools, in my study was measured as (1) very light, (2) light, (3) medium and (4) bevelled, which is represented by a distinct flat and smooth surface along an edge.

### 3.3.4 Polish

Surface levelling through abrasive smoothing is important in many tool-use patterns, as indicated by the common co-occurrence of polish with edge rounding (Plate 1C). This modification of the natural flaked surface on the stone tool has been referred to by Keeley (1980:2) as "polish". He stressed that polishes can be distributed differently over the surface topography and can vary in extent and brightness (Keeley 1980:174). Because the appearance of the various polishes is so highly correlated with the character of the worked material, it is possible to infer the type of material worked and mode of use of many flint artefacts (Keeley 1980:174; Newcomer and Keeley 1979:202).

The unused surface of obsidian is not perfectly smooth and contains some characteristic features (Plates 2A, 2B and 45B). Any modification of these features can be easily identified as a rougher area in comparison with the surrounding surface. Polish
on obsidian tools is generally seen in association with edge rounding (Plates 16C, 33B, 53, 104-111). The distribution of polish, and its orientation, is used as the main criteria for the identification of the worked material. This approach of using polishes in functional studies of obsidian tools is well established. However, there is still no agreement between specialists about the formation process of polish on stone tools (see refs in Fullagar 2006a).

All surface alterations caused by the material being worked pass through different stages of development. As Vaughan (1985:29-30) pointed out, all polish types begin as a generic weak polish from a smooth, pitted polish and then they can become characteristically distinctive. However, not all polishes go through each stage at the same rate. For example, polish resulting from cutting meat rarely progresses beyond the generic weak type (Vaughan 1985:38).

Fullagar (1991) has pointed out that tools made from a highly siliceous raw material like obsidian can develop intensively polished surfaces in many functional tasks independently of the amount of silica within the worked material. He defined four stages of polish formation on stone tools relevant to obsidian. The first stage is related to abrasive smoothing and loss of features on the fresh fractured surface. This stage of polish development on obsidian tools is associated with edge stabilization and very slight edge rounding. Almost every tool with an unstable edge passes through this stage. The abrasion is recognizable as a clearly darker area on the surface of the obsidian artefact, in conjunction with other use-wear/residue features, can indicate which section of a tool was used or hafted, as well as the kind of action undertaken (Fullagar 1991:6).

Fullagar’s second stage of polish formation on obsidian is associated with patches of smoothed polish located within abrasive surfaces. At this stage, physical removal of material, levelling of peaks, deepening of subsurface cracks and impaction of granular material into surface depressions occurs, as well as some flaking out of the surface and polishing on levelled peaks. Polishes sustained at this stage are still not clearly indicative of the material worked (Fullagar 1991:6; Kealhofer et al. 1999:530).

At the third stage, developed polishes, diagnostic of used material such as wood, plant, bone and skin are formed. A predominant mechanism during this stage is the extension of subsurface cracks which flake out of the surface and gradually remove surface defects. The fourth and final stage is characterized by an extensive and well developed polished surface which is commonly formed as the result of processing moist siliceous plant material (Fullagar 1991:6).
A number of qualitative features are taken into consideration when identifying the type of polish on obsidian tools. These include brightness (intense, bright, fairly bright, fairly dull, and dull) and texture (very smooth, smooth and slightly smooth). All of these terms are related to an obvious surface levelling which is distinguishable from the unmodified fresh fracture surface. In my study, I adopt Fullagar's (1991) concept of stages in polish formation. However, I use slightly different terms to characterise the polish development: (1) very light polish which is associated with the first stage, (2) light polish that represents the second stage, (3) developed polish that corresponds with stage 3, and (4) well developed polish which is similar to Fullagar's stage 4 (Plates 1C, 3B, 4B and 12A). A number of other attributes, such as the location of polish in relation to the edge and its extension along the edge are also taken into consideration when identifying the type of polish on obsidian tools.

3.3.5 Hafting Patterns

A combination of scarring, rounding, striations and polish, or, only some of these features, can be seen on the surfaces of artefacts located opposite the working edge. Usually these features are associated with the pattern of prehension or hafting. The identification of hafting wear is important. Hafted tools may create some peculiarities in the rate of polish formation because they allow a more forceful and rapid motion (Kamminga 1982:21; Keeley 1982:799; Odell 2004:152-153; Rots 2003, 2005, Rots and Williamson 2004). As Rots (2003:806) stresses, tools made from flint and some other raw materials have two distinguishable features of hafting use-wear: (1) scarring and (2) isolated spots of polish on the surface. For obsidian tools, the pattern of hafting wear is slightly different and also includes abrasion and striations (Plates 118 and 119). Indicators of the hafting mode include residues such as resin (Plate 115) and leaf phytoliths because these organic materials were often used in the construction of a handle or grip for hand protection (Fullagar 1986:171-2, 2006a:218; Hurcombe 1992:74; Parr 2006:186-7). The formation of hafting wear and residue was not the main subject of my study. However, any modifications of the surface related to the hafted, or held, part of the tool, as well as associated residues, were recorded.
3.3.6 Residues

Residues on stone tools are important sources of information in their functional interpretation (e.g. Ahler 1979:317; Barton, *et al.* 1998:1231-1232; Fullagar 1998:15, 2006a:208-209, 2006b:177; Fullagar *et al.* 2006:595-596, Hayden and Kammenga 1979:5; Hurcombe 1992:26; Keeley 1999; Loy 1994:86-88; Robertson 2005:30-32; Shafer and Holloway 1979:385; Vaughan 1985:44-45). However, there are two potential problems with residue analysis: the first is the level of certainty in the association of the residue with the actual used edge and, the second is the particular residue on the tool may be due to post-depositional processes and not from the use itself (Barton *et al.* 1998; Fullagar 2006a; Robertson 2005:30-31).

Use-related residues usually have a more macerated or smeared appearance on the surface of the tool and can be trapped or jammed into cracks or crevices. Non-use related or incidental residues usually appear as isolated occurrences on a tool. The difference between use-related and other residues can be confidently determined on the basis of the context of the residues, their position on the edge or surface, and soil conditions at the site. Sometimes residues smeared on the edge, and striations within use-related residues clearly indicate direction of tool use (Hurcombe 1992:26; Fullagar 2006b:189). The distinctive structure and shape of residues on obsidian artefacts from archaeological sites in West New Britain, Papua New Guinea, were identified as cellular tissue, starch grains, phytoliths, calcium oxalate crystals (raphides), resins and yellow-red plaques (cf. blood) (Barton *et al.* 1998; Fullagar 1993a, 1994, 1998; 2006a, 2006b; Kealhofer *et al.* 1999; Lentfer 2003; Lentfer and Green 2004; Parr 2006; Parr *et al.* 2001).

Some plants often have with distinct cell structures and sometimes are observed as rough folds of tissue with bright birefringence under polarized light (Plate 65B). It is suggested that this folded tissue with no distinct shape may come from plant tissue that has had its tissue structure and cells broken apart during the use-action (Fullagar 2006a:216-217). Starch and raphides can be seen on the surface of tools and, after extraction, on prepared microscope slides (Plates 46C, 63C, 63D and 283B-D). Starch is formed in most green plants primarily to store energy. Starch granules have shapes that are often taxonomically distinct and, unless they have been heated or otherwise damaged, they have a distinct dark extinction cross, visible under cross polarized light (Fullagar 2006a:217). Raphides are particles formed in plants to provide a defensive mechanism. They often have a needle-like shape, and are made of calcium oxalate with
a bitter or acrid coating. The shapes of raphides can sometimes be taxonomically distinct (Crowther in press; Loy 2006:136).

The colour of blood residues under darkfield, non-polarized light varies from dark maroon/black to light red, and from pale yellow to clear in very thin deposits (Loy 1983; Fullagar 2006a:219). Individual red cells or erythrocytes are sometimes visible, and the presence of a nucleus generally indicates a non-mammalian origin (Plates 44, 51, 112 and 113).

White residues found in my analysis of some obsidian tools have not yet been identified. This residue has a bumpy texture with no clear form and shape (Plates 27B, 36C, 42A, 84C and 119B). There are no similar residues in the database and thus further studies are required including the determination of their chemical composition. However, the patterned distribution of these residues, near used edges and associated with surface microtopography, implies that they were linked to the use of tools.

Although in-depth residue analysis of artefacts has not been conducted by me, I did identify some types of residues on the working edges and use it for my functional interpretation of tools. Some residues were only recorded, extracted from the tool surface and mounted on microscopic slides for further detailed analysis by specialists. This approach was used in my study for both the experimental tools and the artefacts derived from archaeological contexts.

3.4 Experimental Study

Experimental replication is a significant methodological part of functional analysis that allows the verification and assessment of the value of wear criteria for the interpretation of tools and associated human activities (e.g. Boot 1987; Fullagar 2006a; Hayden and Kamminga 1979; Hiscock 1985; Hurcombe 1992; Keeley 1980; Kononenko 1986; Odell 1996a, 2004; Richter 1996; Semenov 1964; Vaughan 1985).

The history of experimental research of stone tools dates back to the late 19th and early 20th centuries. Initially, experiments were conducted in order to test the capability of tools to perform tasks and to support or reject a functional hypothesis for a certain group of tools on the basis of the direct comparison of experimental and prehistoric wear patterns (Hayden and Kamminga 1979:3-4; Vaughan 1985:4). These experiments generally did not study the formation of use-wear patterns, were unsystematic in their nature, and had limited scientific control. The necessity of systematic tool-use experiments and microscopic examination of use-wear traces was demonstrated for the
first time by Semenov (1964; Korobkova and Filippov 1987; Odell 1995). Since the publication of Tringham's (Tringham, Cooper, Odell, Voytek and Whitman 1974) and Keeley's (1980) research a comprehensive range of controlled use-wear experiments has been performed by a number of scholars over many years. (e.g. Fullagar 1986; Hurcombe 1992; Kamminga 1982; McBrearty, Bishop, Plummer, Dewar and Conrad 1998; Odell 2004; Vaughan 1985). These experiments have outlined a number of relevant factors which distinguish the key wear patterns on stone tools and demonstrate all major forms of use-wear: scarring, striations, rounding, polish and residues. It is accepted in recent research that each of these forms of wear can provide significant information for the interpretation of tool functions, but the most reliable data can be obtained through an integrated approach based on a combination of use-wear and residue studies and various techniques of analysis (Fullagar 1986:197, 1994, 1998; Van Gijn 1998).

In my study of obsidian artefacts, systematic tool-use experiments were necessary as an empirical basis to verify the use of artefacts and to examine the factors which caused the formation of wear traces. This part of my research is reported in Chapter 4.

3.5 Surface Preservation on Obsidian Artefacts

In my analysis, the main variables of use-wear were examined in order to determine tool function. However, there are many contexts, other than use, that may cause non-use modification of the edges and surface of stone tools (e.g. Keeley 1980:4-5; Tringham et al. 1974; Vaughan 1985:23-25, 41-44). Surface alteration on obsidian related to physical and chemical factors associated with post-depositional effects can destroy or mask use-wear patterns and greatly reduce the opportunity for an accurate functional definition of used tools (Hurcombe 1992:34-5). It is important to understand these factors before studying use-wear patterns.

The physical structure of obsidian presents as a fine amorphous matrix with scattered small crystals of silica (Hurcombe 1992:24). This structure means obsidian produces a good conchoidal fracture. Consequently, it has excellent flaking properties. Since a freshly flaked obsidian surface is very smooth and bright, contact, with particles generated by use, will cause damage to the surface or crush the edge thereby leaving traces on the surface of the tool. Other distinct features of a freshly flaked surface are irregularities (Plate 45), stress fissures (Plate 2) and ripple marks (Plate 94) (Hurcombe 1992:24) which are visible under a microscope. All these features are present on each
obsidian flake and are easily distinguished from any other features by their characteristic shape and orientation.

However, there are two main factors which influence the surface of obsidian artefacts: physical damage and chemical alteration (Hurcombe 1992:71–72). Obsidian is a very brittle raw material with a reactive surface, and it is susceptible to non-human physical processes. Contact with gravel and soil particles causes edge damage, surface abrasion and striations (Plates 126 and 127). In addition, archaeological excavation, sieving, washing and storage may all contribute to the physical alteration of artefacts.

One of the distinct features of post-depositional edge damage on archaeological obsidian flakes is the sporadic nature of the distribution of scars, their irregular shape and size. Often, irregular and step scars are associated with a crushed edge, reflecting random impact on the surface. Some artefacts have irregularly distributed scars with very fresh flaked surfaces that clearly contrast with other parts of the artefact surface (Plate 211A). Obviously, most such fresh scars have been formed recently, perhaps due to recovery, transportation, bagging and storage. In many cases, the surface within scars on the artefact is differentiated from a very fresh scar by the intensity of smoothing and brightness.

Abrasion and striations which appear on obsidian as a consequence of natural or post-depositional factors are easy to recognise. Unintentional abrasion and striations normally do not have a regular pattern in their distribution and are not related to the flake edge (Plates 126 and 127). Experiments conducted by Hurcombe (1992:48) showed that such wear contributes to a "background noise" of post-depositional features and therefore cannot be confused with intentional use-wear. However, abrasion, if located close to the edge, may mask the use-wear polish in some cases.

Chemical damage of obsidian surfaces in the form of a number of roughly hemispherical pits unequally distributed on the surface has been observed on some of the artefacts I studied (Plates 158A-C). This surface alteration indicates that some natural combination of chemicals has etched the original flaked surface, perhaps over time. As a result of chemical damage, use-wear features on the working edge can be destroyed or greatly altered (Hurcombe 1992:81).

Since the degree of chemical damage is different on each artefact, I used a scoring system: "slightly pitted"; "medium pitted", and "heavily pitted". These categories correspond with the Fullagar's categories (Kealhofer et al. 1999:530).

In addition to the physical and chemical damage, other weathering processes (e.g. wave action) can contribute to the surface alteration of obsidian artefacts. The
combinations of these factors may have affected use-wear features to different degrees. Sometimes the surface may be so greatly altered as to render any use-wear definition impossible. Fortunately, since the number of obsidian artefacts with completely altered surface is relatively small, productive use-wear/residue studies can be made at the FAO site.

3.6 Microscope and Camera Equipment

All obsidian artefacts were examined using a stereomicroscope (Orient SM 1) with an external light source and an Olympus BX60M microscope fitted with both vertical incident and transmitted light sources.

The first step in the study of use-wear/residue was made by observation of the entire artefact under the stereomicroscope with magnifications ranging from 6x to 50x. These low magnifications with an external reflected light provide a three dimensional view of the obsidian artefact and permit the examination of edge scarring, surface alternation (e.g. abrasion, smoothing), striations and some residues. All of these features were noted on the recording sheet with a drawing and inferences were made which guided further microwear analysis (Figure 3.1). The artefacts were hand held or set on a stage to enable them to be viewed under a stereomicroscope, in such a way that the angle of external light, reflected on the surface, could be adjusted and to allow the observation of tools of different sizes.

In the second step, the metallurgical microscope Olympus BX60M, with vertical incident and transmitted light, bright and dark field illuminations and cross polarizing filters, was used as the main instrument for use-wear/residue studies of obsidian tools. The long working distance lenses and brightfield and darkfield illumination of this microscope provide excellent resolution of the surface features for examination of edge rounding, polishes, striations and residues under magnifications from 50x to 1000x. The darkfield view with focused light at a low angle permits the observation of three-dimensional relief of shallow scars, striations, residues and distinctive surface features. The transmitted light was used to examine residue extractions mounted on glass microscope slides.

During use-wear/residue analysis, different microphotographic systems were used through cameras attached to the metallographic microscope. In the early stage of the study colour slides were taken with the Olympus PM-10AK camera attachment. The colour reversal film (Kodak Ektrachrome 160) used by this camera provides high
quality records of the distribution of scars, striations and residues on the surface of black obsidian artefacts.

Secondly, a number of artefacts were analysed and recorded with a Nikon Coolpix 950 digital camera attached to the microscope. The advantage of this camera system is the ability to take a large number of images and to store them in a computer database. Printed colour images give a wide range of information about the surface preservation of artefacts, use-wear and residues, but with increasing magnification (500× and 1000×), it became difficult to obtain a good focus and contrast in the image. Also there are some problems with labelling and scaling of images and their recording in the computer data base.

These disadvantages disappeared with the use of ColorView II camera and Soft Imaging System GmbH attached to the metallographic microscope. This digital camera system produces images of improved quality and makes it easy to record and store information in the computer database.

Finally, a few artefacts were studied under the scanning electron microscope (SEM) at the Australian Museum in order to obtain additional information about the elemental composition of some specific residues.

3.7 Recording

The recording of use-wear/residue results from both artefacts and experimental tools was undertaken in two steps. First, during the process of microscopic analysis, drawings were made of the artefacts showing the locations of residues and use-wear and these were included on the recording form for each tool (Figure 3.1 and 3.2). These data were supplemented by digital images. Second, summary use-wear and residue information for each artefact was recorded in an Excel database. The locations where images were taken were noted on the drawing and marked as "point 1" or "point 2", etc. The features of use-wear and residues observed on each point were described on the recording form (e.g. "point 1 – micro-scars with parallel striations, light polish and starch residues") (Figures 3.1). Each image was labelled and described using a ColorView II camera and Soft Imaging System GmbH. Next, on the basis of detailed observations, an inference was made about the mode of use of the tool (e.g. scraping), the worked material (e.g. soft starchy wood), approximate time duration, the possible pattern of hafting and the type of residue (e.g. tissue, starch). These recording forms with drawn artefacts, descriptions and supplementary images were then used for the
comparison with available experimental data. Finally, the data were put into a table of results.

The results table was created as an Excel database and includes four main types of information about each examined artefact (e.g. Table 7.1). The first is the archaeological context of an artefact (e.g. an individual number, unit, level). Second, some technological and morphological features are given (e.g. flakes and their size, the presence of cortex, scars, and retouch). The third category of information is related to the surface and wear-characteristics (e.g. surface preservation, edge rounding, polish, striations, mode of use, and type of worked material, use-duration and intensity of use, pattern of hafting). Finally, the description of residues and their location on the surface of artefacts, as well as the results of studies and definitions by specialists (Barton et al. 1998; Kealhofer et al. 1999; Lentfer 2003; Parr et al. 2001) have been included.

Experimental data about tool use and residues were recorded in a similar manner as that adopted for the prehistoric artefacts (Figure 3.2). Before use, each experimental tool was drawn on a separate sheet noting the working edge. The recording form included information on (1) the name of person who conducted the experiment with each particular tool; (2) use-action (e.g. sawing); (3) use-material (e.g. bamboo); (4) time duration (e.g. 15 minutes); (5) mode of hafting (e.g. wrapped in banana leaf); (6) description of the visible features which appeared on the tool during its use (e.g. irregular scars on the edge after 5 minutes of use). Data obtained through microscopic examination including the predominant types of scars, the predominant morphology and orientation of the striations, intensity of rounding, the degree of polish development, the type of residues were also recorded on the form and in an Excel database (Table 4.1). Each experimental tool was scanned on both faces under microscopes with magnifications from 50× to 1000×. The section with wear and residues was then photographed before and after cleaning (e.g. Plates 3A and 3B). The images are essential for standardising the interpretive criteria which were used in the examination of artefacts and, consequently, much effort was expended in obtaining images which would represent as accurately as possible the aspect, configuration and minute details of the wear traces as seen through the microscope.

3.8 Summary

The structure of my use-wear/residue study of artefacts has been determined by methodological approaches for functional studies of stone artefacts, particularly
obsidian tools. All obsidian artefacts have been examined in four stages. First, all samples followed a standard preparation procedure for use-wear analysis that included preliminary observation of the surface using microscope equipment, cleaning, drawing and recording. Second, during initial use-wear analysis it was important to assess surface preservation in order to understand the factors which might have altered the use-wear pattern on the tools. Third, further microscopic analysis was conducted using the detailed examination of use-wear characteristics such as scarring, rounding, striations, abrasion polish, and to a lesser extent, residues. The pattern of these features was then used to determine aspects of tool function such as mode of use, material processed and duration of use. Finally, the functional interpretation of tools was made on the basis of comparing characteristics of use-wear/residues observed on artefacts with available experimental samples and known ethnographic analogies.

Having developed and set out the analytical approaches for the study of obsidian artefacts, the next stages of this research involved, firstly, the testing of the variables leading to the formation of characteristic wear features and residues generated by specific tasks and functions and, secondly, producing a comparative database for the interpretation of prehistoric tool use strategies. This was achieved through an appropriate experimental program which is described in the following chapter.
Chapter 4

Experimental Program: Methodological Approach and Results

4.1 Introduction

The microscopic observation of wear patterns on tools allows inferences to be made as to how and for what purpose particular tools were used. An assessment and understanding of why and under what conditions fundamental types of use-wear patterns, including scarring, striations, rounding, polish and residues are formed requires comparison with known activities. The distinguishing features of both use-wear patterns and residues create the variables which are used in my comparative analysis. Significant insight into the function of artefacts can be gained through experimentation and ethnographic analogies involving the replication of activities which used stone tools. Experimental verification provides a basic understanding of the processes contributing to the wear formation and makes it possible to recognise and interpret wear patterns on prehistoric artefacts. Ethnographic analogy allows the suggestion of modes of tool use and the choice of materials for experimental comparative studies.

There are two main factors which necessitate the experimental research for the functional interpretation of tools found in the middle and late Holocene deposits at FAO on Garua Island. The first is that tools within assemblages at the site are made of obsidian raw material with particular physical properties that are distinctive from, for example, flint. As a consequence, the formation of wear patterns on obsidian tools appears to be quicker than on flint and produces some peculiarities (Hay 1977; Hurcombe 1992:24; Semenov 1964:13) which are important to examine through experiments before functional definition of artefacts from the site can be made. A number of researchers have attempted to investigate use-wear variables on obsidian tools using an experimental approach (see Hurcombe 1992:126, Table 3). Although previous experimental studies covered all the main aspects of wear formation, the level of investigation of particular variables lacks a consistent approach. Moreover, not all researchers provide detailed and well documented experimental data and this makes it difficult to use their results for further comparative analysis. An exception is Hurcombe's study (1992) which represents an excellent summary of the functional analysis of obsidian tools based on a series of well documented experiments. Her published data (Hurcombe 1992) were used as important sources for comparison with the experimental results obtained in my project. Although my task-oriented
experiments, based on local ethnographic information and local resources, did not always correspond with Hurcombe's use-wear characteristics and this necessitated the further verification of some aspects of use-wear formation in this project.

The second factor is related to the nature of worked material. The tropical environment of Garua Island and the adjacent mainland of the Willaumez Peninsula provided a wide variety of plants which have different silica contents and densities that have the potential to create distinctive features of wear and residue on obsidian tools (Fullagar 1986:93; Fullagar 1991:21; Kamminga 1982:56; Kealhofer et al. 1999:541). My experimental program designed to study wear formation on obsidian tools used for processing resources from tropical environments. This includes the extensive documentation of numerous experiments, many of which have never been done before, and new findings from those experiments relevant to wear variables on obsidian tools used for processing new materials. Conducting experiments also makes it possible to obtain comparative data essential for identifying which local materials were used in prehistoric times on Garua Island.

The purpose and structure of my experimental study of obsidian differed in important respects from other experimental studies of stone assemblages in the Pacific previously undertaken by Akerman (1998; Akerman, Fullagar and Van Gijn 2002), Davenport (2003), Fullagar (1986) and Kamminga (1982). However, the general approaches developed by these scholars, as well as by Hayden (1979), Hurcombe (1992), Juel Jensen 1994; Keeley (1980), Semenov (1964), Odell (2004), Tringham et al. (1974), and Vaughan (1985) were used to guide my research design.

Previous experimental and theoretical studies of stone tools have revealed that the formation of use-wear features on stone tools is a complex and interrelated process which is greatly influenced by the type of stone, material worked, mode of use, duration of use and morphological characteristics of the tool (e.g. Ahler 1979; Fullagar 1986, 1991; Hayden 1979; Hayden and Kamminga 1979; Hurcombe 1992; Kamminga 1982; Keeley 1980; Semenov 1964; Odell 2004; Tringham et al. 1974; Vaughan 1985). Scholars have emphasised that use-wear patterns on obsidian tools have some distinctive features. These require specific examination and analytical techniques to obtain functional data (Hurcombe 1992:23, Semenov 1964:15).

A systematic experimental study of obsidian by Hurcombe (1992) was designed to investigate many aspects of wear formation including polish, striations, attrition and residues. In order to understand the factors that cause the differences in wear characteristics, Hurcombe (1992:29-38) has examined use-material and its state, use-
actions, duration of use, and wear features which occurred on the surface of obsidian independently from human activity. However, her comprehensive description of wear did not include detailed analysis of scarring patterns that resulted from use. Also when characterising the state of plant materials involved in the experiments, Hurcombe (1992:39-43) did not specify their silica content and density properties which play an important role in the formation of polishes (Fullagar 1991) and other wear features. Finally, despite a wide variety of worked materials in Hurcombe’s (1992:133) experimentation (e.g. plants, animal meat, hide, bone, antler, fish, feather, human hair and beard) a number of materials which are important for my study were not included: tropical plants, shell and clay. These materials were involved in my experimental program.

In contrast, the main objective of experimental research by Fullagar (1986, 1991, 1998; 2006a, 2006b; Fullagar et al. 1998) was the study of polish formation and residues as major indicators of worked material (Fullagar 2006a, 2006b). Using a range of tropical and subtropical plants, animal, fish and shell, Fullagar concentrated on the examination of the origin, nature and stages of polish development on stone tools including obsidian and the interpretation of associated residues. Other variables, such as scarring, striations and rounding and their interrelationship with worked material and duration of use were considered to a lesser extent. I recorded these variables in detail in my study.

A variety of wear patterns resulting from specific activities was obtained by Kamminga (1982) in his systematic experimental study of tools made from a wide range of lithic materials including 44 obsidian samples (Kamminga 1982:116-177). The purposes of his experiments were, firstly, to study the efficiency of stone material in the performance of tasks associated with the processing of organic materials widely used by Australian Aborigines. Secondly, he aimed to identify the general wear patterns that occurred on experimental tools in order to support functional interpretations derived from the examination of prehistoric artefacts. In analysing experimental data, Kamminga (1982:19) used microscopes with magnifications mostly between 50x to 100x. These allow the analysis of use-scarring, striations, rounding, abrasion and polish in their developed stage. Unfortunately, initial stages of wear formation and some specific polish characteristics, which can usually only be viewed under higher magnification were rarely recorded. In my examination of obsidian tools, I used microscopes with both low and high magnifications which allow the recognition and recording of all types of wear variables.
In contrast to previous experimental programs, my study addresses three interrelated problems that were examined through a number of experiments involving the replication and use of obsidian tools similar to the archaeological examples found at FAO. The first problem is associated with theories about how use-wear is formed on obsidian, a topic that is not well understood (Hurcombe 1992:57-61; Fullagar 1991). My experimental study of how variables including scarring, striations, rounding, polish and residues, are formed, has contributed significant new knowledge relevant to the earlier stages of wear development that are recognisable in certain tasks using certain materials.

The second theme of my experimental program is the relationship of wear patterns, tool efficiency and use duration, in respect of tools which were involved in the processing of a wide range of tropical plants and other non-plant materials which were and are well known and used by recent indigenous people in West New Britain.

Finally, my experimental program focused on obtaining functional data comparable with archaeological tools and could, therefore, be helpful in interpreting their function. These data could then be used to answer wider questions about human behaviour, such as subsistence, craft activities and settlement patterns.

In the first part of this chapter, I consider the aims, approaches and general principles of experimental studies of lithic assemblages and particularly of obsidian tools. The review provides the basis for the choice of the methodological strategies which I used in my experimental program. Next, I present the design and framework of my experiments that includes a systematic recording procedure for microscopic wear that has often been lacking in previous research. I then consider the factors associated with wear formation on obsidian tools paying particular attention to the assessment of when the surface alteration became distinctive of a specific function. I go on to set out the wear variables examined during my experimental work and discuss the attributes of tools that I made and used in my experiments. Finally, the tasks and approaches to non-use wear experiments conducted in this project to clarify the potential influence of taphonomic factors on the surface alteration of the tools are briefly outlined.

In the second part of the chapter, I summarise the range of use-wear and residue patterns recognised on my experimental tools. In the concluding section of the chapter some methodological approaches and the criteria for further assessment of artefact functions are proposed.
4.2 Aims and Design of the Experimental Program

The specific aims of my experiments were to examine (1) when, and under what conditions, major forms of wear such as scarring, striations, rounding, polish and residues are formed on obsidian tools; (2) to what extent obsidian flake tools are efficient in the performance of specific tasks in terms of the duration of use-life; and (3) to produce a set of experimental tools that would assist in the interpretation of use-wear patterns observed on prehistoric obsidian artefacts. To achieve these goals, it was also important to conduct a series of experiments on obsidian raw material which was identical to that of the prehistoric artefacts which comprised the assemblages which were the subject of my study.

To achieve the aims of the experimental program, I began by assessing the use-wear/residue characteristics of the prehistoric artefacts from Garua Island and FAO particularly. It was then important to do a review of ethnographic information from the study area to find out what plants and non-plant resources had been used in the recent past (Chowning 1978; Floyd 1954; Parkinson 1999; Specht 1981). Relevant information was also compiled from literature (Table 5.1) on the aboriginal cultures of the tropical Pacific region and Australia (e.g. Allen, Holdaway and Fullagar 1997; Conte 2006; Fullagar, Meehan and Jones 1992; Haddon and Hornell 1937; Hogbin 1938; Kamminga 1982; Sillitoe 1988; White 1967, 1968; White and Thomas 1972).

The framework of my experiments is relevant to the actual situation of the site under study and to its ecological setting. FAO contains a specific set of obsidian tools which were employed during the mid-late Holocene. This archaeological context has determined which experiments were necessary to be conducted using appropriate materials from the local environment. This approach provides an opportunity to obtain reliable and comparable data for the interpretation of the function of tools involved in past human activities on Garua Island.

Although ethnographic and ethnobotanic data do not, of themselves, enable direct analogies, consideration of the forms of resource exploitation and tool-use behaviour of indigenous population in particular environmental regions contributes important evidence for the study of relationships between experimental and prehistoric wear patterns and their interpretation (Davenport 2003; Fullagar 1994; Kamminga 1982:29). In my study, ethnographic and ethnobotanic knowledge were employed, both to structure the experiments and to support functional interpretations of tools when the results of the experiments were analysed.
There are some limitations in experimental research. First, it is not possible to completely replicate past human behaviour and environments even if general or approximate, "contemporary" conditions can be simulated through the performance of the experiments within the natural resources surrounding the site (Hayden and Kamminga 1979:5; Keeley 1980:6). Second, in any experimental program it is not realistic to replicate all the possible variations in function which may have occurred in prehistory (Hurcombe 1992:29; Vaughan 1985:9). Finally, archaeological wear patterns do not match exactly those observed on experimental tools made from freshly flaked obsidian and therefore cannot provide precise analogies for prehistoric tasks (Fullagar 1986:82; Hurcombe 1992:29; Keeley 1980:6). However, it is possible to construct a reasonably comprehensive and realistic framework of use-wear experiments that would provide a means of observing trends that can be applied to the study of obsidian assemblages in the Pacific region.

Experimental and theoretical studies of obsidian (Fullagar 1986; Hurcombe 1992; Kamminga 1982; Semenov 1964) have proved that (1) the worked material on which the tool was used, (2) the mode of use, and (3) the duration of use are the three major factors that influence the formation of interrelated use-wear variables: scarring, rounding, striations, polish, and residues. My tool-use experiments were designed to study the reliability of these variables in simulated prehistoric conditions. For this reason, the experiments were performed in as realistic situations as was possible while observing and recording results in a scientifically controlled manner. These task-oriented experiments involved a combination of tool movements because this was a more realistic mode of use than such as being restricted to a single movement. For example, processing tubers usually requires both scraping and slicing actions by the same working edge.

Task-oriented tools reflect a more complicated combination of wear variables than more controlled and limited experiments (Plates 4, 11, 37). It is not surprising that such wear patterns are more often observed on prehistoric tools (Plates 155, 158, 164). For example, some of my experiments were performed by local people from West New Britain. They were given the task to make a spear, handle, comb and knife from local plants and they often used only one or two obsidian flakes for whole process (Plate 138C). In other experiments the completion of the whole of a particular process was not attempted, although a more limited version of a task used the same materials and motions as would be the case if the tasks were being performed in prehistoric situations. For the most part, experiments were conducted in the field in West New Britain, Papua
New Guinea and others were made in the laboratory at the Australian Museum. The tools were mostly employed to carry out single tasks, although the multifunctional use of particular tools was the subject of some experiments.

My experimental study involved 292 separate experiments each using a separate tool. Of the total 292 experimental tools, use-wear and residues were systematically recorded on 154. Residues were recorded on the basis of their obvious and distinctive form thus indicating the presence of starch grains, blood cells, fibre, and film. The remaining tools form a reference set for future residue studies. In addition to my work, 15 experiments had been previously conducted and partly examined by Fullagar (1992, 2006; Kealhofer, et al. 1999) A complete list of the experiments is summarised in Table 4.1.

To maintain coherence and continuity in an understanding of how variation in factors affect the use-wear variables, I will describe separately the type and state of material used in the experiments, the actions or mode of use involved in processing these materials and the duration of use. I will then briefly summarise the wear variables on obsidian which I recorded in my experiments.

4.3 Key Factors in Wear Formation

The factors which cause wear formation on obsidian include the type of materials worked by the tools, the condition of the worked material, the actions which were used to process materials and the duration of use of the tool (Hurcombe 1992:30).

4.3.1 Use-Material Variety

The materials used in my experiments were determined by my previous examination of use-wear patterns observed on obsidian artefacts, ethnographic data about native plant species used by indigenous people for daily needs and as food resources in West New Britain and by present local environmental conditions around Garua Island and the Talasea region. All of the materials used in my field experiments (Table 4.2) were available locally through local informants, who provided plant species which are still used today, and personal observation and selection by Dr. White and Dr. Torrence who participated in the field project. The limited time available in the field in West New Britain led to a decision to conduct some experiments, particularly those
related to non-organic materials, soils and skin both inside and outside the laboratory with comparable materials available in Australia.

Materials on which the experimental tools were used belong to the following categories: (1) plants, (2) soft, elastic materials and (3) hard, dense materials. Plants included 31 identified and 5 non-identified species. All of these are widely known in West New Britain (Floyd 1954, Lentfer 1995; Powell 1976) except Eucalyptus sp. which was processed in Australia. The range of plants includes trees, shrubs, grasses and tubers. Because the distinction between trees and shrubs, as well as between tall grasses (e.g. bamboo) and shrubs is not precise (Floyd 1954), I divided the plants into four groups, according to the density of the material and their silica content which was known from previous research. Previous research has indicated that both the density and the silica content are closely related to the formation of wear and residue pattern on obsidian tools (Fullagar 1986:93, 1991:21; Kamminga 1982:56; Kealhofer et al. 1999:541). The first group involved 7 species of palms, including the highly silicious palm-rattan (Calamus spp.) and dense black palm (Caryota sp.). The second and the third groups consist of 17 species of soft and hard wood which vary in silica content. Finally, 9 species of herbs, grasses and tubers were combined in a group of "non-woody plants" (Table 4.2).

The soft elastic materials are represented by 3 species of fish including parrot (Scaridae), wrasses (Labridae) and salmon (Oncorhynchus gorbuscha) and chicken. Additional use-material such as human skin was also included in the experimental program because ethnographic observations which refer to the use of obsidian for shaving the face, cutting beards and hair, trepanation, circumcision and ritual blood-letting (Parkinson 1999:95-96; Specht 1981:347-348). Human skin has similar relevant characteristics to raw chicken breasts (David, Castle and Mossi 2006). Experiments with thin chicken skin were conducted in order to imitate piercing and cutting human skin.

Hard dense materials studied included half-dry clay and two species of shells: cowrie (Cypraeidae spp.) and cockle (Katylesia spp.).

4.3.2 Use-Material State

The condition of the worked material may affect variations in scarring, striations, rounding and polish on obsidian tools. Therefore, the state of worked samples was assessed in all experiments with particular attention being paid to moisture content as
one of the significant factors that soften worked material, reduce friction, and slightly increase the density value for plants (Fullagar 1986:99; Hurcombe 1992:31; Keeley 1980:44; Vaughan 1985:9).

Most of my experiments were conducted with green, fresh plants when they still contained sap and moisture. Used parts of plants include stems and branches, vine, spathe, midrib and pith of palms, bark, fronds, leaves, roots, grasses and tubers. Exceptions were two species of hard wood and one species of soft wood which were all used in a half-dry or dry condition as was dry coconut shell. Tuber were processed both in raw and cooked states and fresh fish was gutted and sliced. A limited number of experiments were carried out involving shaving human skin and processing chicken in a fresh state. In contrast shell and clay were used half-dried (Table 4.2).

4.3.2 Mode of Use

Use-action determines certain aspects of wear attributes including the location and distribution of scars, direction of striations, features of rounding, polish and abrasion (Semenov 1964:15-8; Hurcombe 1992:33). The actions employed in my experiments consisted of the basic modes of tool use that are not directly influenced by cultural or environmental factors because there is a limited choice of tasks that can be applied to particular materials (Kamminga 1982:29; Vaughan 1985:16).

The use-actions of experimental tools involved in processing a range of materials are summarised in terms of transverse and longitudinal actions as general categories (Semenov 1964:3-4). In transverse actions, the tool is oriented in a perpendicular direction to the worked material. Differences in contact angle and edge angle generated several variations (Vaughan 1985:16.). In my experiments these actions are represented by scraping, whittling, planing and chopping (Table 4.1).

Longitudinal actions refer to the motion of the tools oriented parallel to the worked material. There are some variations in actions that are associated with uni- or bi-directional, parallel or slightly angled movements of the implement (Fullagar 1986:89-92; Hurcombe 1992:33-34; Vaughan 1985:24-25). My experiments included cutting as a more general action which could include both uni- and bi-directional movement: sawing defined as bi-directional use of the tool; slicing, which is generally performed by a slightly angled action; and carving, involving a more complex cutting action with a combination of whittling and scraping motions performed by a small area of edge or a tip of a pointed tool.
Some experiments were conducted using rotative action (drilling wood, piercing skin and green leaves). This action combines transverse and rotary movements and produce wear traces oriented in two directions: perpendicular to the tip and rotational around the side edges (Semenov 1964:18; Vaughan 1985:16).

My experiments were designed to perform a single task so the mode of use was relatively simple and repetitive. However, because most of the experimental tools were used without hafting devices, hand-held implements were not able to precisely repeat the same action. This means that any simple action potentially involved occasional movement in more than one direction. This resulted in some variations of the striation orientation on the working edge. For example, some tools used for sawing palm and wood indicate mostly parallel striations although a few isolated diagonal striations are observed as well (Plates 11 and 34).

During the experiments, a combination of two and, rarely, three motions were sometimes used as a more effective way to process the material (Table 4.2). For example, whittling wood required occasional cutting or sawing actions (Plate 51A, 51B and 56B). Processing tubers was more effective if both scraping and slicing actions were used (Plates 91B, 92B). However, multiple uses of obsidian tools were minimal because the design of simple flake tools limits their utility and ability to perform multiple tasks. That is, simple flake tools are commonly used for a single purpose only and this is supported by the observed use-wear characteristics of the prehistoric artefacts. The assemblages that I studied had a low number of tools involved in two or more actions.

4.3.4 Use-Duration

Use-duration is important because it affects the sequence, or stage, of wear formation and the degree to which a tool is exhausted. Experimental studies have indicated that different periods of time are required before wear variables such as scarring, striations, rounding, polish and residues will be developed on the natural, freshly flaked surface of the tools. Use-duration, the material worked, mode of use, and the angle of working edge are interrelated factors from which the extended use of a tool is dependent (Fullagar 1986:88; Hurcombe 1992:34-35; Schiffer 1979:18-19; Vaughan 1985:15).

There are various ways of measuring the use-duration in experimental research. Some scholars count the number and length of strokes as the basic unit of the
measurement of the degree and duration of tool use (Schiffer 1979:18; Tringham et al. 1974). Others employ strokes, time duration, or amount of material worked (Fullagar 1986:88; Kamminga 1982:21; Vaughan 1985:15). In my experiments I adopted Hurcombe's (1992:34) measurement of elapsed minutes.

The purpose of establishing a standardised fixed time for tool use was to more precisely observe the major stages in the formation of particular wear attributes during 5, 15 and 30 minutes. According to Keeley (1980:82-83), most wear on the tools is formed in about the first 20 minutes of use. In the case of fragile obsidian, the actual time of use appears to be much shorter, although some tools were used for 60 minutes or more before they were exhausted.

Employing a standard use-time is a good way to assess changes in wear patterns at a given time. This also makes it possible to compare the rate of wear development on tools involved in processing the same material by one action. Moreover, because realistic modes of use were attempted in my experiments within the controlled use-time, it is possible to establish general guidelines for estimating approximate use duration of prehistoric artefacts on the basis of comparative analysis of wear attributes.

In the next section, I will briefly summarise the wear variables which I recorded and the attributes of tools which I used in my experiments. Finally, the results of non-use wear experiments will be outlined.

4.4 Use-Wear Variables and Residues

As was emphasised in Chapter 3, the main variables that I have selected to describe use-wear on experimental tools are derived from previous studies (e.g. Ahler 1979; Cotterell and Kamminga, 1979; Hayden and Kamminga 1979; Fullagar 1986, 2006a, 2006b; Hurcombe 1992; Keeley 1980; Loy 1994; Odell 2004; Shafer and Holloway 1979; Semenov 1964, Vaughan 1985). These include edge damage or scarring, striations, edge rounding, polish and residues. These forms of wear have common mechanics of genesis but the physical properties of brittle obsidian contribute to some peculiarities in the rate and appearance of wear patterns on tools (Fullagar 1991; Hurcombe 1992:24-27; Kamminga 1982:4-5). I have therefore concentrated on variables which have been shown to be particularly relevant to use-wear patterns observed on obsidian.
4.4.1 Scarring

Scarring is formed on obsidian far more frequently than on other lithic raw material used for the same task. The relationship between types of scars, material worked direction of action and the shape and angle of cutting the edge of the tool was recorded during experiments (Table 4.2).

The most common types of scars observed on my obsidian experimental tools are bending (Plates 3B, 9), feather (Plates 3C, 13) and step scars (Plates 57A, 67B). Often a combination of two or, in rare cases, all types are present (Plate 14C). Flake scars with a hinge termination are extremely rare and were usually recorded in association with step or feather scars. In addition to use-scars, scars formed as a result of accidental or post-depositional factors were examined in a series of experiments.

4.4.2 Striations

In my experiments, striations were noted for most tools, and their orientation, morphology, size and number were recorded. The number of striations was not counted but their density or isolation from each other was noted. These attributes were examined in detail by Hurcombe (1992:37) and her approach and definitions are adopted in this study. Striations were recorded as parallel (or longitudinal), perpendicular (or transverse), diagonal and crossed in their orientation in relation to the axis of the edge (Table 4.1). They were also characterised as sleek (Plates 3C, 37C and 90B), rough bottomed (Plates 23D and 26F), intermittent (29C, 60 and 77C), fern-like and flaked (Plate 27E) types of striations. These different types do not correlate precisely with a specific function, but they do indicate the orientation of the tool during use, the way the tool was manipulated and the nature of contact with the processed material (Kamminga 1982:10).

4.4.3 Edge Rounding

Rounding was common on most experimental tool edges and this was often associated with polish. In my experiments, the assessment of edge rounding was made using a modification of Fullagar's (1986:80) definitions (Table 4.2): (1) very slight (Plates 24B, 26A-C, 30B and 102B-D), (2) slight (Plates 36D and 72B) (3) medium (Plates 25B-C, 58B and 123F) and (4) intensive (Plates 28C, 57B, 90B, 105A, 107A, 109A, 110 and 111).
4.4.4 Polish Variables

My approach adopts Fullagar's (1991) concept of stages in polish formation. However, I use slightly different terms to characterise the polish development: (1) very light polish which is associated with the first stage (Plates 86, 87); (2) light polish associated with the second stage (Plates 6B, 30B, 58B and 77C); (3) developed polish that corresponds with stage 3 (Plates 25B, 32B, 98B and 100B); and well developed polish which is similar to Fullagar's stage 4 (Plates 1C, 4B, 12A, 15B, 17B, 16C, 21, 28C, 29B-C, 33A-B, 44B, 52B, 53C, 54, 57B, 64, 66, 74A, 75, 76A, 85B, 88B, 90B, 99A and 104-111). A number of other attributes are also taken into consideration when identifying type of polish on experimental obsidian tools. These include brightness (intense, bright, dull), texture (very smooth, smooth, and slightly smooth), the location and distribution along the edge (Hurcombe 1992:36-37)

4.4.5 Residues

My experimental program was designed to investigate particular wear patterns and the associated residues when processing a diverse range of materials. The aim was to gather valuable information about residue accumulation, including type and distribution on the working edge of tools. Taxonomical identification and detailed characteristics of residues were not part of my study and, therefore, only general categories of residues were described. Residues that were recorded on experimental tools include oily film (Plates 3A, 14A, 50A, 62A and 72A); plant tissue (2A, 18A, 19A, 23A, 27D, 29A, 41B, 65B, 78A, 116A, 123C-D and 124B); animal tissue, including rainbow coloured residues (94A-B, 94F, 95D, 96 and 114E-F) and human skin (Plates 100A, 101A, 102A, 102C and 103A); fish scale (Plate 114D); starch granules (Plates 8, 16D, 20B, 27C, 40C, 41C, 58C, 74B, 76B, 77D, 83B, 85C, 115E, 116B and 123B); resin (Plates 23C, 26F and 115); needle-like residues some of which may be raphides (Loy 2006:136) (Plates 1D, 12B, 30A, 30C, 63C-D, 85D, 115F); blood-like residues (Plates 44C-F, 51C-F, 112, 113 and 114A-B), and unidentified white coloured residue (Plates 25C, 27B, 36C-D, 40A, 42A, 53C, 84C, 105B, 110B, 111C and 119B).

Another significant aspect of residue experiments concerns the comparison of a reference collection through the extraction of residue from the tools and their storage on glass slides. Since the residues have not been removed from some experimental tools, this experimental collection of residues will provide essential data for future
comparative residue analysis and identification of species of plants and other organic material.

4.5 Hafting Wear and Residues

Most of my experimental tools were hand-held, although some tools were hafted in a wooden device. Hand-held patterns of tool use were achieved in two ways: tools wrapped in plant leaves or vines (Plates 133A-F) or in the bare hand without additional protective materials (Plates 134A-D). Wooden handles were used for some stemmed tools and adzes (Plates 132A-E). The formation of hafting wear and residue was not the main subject of my study; however, any modifications to the surface related to the hafted part of the tool, as well as associated residues, were recorded and used for comparative analysis with the patterns of wear observed on obsidian artefacts.

4.6 Taphonomic Wear Attributes

In order to examine the processes and nature of surface damage not related to tool use, 24 obsidian flakes were buried within a loam deposition on a slope for 22 months (Plates 121A-F). Although the time scale is short, these experiments suggested that certain natural and accidental factors can produce physical and chemical damage to obsidian surfaces. These results, therefore, may be used as a general guide to the potential changes of freshly flaked obsidian surfaces and altered surfaces of artefacts that might have occurred in the past.

4.7 Manufacture of Experimental tools

The tools made for this project are mostly unretouched flakes, similar to those in the archaeological assemblage from FAO, although, a few stemmed tools were also made. Obsidian cobbles and nodules for knapping were collected at both the Baki source on Garua Island and the Kutau source at Bitokara Mission (Torrence, Specht, Fullagar and Bird 1992). Most cobbles had an angular shape with potential flaking platforms and good flaking abilities (Plates 128A-B). However, many larger pieces included air bubbles and very thin, fractured layers that affected the strength of cores and the predictability of fracture paths. These physical features generated large quantities of waste and required a large amount of raw material for knapping. This was also a
limitation for the manufacture of large Kombewa cores and flakes used in the production of stemmed tools. In my knapping experiments some Kombewa cores and Kombewa flakes were obtained (Plates 128B-E), but their size was limited by the size of pieces and blocks of obsidian brought from the sources.

The knapping was carried out over a large plastic tarpaulin placed on a sandy ground surface. During knapping, flakes with a suitable edge were collected and placed in large shallow plastic trays. In the selection of flakes for the performance of particular tasks, several specific attributes, which I thought would be significant in the use-wear formation, were carefully considered. These included (Table 4.1):

1. Size of flake (large, medium, small);
2. Shape of edge (straight, concave, convex);
3. Edge angle: 1 – very thin, less than 15°; 2 - medium, between 15° and 55°, and 3 – thick, more than 55°;
4. Mode of hafting (hand, wrapped, hafted in wood).

Other morphological attributes of the flakes were recorded when relevant. None of the tools were sharpened before use because the unretouched obsidian cutting edge is already thin and sharp. The tools were used as naturally as possible although they were not dropped, stepped on, or used with gritty hands, and generally treated as casually as prehistoric tools perhaps were. Exceptions were those experiments performed by indigenous people (Bongi, Blaise, Camilus, Mary, Jessie and Lydia) who used tools more casually in their natural behaviour and which involved dropping the tool on the sandy ground, or putting it on stone platform or wooden bench, holding it in the mouth between teeth during a break or after the work. In same cases this tool use behaviour was reflected on the edge and surface of experimental tools (non-patterned edge damage and abrasion) and was recorded.

4.8 Results of Experimental Study

In this part of the chapter, I outline the range of use-wear and residue patterns on my experimental tools which were used for processing a variety of materials. Some of the experiments have not been carried out before. The results of the experiments are presented in categories based on differences in use-material. Within each use-material category, the types of use actions and the duration of use are presented with detailed characteristics of the main forms of wear variables including scarring, striations,
rounding, polish and residues. This approach allows an understanding of the ways in which use-material, use-action and duration of use affect the kind, degree and rate of wear formation on experimental tools. It also allows an assessment of the extent to which these data can be used to identify the function of prehistoric artefacts. Because the particular form of use wear may be consistent with the apparent residues resulting from contact with processing materials (Fullagar 2006b:201), it is also important to describe residues and their distribution on experimental tools. Data derived from hafting wear patterns and taphonomic experiments are presented as additional useful information which may assist in the analysis of artefacts. The concluding section of the chapter describes how these results can be employed in the interpretation of the function of prehistoric tools.

The experimental results are presented in the Table 4.1. Most of these experiments are accompanied by images (Plates 1 to 146). These images make it clearer and easier to appreciate trends and variations in the data.

4.8.1 Palms and Pandanus

Palms are very starchy plants which are widely recognised as economically significant species in the Pacific region (Kealhofer et al. 1999:543; Powell 1976:182). In my experiments 7 species of palms were processed by different modes of use (Table 4.1). Most of the palm species are of light to medium density and have high silica content, with the exception of the very dense Caryota sp. (black palm) which is comparable with hard wood (Fullagar 1986:96). Because the spathe, frond, midrib and stem of palms, as well as the shell of coconut, are of similar density and hardness to soft wood, they produce similar scarring patterns on obsidian tools. In order to see how the main forms of wear, such as scarring, striations, rounding, polish and residues are built up, experiments for 5, 15, 30 and more minutes were conducted in many cases.

The sawing of palm (Figures 4.1: 3-4; 4.3: 1-3 and 4.4: 1-2 and 4) resulted in small and medium scars with feathered and bending fracture terminations which prevail on the working edge (Plates 1A-B, 10 and 11). They are intensively formed within the first few minutes (1A-C and 28A-B), but with continued use, the initially acute edges of tools are relatively stabilised by rounding and polish development and this prevents, to some extent, further use-fracturing (Plates 2A-B, 11, 13 and 29A-C). Scars are irregular in shape (Plates 11, 28A and 29A) and are continuously distributed (Plates 14C
and 29A-B) on either the ventral or dorsal surface depending on which has had the most contact with the worked material. Occasional scars are distributed in a discontinuous manner along the opposite surface (Plates 15A and 15B) and are oriented towards the edge in a perpendicular or slightly diagonal direction. Similar scar patterns appear on edges used for cutting actions (Plates 13 and 14A-C). Scarring increases in frequency when material of higher density is worked. For example, sawing dense black palm for 5 and 15 minutes produces very intensive and continuous edge scarring (Plates 17 and 19). As a consequence of scarring, particles of obsidian, which break from the working edge, become embedded in the worked material and accelerate the development of smoothing abrasion (Plates 16A-C), striations, and edge rounding.

Striations from sawing actions are parallel to the edge, extend from the higher peaks down to the lower surface and often spread inside micro-scars (Plates 1, 2, 10, 11, 15 and 28C). When a working edge shows intensively sustained bending fractures, striations running parallel to the edge can be seen between these fractures (Plate 17B). The sleek, straight-sided and rough-bottomed types of striations are most common, but intermittent striations (Plates 10, 11, 19A-B and 31A-B) can also be present and can be often observed on the tools used for processing black palm (Plates 17B and 22). In well developed polish areas, the striations are mainly of the shallow and short sleek type (Plates 1B, 2B, 13, 14C, 15A-B, 28 and 29B-C). Sometimes both parallel and diagonal patterns of striations appear as a result of an occasional whittling action (Plate 11 and 30B). Striations are formed during the first 5 minutes of sawing (Plates 1A-C, 9, 17A-B and 28A-B) and their density dramatically increases in the following 15 (Plates 2A-B, 15 and 31B) and 30 minutes (Plates 11, 20A and 29B-C).

Edge rounding is common on most tools used for sawing palms and is often associated with smoothing and polish. Slight edge rounding, which forms during the first few minutes of sawing (Plates 1A-B, 9, 17A-B, 28A-C and 30B), often develops into intensive rounding that can be observed on the preserved edge areas (Plates 11, 13, 20A and 29A-C). With further use of the tool for 30 and more minutes, all prominences on the working edge and the flake scar intersections were rounded to varying degrees (Plates 13 and 20A).

All experimental tools involved in sawing palms demonstrate developed and well developed stages of polish formation during the first 5 to 15 minutes (Plates 1C, 9, 10, 14C, 15A-B, 17A-B, 28C and 31B). Very smooth polish appears to be more even and the polished area occurs most extensively along the surface prominences which have experienced the most forceful contact with the worked material (Plates 9, 10, 20A and
28C). This polish does not extend fully from the highest peaks into the surface depressions (Plates 1C, 10, 13, 15B, 20A, 28C and 29C) even after 1 hour of sawing (Plate 22) and it is usually more widespread on one side of the edge than on the other.

Sawing experiments indicate that highly siliceous palms with light and medium densities are able to produce identifiable wear features during short time periods. The combination of visible scars, longitudinal striations, slight to medium rounding and developed polishes occur on the working edge after only 5 minutes of use. But the association of rounding and polish can be more reliable in the identification of the worked material after 15 minutes. Moreover, experiments show that sawing palms by unretouched flakes with edge angles of between 15° and 55° can be most effective during 10-15 minutes and, to a lesser extent, up to 30 minutes of use. In respect of the shape of the working edge, experiments demonstrate that the straight edge of the tool is more convenient for a sawing action, although convex and concave profiles of the edge are equally effective in the performance of tasks.

These results indicate that prehistoric artefacts with similar morphological features and wear characteristics can be assessed as tools with a short-term use history which were discarded probably after some 15-20 minutes of use. In relation to microscopic analysis, it should be stressed that, in contrast to the edge scarring and striations which can be relatively easily seen under 100x magnifications, observation of edge rounding and especially types of polishes require higher magnification from 200x up to 1000x.

Scarring patterns on the tools used for whittling palms (Figures 4.2: 1 and 4.4: 3) are generally restricted to one side of the edge. Most scars have bending and feather termination, although shallow feather terminated scars prevail on the contact edge. They are oriented at a slight diagonal to the edge (Plates 3A-C and 18A-B) and a few isolated small scars may also be observed on the opposite side. Scars occur during the first few minutes of use as discontinuous fractures of the edge, but their number gradually increases. These form a continuous distribution on those parts of the edge which had the most contact with the worked materials.

Striations have similar features to those described during the sawing motion and include shallow, short sleeks, rough-bottomed and intermittent types, but they are oriented mainly diagonally (Plates 3C and 18A-B). Sometimes both diagonal and parallel striations which cross each other are formed as a result of the cutting action (Plate 3B). Because of intensive use-scarring, only patches of edge rounding can be
observed on some locations. Rounding varies from light to intensive and is restricted to the immediate edge (Plates 3B-C).

Some patches of smooth, light or developed polishes preserve on the surface prominences and the scar intersections (Plate 3C). The formation of abrasion and polishes begins during the first 5 minutes (Plate 18B), however, subsequent scarring often removes the altered surfaces. The distribution of polishes is restricted mainly to one side of the edge and is associated with the highest points of the surface topography and does not spread into depressions.

The type of scars, their orientation and location on the edge of experimental tools in combination with diagonal and relatively dense striations, patches of intensive rounding and developed polishes which resulted from the whittling of palms, can be used as a guide for the functional identification of artefacts with similar wear patterns.

The scraping motion results in intensive use damage of the edge by all types of scar terminations during the first few minutes of action. Scars have a continuous distribution along the edge but are usually restricted to one side of the tool (Plate 12A). Scraping at an acute angle, less than 15°, mostly results in spreading bending scars on the upper surface. The tools with an edge angle of between 15° and 55° produce predominantly step and feather scars and, to a lesser extent, bending scars. Closely packed, overlapping step scars are prevalent on tools with an edge angle greater than 55°. A few scattered feather and step fractures may occur on the opposite side of the edge. The scars are oriented perpendicular to the edge and vary from very small to medium in size (Plate 12A).

Striations from the scraping action occur on the underside of the tool as a dense net of shallow, short sleeks, rough bottomed and intermittent types. They are oriented perpendicularly or slightly angled to the working edge (Plates 4A and 12A).

Scraping palm produces intensive edge rounding and well developed polishes within a matter of a few minutes. This leads to the rounding and smoothing of all prominences on the surface and on flake scar intersections (Plate 12A). As a result, the working edge becomes progressively blunt and loses efficiency after 10-15 minutes of use. Because of use-scarring, the distribution of polishes can have a patchy character on the edge.

Some peculiarities in scarring patterns are observed on the tools used for scraping dense, hard black palm and coconut shell (Plates 135B-C). Because of the high density and hardness of these worked materials, the edge immediately sustains multi-
layered scars that severely modify the shape and profile of the edge. After only 5 minutes of use, the edge becomes irregular in plan view and, with continued use the tool is further modified by subsequent scars. When work ceased after 30 minutes, the upper side of the edge is covered with complex overlapping step and feather scars accompanied by dense deep and shallow striations, intensive rounding and polish (Plate 4A-B and 16A-D). An intensive blunting by scars, rounding and polish makes the working edge inefficient after 5-10 minutes of use.

**Carving**, as a mode of use, involves a combination of cutting, scraping and whittling motions which are performed by a small area of the edge (Plate 135D). Accordingly, relatively complicated scarring patterns and striation distribution can be seen after a few minutes of use. However, the characteristics of rounding and polish resulting from working palms are similar to those which are observed on the tools used separately for each particular task.

In general terms, wear variables on obsidian tools used for processing relatively hard parts of palms (frond, stem, spathe, midrib and coconut shell) have distinctive peculiarities due to their high silica content. This is especially relevant to the stages of polish formation and rounding patterns (Fullagar 1991:21). Both well developed polish and intensive rounding occur on the working edge quickly enough (within a few minutes) to be identifiable under higher magnifications. Striations on flattened polish areas are mostly shallow and short, densely packed, sleek and rough bottomed types. Scar ridges are usually smoothed and rounded. The surface depressions of scars are often covered by striations.

This set of wear variables on obsidian tools used for palm processing was not described in previous experimental studies by Fullagar (1986), Kamminga (1982) and Hurcombe (1992), although Fullagar (1991) emphasised that the high silica content of palms always produces a developed polish on tools having relatively short use duration (Fullagar 1991:17). The wear patterns obtained in my experiments establish significant diagnostic criteria for functional identification of those artefacts having similar wear attributes. Moreover, the experimental data indicate that identifiable wear builds on most used tools during the first 5-10 minutes and after 15 minutes tool effectiveness dramatically decreases. This short use-life history of obsidian flakes involved in working palms leads to the high rate of discard and must be taken into account in assessing prehistoric artefact assemblages.
A number of experiments were also conducted to process softer parts of palm species (scraping and slicing coconut meat) (Plates 5-8 and 135A; Figure 4.2: 1-2), cutting thorns from green leaves of *Pandanus* *spp.* (Plates 24-27 and 134A-B; Figure 4.2: 3-5), and cutting green skin from *Calamus* *spp.* which are used for the manufacture of plant string (Plates 30, 31 and 131; Figure 4.3: 1-2).

**Scraping and slicing coconut meat** (Figure 4.2: 1-2) does not produce developed wear patterns even after 30 minutes of use. Discontinuous scars with bending and feather terminations occur as a result of close contacts with nutshell during scraping or slicing actions. They are small in size and irregular in shape and distributed on one side of the edge (Plates 6A-B). Striations have a patchy distribution alone the edge and are associated with areas of use scarring. They are seen as isolated sleeks (Plate 5B), deep intermittent (Plates 6A-B) and rough bottomed (Plate 7) striations with diagonal and parallel orientation. The working edge is usually very slightly or slightly rounded (Plate 6A), and rare patches of very light polishes may be observed under the highest magnifications. Despite continuous use for 30 minutes, the working edge of the tool maintained its sharpness and could still be used.

**Cutting and slicing pandanus leaves and stems** (Figure 4.2: 3-5) is indicated by a more obvious set of wear attributes that form after 15 minutes of use. Continuous distribution of small scars with bending and feathered terminations is observed mainly on one side of the edge (Plates 23A-B, 24A-B, 25C and 27A). Patches of shallow and deep sleeks (Plate 26C), rough bottomed and intermittent striations (Plates 23B, 24B and 25A) are preserved on some parts of the edge. They are separated from each other and oriented both slightly diagonal and also parallel to the working edge (Plates 23B, 24B, 25A and 26C). Edge rounding varies from very slight to slight (Plate 26C) and rare patches of developed polish can be observed on some spots of the edge after 30 minutes of use (Plate 25B). The tools maintain their efficiency in cutting leaves for up to 2 hours. A longer period of use increases the density of short intermittent and rough bottomed striations and leads to the formation of a medium rounded edge with patches of developed polishes (Plate 27A).

Both scraping coconut meat and cutting/slicing pandanus leaves/stems were not included in previous experimental studies. My experiments demonstrate that wear formation on the tools from processing softer parts of palms and pandanus requires a
much longer period of tool use. This also supports the inference that silica content varies significantly within different parts of the same plant (Fullagar 1991:7). Although wear increases with time, only after 30 minutes is a combined set of scarring, striations, rounding and polish able to indicate the mode of use and, to a lesser extent, the material worked. However, in the situation when polishes and rounding are not well developed and intensive, a more confident interpretation of processed materials can be made on the basis of attached and preserved residues such as plant tissue, starch grains and needle-like residues (Plates 23A, 24C, 26D-E and 27C-D).

4.8.2 Soft Wood

In my experiments, 10 species of soft wood including highly siliceous *Homalium foetidum* (malas) and *Calophyllum* sp. were processed by a variety of modes of use (Table 4.1; Figure 4.6).

**Sawing** soft wood using flakes with an edge angle of less than 15° results in very intensive scarring with mixed types of terminations. Scars appear during the first 2-3 minutes of use of the tool. Small bending, feather and step scars are distributed mainly in a continuous manner on either the ventral or dorsal surface depending on which has had the most contact with the worked wood (Plate 32A). Occasional scars may occur on the opposite surface. Tools with an edge angle of between 15° and 55° sustain less use damage at the beginning, but with continued use, the number of small and medium scars with bending and feathered terminations increases.

A number of long, deep, sleek and rough bottomed types of striations are predominant, although intermittent striations can be present as well. Striations are oriented parallel to or at a slight angle to the working edge and sometimes cross each other (Plates 33A-B and 34A-B). They are isolated from each other despite their relative density. In contrast, species of wood with high silica content, such as malas and *Calophyllum* sp., produce closely packed short, deep and shallow striations between which rough bottomed types dominate (Plates 45, 46 and 51A-B). These data contradict Fullagar's (1986:180) results obtained on the tools made of flint which emphasize the absence or rare occurrence of sleeks or rough bottomed striations on woodworking tools, but correspond well with Kamminga's (1982:64-65) conclusion that long striations in association with smoothing, rounding and blunting are common features of wood sawing experiments.
Edge rounding forms within a relatively short time period on the tools used for sawing soft wood (Plate 32B). After 15 minutes of use medium and intensive rounding increases the thickness of the working edge leading to less efficiency in the performance of tasks. Some patches of rough abrasion may extend from an intensively rounded edge to the surface (Plate 33).

Patches of smoothed, developed and well developed polish may appear during the first 5 minutes of tool use (Plate 32B). Polish does not extend deeply into surface depressions and its distribution is restricted to the highest points of the surface microtopography and the scar intersections. Siliceous wood produces a continuous line of well developed polish that extends further on the surface from the edge after 15 and 30 minutes of use (Plates 45 and 46).

Thus the difference between wear patterns on the tools involved in sawing palms and less siliceous soft wood is particularly obvious in terms of the appearance and distribution of striations (e.g. Plates 1, 2, 10, 11 and 33-34). This may be used as a significant indicator for the functional identification of artefacts, especially in conjunction with other wear variables and residues. However, if the wood has high silica content, differentiation from palms on the basis of use-wear data alone probably cannot be made because wear patterns are very similar.

A whittling mode of use requires more pressure than sawing and this causes more edge damage on brittle obsidian (Hurcombe 1992:41). Continuous or discontinuous scarring patterns can be observed on those parts of the edge which have had close contact with wood. Most scars are characterised by bending or feather terminations which are oriented at a slight diagonal to the edge (Plates 35A-B, 38A-B, 43 and 50A-B), and which are mainly distributed on one side of the edge, with the exception of a few isolated small scars that appear on the opposite side.

The sawing and whittling modes of use can be clearly distinguished by the orientation of striations and polish. However, because of the edge scarring, many areas with wear are often destroyed during the use. It is possible to detect a few isolated, diagonal striations after 5 minutes of whittling (Plate 38B), but a patterned appearance forms only after 20-30 minutes. The patterns are represented by long shallow and deep sleeks (Plates 37 and 41) and rough bottomed striations (Plates 35B).

Edge rounding varies from very light to medium. Patches of very light or light polishes can be seen on some relatively stabilised parts of the edge (Plate 35B). Species of wood with higher silica content (e.g. Hibiscus tiliaceus), produce slightly more
intensive rounding and polish (Plates 38B and 40B) than less siliceous erima (*Octomeles sumatrana*). On the basis of these experiments, it is obvious that the whittling mode of use, if it was applied to non-siliceous soft wood for less than 30 minutes, would be difficult to identify on artefacts.

Intensive rounding with well developed polish and patches of relatively dense striations, can appear on tools involved in the processing of non-siliceous soft wood, if they have been used for a longer period in particular activities. For example, scraping erima for one hour results in mixed scar patterns with stepped, bending and feathered terminations on one side of the edge (Plate 37D-E). Continuous distribution of all types of scars resulting in the blunting of the edge is common for wood scrapers (Kamminga 1982:67).

Slightly diagonal and perpendicular striations are long, deep and also include shallow sleeks, rough bottomed and rarely intermittent types. They are located predominantly on one side of the edge. Some patches of striations are visible at the intersection of scars and sometimes on the surface within the scar depressions (Plates 37C, E). Smoothed rounding and well developed polishes are observed on some points of the edge (Plates 37A-C).

Occasionally, in addition to scraping, a sawing action was performed with different parts of the same edge and this is reflected in parallel and slightly diagonal oriented striations, randomly distributed feathered scars and very light rounding (Plate 37F).

Experimental tools used for carving and engraving soft wood are characterised by mixed scarring with prevalent bending and feather terminations (Plates 42B and 47; Figure 4.6: 4). Because these actions mainly involve cutting motions, distinctive long and deep striations are oriented in parallel or slightly diagonal directions (Plates 36D, 41A, 48A-B, and 49A-B; Figure 4.6: 2-3). Sleeks and rough bottomed types dominate although intermittent striations are present to a lesser extent. The density of striations increases on the intersections of scars and on other elevated parts of the surface microtopography (Plates 48-49).

There are two main factors that influence the degree of polish formation and rounding: the silica content in the wood and the duration of use. Carving erima for 15 minutes produces slight to medium rounding and light polish (Plate 36D). In contrast, carving siliceous malas for the same time duration results in intensive rounding and well
developed polishes, which have patchy distribution on the edges. On the other hand, the hibiscus and red cedar species, which have a medium silica content, form intensive rounding and well developed polishes on the tools which were used for more than 25-30 minutes (Plates 41A, 48 and 49). This means that it will be difficult to distinguish wear patterns between artefacts used for short-term carving of soft siliceous wood and long-term carving of soft wood with low or medium silica content.

**Gouging.** sawing and carving soft wood (erima) using a small obsidian core with a flat percussion platform reflects a different set of wear patterns on particular parts of the used edge. The gouging action indicates an intensive abrasion, rounding with patches of well developed polishes in association with closely packed intermittent and rough bottomed striations (Plates 36A-B). In contrast, sawing and carving are characterised by discontinuous bending and feather scars, long and deep sleeks and rough bottomed striations, medium to intensive rounding with patches of developed polishes (Plates 36A-D). The tool was effective in the performance of the task for the first 5-10 minutes. This experiment suggests that some small cores with flat platforms and relatively sharp edges are able to perform particular woodworking tasks for short time periods.

**Drilling** soft wood by pointed non-retouched flakes (Figure 4.6: 1) produces intensive scars with prevalent step and bending terminations on both sides of the edges in 1-2 minutes. With increased use-time, the edges are stabilised and blunted by scars. All prominences on the surface along the edges and scar intersections become intensively rounded after 15 minutes of use (Plates 52A-B). Short, deep and shallow, sleek and rough bottomed striations orient rotationally around the side edges. Patches of smoothed, well developed polishes (Plates 52A-B) can be observed on the highest points of the working edges. Polish and rounding resulted mostly from auto-abrasion (Kamminga 1982: 66). In conjunction with striations and scarring, these form very distinctive wear patterns which can be relatively easily identified on artefacts.

The **smoothing/polishing** action on siliceous wood, which was initially worked by scrapers, produces well developed wear on the dorsal side of the flake used as the working surface (Plates 53A-D). After 15 minutes of smoothing, microfractures which occurred on ridges of the flake were intensively rounded. A dense net of deep and mostly long sleek and rough bottomed striations were formed on the prominent parts of
the surface (Plate 53B). Bright, smooth and well developed polish intensively flattened the working ridges, but this polish does not deeply penetrate into microdepressions (Plate 53C). In archaeological assemblages such smoothing implements may not occur, but use-wear characteristics resulting from intensive contact with soft and siliceous wood represents a particular area of interest for my experimental studies of the wear formation.

The wear on woodworking tools used for processing non-siliceous soft wood differs from wear produced by working palms. First, striations on woodworking tools are generally longer, deeper and tend to be more separated from each other (e.g. Plates 11 and 34 B). Second, there are some differences in the rounding and polish characteristics which form during the same duration of use on palm and woodworking tools. Moreover, if one compares the wear patterns that resulted from working palms and siliceous soft wood then it becomes apparent that polished areas on tools used for working palm for 5, 15 and 30 minutes are usually very smooth and more intensively flattened than on woodworking implements which processed highly siliceous malas during the same time interval (e.g. Plates 2B, 9, 11 and 44A, 45B, 46B). These variations in the size of striations, rounding and polishes may be potentially used to differentiate the two types of materials (palms and siliceous wood) worked by obsidian artefacts. However, to clarify these differences, further experimental studies are required. At this stage of the analysis, the functional differentiation of prehistoric artefacts can be made between two groups: (1) tools used for working siliceous soft wood and palm (which produce similar wear patterns) and (2) those tools that used for processing non-siliceous soft wood.

4.8.3 Hard Wood

My experiments included 8 species of hard wood which were processed by sawing, whittling and scraping (Table 4.1). The most common wear feature on the tools used for working hard wood is intensive scarring that often removes other use-wear variables from the working edge, such as striations, rounding and polish (Figure 4.5).

This is especially typical of the tools used in the whittling action (Plates 54-56). Bending and feather scars appear on the edge in the first few minutes of use. Scars that are irregular in shape and medium and large in size generally occur on one side of the
edge in the whittling mode of use. Their number increases with continued use and this leads to the formation of overlapping fractured edges with irregular plan view (Plates 55A-B and 56A-B). A few isolated, diagonal striations can be seen on some parts of the edge. Sometimes they are long, deep rough bottomed and sleek types (Plate 54B), but more commonly they are intermittent striations which appear as patches of densely packed short scratches (Plate 55B), or long isolated lines (Plate 56B).

In most cases very light or light rounding can be observed on rarely preserved spots of scar intersections. Sometimes the same spots may contain patches of light or developed polish (Plates 56A-B). The areas close to the edge are often characterised by light attrition that contrasts against the smoothed background of the natural surface of obsidian (Plate 56B). Attrition occurs most often on hardwood tools (Hurcombe 1992:41).

Scraping of the same species of hard wood *Pometia pinnata* (ton) for 30 minutes produces more pronounced rounding and polish with isolated perpendicular striations on one side of the edge (Plate 57B). The opposite side is damaged by continuous step, feather and bending scars (Plate 57A). Similar wear patterns are observed on tools used for scraping other species of hard woods (Plates 58A-B).

In addition to intensive scarring and light attrition on the surface, the common trend in wear characteristics for tools used for processing hard wood is the constant occurrence of patches of rough intermittent striations irrespective of the mode of use, but in association with prevalent rough bottomed and sleek striations (Plates 55B, 61B and 62B).

These peculiarities in the distribution of striations on the highly fractured edges with patches of rounding and polish which are formed on the tools involved in working non-siliceous hard wood can be significant indicators in a use-wear study of artefacts and their functional interpretation. However, there seemed to be no clear differences in wear attributes between sawing siliceous hard wood *Mangifera indica* (mango) and siliceous hard palm *Caryota sp.* (black palm) (e.g. Plates 17A-B, 20A and 59-60). This means that those artefacts which were used for some hard and highly siliceous species of wood and dense, hard palms cannot be distinguished on the basis of wear data, although separation may be achieved through analysis of residue materials.
4.8.4 Non-Woody Plants

Species of green bamboo (*Bambusa* spp.) and cane (*Saccharum* spp.) are highly siliceous plants with similar densities to palms (Fullagar 1986:148-150; 1991:16-17). It is, therefore, not surprising that there are similarities in wear variables between tools used for processing palms, bamboo and cane, including scarring, striations, rounding and polish development. For example, sawing coconut palm (Plates 1A-B and 2A-B), bamboo (Plates 63A-B and 64A-B; Figure 4.3: 4-6) and cane (Plates 68A-B and 69A-B; Figure 4.7: 1) for 5 and 15 minutes, leads to almost the same stage and rate of wear formation.

The difference in wear pattern is seen in the dominance of certain types of striations on tools used for cutting/whittling cane (Plates 68-70). Intermittent and some fern-like striations are more common on these tools. This is probably associated with sand and soil contamination attached to uprooted growing grasses (Plate 134F). Among these tools there are some peculiarities in scarring patterns that relate to the initial angle of the edge. Tools with thin, acute edges are more susceptible to bending scars during the first 5 minutes of use than tools with edge angles between 15° and 55° (Plates 63A-B, 68A-B and 138A-C).

Based on my experimental data, it will be difficult to distinguish, with confidence, the differences between wear patterns resulting from working palms, siliceous soft wood, bamboo and cane on prehistoric artefacts, unless residues are diagnostic. Consequently, this overlapping pattern of wear creates the basic criteria for the definition of a category of "siliceous soft wood, palm and bamboo" which I use for my functional classification of obsidian artefacts from FAO (e.g. Tables 7.1 and 8.1). In contrast, processing siliceous hard wood and hard palm, although producing some similarities in the appearance of striations, edge rounding and polish, generates very distinctive scarring patterns that influence the location and distribution of other wear variables. This leads to the definition of a "siliceous hard wood and hard palm" category in my use-wear classification of artefacts from FAO (e.g. Tables 7.1 and 8.1).

**Working leaves and stems of soft siliceous non-woody plants** including banana (*Musa* spp.), fern (*Asplenium nidus*), croton (*Codiaeum variegatum*), ginger (*Zingiber officinale*), aibika (*Hibiscus manihot*) and taro stem (*Colocasia esculenta*) usually produces very small and small bending and feathered scars which are often distributed in a discontinuous manner (Figure 4.7: 2-7).
Cutting siliceous banana leaves results in light surface alteration after 5 minutes of use (Plate 71B) which gradually transforms into light (Plate 72B) and developed (Plate 73B) stages of polish with increased time duration of up to 30 minutes. The tools were still perfectly useful when the experiments were completed. A few, isolated, parallel, sleek striations occurred at the beginning, but with continued use their number and density increased. In contrast, scraping banana stems (Plate 134E) produces very intensive rounding and well developed polish which deeply extends into the surface depressions and scars (Plates 75A and 76A). Under higher magnification, perpendicular sleeks and rare intermittent striations can be observed.

Processing fern by cutting and whittling actions for 5 and 10 minutes produces very light or light rounding and very light polish (Plates 77A-C and 78A). Fullagar (1986:182) noted that slicing bracken fern with flint tools for 45 and 60 minutes produces a relatively extensive polish. Some long, isolated, sleek and rough bottomed striations oriented parallel or slightly diagonal to the edge can be observed (Plates 77B, 78B). Discontinuous scars with bending or feather terminations are dominant. Similar wear features form on tools used for cutting aibika and taro leaves for 15 minutes (Plate 84A and 87).

Working croton and ginger (Plates 134C-D) demonstrates the stages of development of wear variables over time. After 5 minutes of use there are few bending and feather scars, very light rounding and some isolated parallel and slightly diagonal striations (Plates 79B and 82). The next 15 and 30 minutes of tool use produce more intensive rounding, developed polishes and more dense, shallow and mostly sleek striations (Plates 81B and 83A). In fact, although wear increases with time, the tools were still relatively sharp and useable and could have built up more wear.

Experiments with working green leaves and stems of non-woody plants show that there is less intensive edge damage in the form of small scars and microscars in comparison with the scarring pattern on the edges of woodworking tools. A few to a moderate number of striations of shallow, sleek types are prevalent, and (much more rarely) rough bottomed or intermittent types occur. Some patches of weakly developed polish may contain very light striations after 10-15 minutes (Plates 72B, 78B and 80B). There are obvious stages in the formation of rounding and polish that depend on the duration of tool use (Plates 71-73 and 79-81). Similar trends in wear formation were
observed on the tools that were used for processing pandanus leaves and coconut meat. All of these features indicate that those artefacts which preserved diagnostic wear patterns, which were similar to the experimental tools involved in working softer parts of woody plants and non-woody species, were used for much longer time periods (probably over 30 minutes) than implements identified as woodworking tools. The existence of common features of wear patterns, however, does not exclude some peculiarities in detail in polish development and the type and appearance of striations observed on the tool used, for example, in the extraction of coconut meat (Plates 5-8) or processing croton or ginger (Plates 79-83). However, in the archaeological context such peculiarities of wear patterns on the tools it is difficult to correlate precisely the particular species of plant and use-wear unless detailed residue identification is made. In my project, artefacts, with wear patterns similar to experimental tools, were considered as a group of implements used for working non-woody plants and named "greens" and which included leaves, green stems and grasses.

Previous experiments involving stone tools used for processing tubers, such as raw and roasted taro (*Colocasia esculenta*), yam (*Dioscorea esculenta*) and sweet potato (*Ipomoea batata*), showed that discontinuous, non-distinctive scarring patterns occurs on the tool at the beginning of use (Fullagar 2006b:200, Kamminga 1982:55). These results are supported by my experiments with raw tubers (Plates 85B; Figure 4.8). With continued use, the number of scars slightly increases. In a slicing motion a tool penetrates into the tuber cutting off slices of worked material (Plate 137A and 137F). This produces scattered small bending and feather scars on one side of the edge and is accompanied by isolated, long and shallow sleek (Plates 86 and 92B) and rare intermittent striations (Plate 93A) which are slightly angled to the edge and sometimes intersect each other. Patches of a very light rounding may be formed on the intersection of scars after 10-15 minutes of use. Compared with simple slicing, Scraping and scraping/slicing raw tubers results in more pronounced edge rounding and polish development which may be observed on some spots of the edge and scar intersections under higher magnifications (Plates 85B and 92B).

In natural situations where sand and soil adhere to the surface of tubers after digging or roasting in on-ground open fires (Plates 137C-E), abrasive agents cause the formation of all the main wear variables during a shorter period of use duration. Scraping roasted taro with the tool oriented at 90° to the tuber (Plate 137E) results in small to very small bending scars, a few stepped and, rarely, feathered scars all of which
are mainly oriented in perpendicular or slightly diagonal directions (Plates 88B and 90A). They are usually restricted to one face of the tools having the closest contact with worked material, although a few isolated scars may occur on the opposite face. The appearance of scars on both faces is related to "forward" and "back" actions during scraping. Slight to medium edge rounding forms between 5 and 15 minutes of use. The intensity of rounding increases after 30 minutes of use. Bright and smooth, continuous merging polish is very distinctive and strongly contrasts with the fresh unused surface (Plate 88B, 90A and B). On areas with well developed polish, a moderate number of perpendicular striations dominate. They are mainly the wide, shallow, sleek type, although some rough bottomed and rare intermittent types may occur (Plate 90B). In the performance of scraping and slicing actions, straight and slightly convex edge shapes are more efficient.

The following set of variables appear to be characteristic of wear for tools used for processing roasted tubers for more than 15 minutes: (1) low intensity of use fracturing by small bending and feathered scars; (2) a moderate number of long and shallow striations well separated from each other; (3) medium and intensive rounding and (4) well developed, merging polishes. The comparison of wear patterns between experimental samples and artefacts in association with residue data may have a significant role in the functional determination of prehistoric tools which were involved in processing taro and other tubers.

4.8.5 Soft Elastic Materials

My experimental program included working soft elastic materials, such as fish, chicken and human skin, by respectively, gutting, cutting, piercing and shaving modes of use (Table 4.1; Figure 4.9). This group of materials has not been widely involved in previous experimental research, although some obsidian tools were tested on animal skin (Kamminga 1982:45-47), fish (Fullagar 1986:285; Kononenko 1986) and for shaving human skin (Hurcombe 1992:46). Piercing and cutting chicken skin, as a suitable substitute for human tissue (David, et al. 2006), was performed in order to imitate tattooing and scarification of human body widely known among the people of the Pacific region (e.g. Elkin 1935:4-5; Krieger 1932:15-16; Nilles 1943:113-116; Parkinson 1999:48-50, 63, 347; Sillitoe 1988:443-444; Specht 1981:347-348 Watson 1986:5-6). These kinds of experiments never have been done before. However, use-
wear data obtained from both experimental tools and prehistoric artefacts may provide insight into the origin of such social activities as tattooing and medical treatment in the Bismarck Archipelago.

Experiments indicate that edge sharpness is an important attribute for cutting and piercing chicken skin and shaving the human face. Although acute edges with less than 15° on obsidian tools sustained microscarring in the earlier stages of use, small scars with bending and, to a lesser extent, feathered terminations, are rare on skin cutting and piercing tools even after 25-30 minutes of use (Plates 96A and 98A). Piercing skin with flakes having a triangular cross-section involved vertical pushing and rotative actions that occasionally lead to small snapping spalls. Kamminga (1982:45) emphasised that tip-snapping spall is a common feature of skin awls. Chicken skin used in my experiments is thinner than most mammalian skin and, therefore, spalls rarely occur.

In some cases patches of continuous, small scars on particular parts of the edge are associated with the concentration of short and shallow, intermittent striations diagonally oriented to the working edge (Plate 96A). Usually, however, striations are much less common and are mostly represented by isolated, long and shallow sleeks which can be more easily visible under higher magnification (Plates 96A-B). Occasionally single deep, long sleeks and a few intermittent striations occur on the working surface. On piercing tools striations are parallel or slightly diagonal to the edges and perpendicular to the pointed tip (Plates 98 and 99A). The striated zones of the working edge are accompanied by a thin line of slight to medium rounding and patches of light to developed smoothed polishes which can be observed under more than 200× magnifications (Plates 98A-C).

Use-wear variables on experimental tools used for cutting and piercing chicken skin in association with the shape and angle of the working edges and residues can be used as a suite of indicators for the identification of prehistoric artefacts which could have been used for tattooing, scarification and medical treatments of the human body.

Shaving human faces (Plates 139A-B) produces a very dense layer of organic residues which cover the edge in 1-2 minutes (Plates 100A, 101A, 102A and 103A). Edge modification resulting from use for 3-5 minutes is very light with only few bending microscars distributed in a discontinuous manner on one side of the edge (Plates 101C-D and 102D). A thin line of extremely light edge rounding and a few
perpendicular and slightly diagonal, shallow sleek striations can be seen under 200× and higher magnifications (Plates 101D and 102B). Very rare spots of more intensive rounding and patches of smoothed, developed polishes are visible under 500× magnifications (Plates 100B and 101D). Slightly more bending scars and more pronounced light rounding with a few isolated striations are observed on the tool after 10 minutes of shaving (Plate 103B).

These shaving experiments demonstrate a limited ability of use-wear analysis to determine artefacts related to shaving of human skin. However, in conjunction with residue studies, it may be possible to make an approximate identification of the most intensively used shaving artefacts. It should also be noted that the men who performed experiments emphasised that flakes with thin and sharp edges can be efficient in shaving for only a very short time (2-5 minutes) before the blades become blunted.

**Gutting/cutting parrot fish** (*Scaridae*), **salmon fish** (*Oncorhynchus gorbuscha*) and **wrasse fish** (*Labridae*) is more efficient using a sharp, slightly convex, stable edge with the angle ranging between 15° and 55°. Continuous or isolated, irregular, banded and some feathered scars occur on the working edge as a result of impact with fish scale and bone. Scars appear more frequently on one face and are rarely observed on the other side even after 30 minutes of use (Plates 94D, 95C and 96A). A slightly rounded edge is typical of the tools used for 15 minutes (Plate 94C, D) and abrasion and spots of very light or light, smoothed, undeveloped polishes are observed on prominent points along the profile of the edge (Plate 94E). With increasing use-time, up to 30 minutes, patches of developed polishes are formed (Plates 95A and 96B). Smooth, bright polish is extended from the higher zones of microtopography into surface depressions and is in contrast with the non-altered natural surface of a tool.

Striations are particular features of fish-working tools (Hurcombe 1992:44, Semenov 1964:107). The density of striations is low, but in combination with their alignment, they show a clear gutting/cutting pattern of motion. Though mostly parallel, they are often associated with randomly oriented, intersecting striations (Plates 94C-E, 95A-C and 96A). Isolated, long and shallow, rough bottomed striations are prevalent. Long sleeks and short, shallow, intermittent striations are relatively rare (Plates 94D and 95A).

The correlation of duration of use and wear development on experimental fish processing tools indicates that more than 30 minutes of use is required to produce identifiable wear patterns, although Hurcombe (1992:44) noted that more than 20
minutes of use is required to produce a surface alteration. This means that any artefact exhibiting such wear must have been used for a similar task for a relatively long period. The distinctive use-wear apparent on prehistoric tools used for processing fish enables their determination on the basis of comparison with experimental tools. In addition to wear features, distinctive animal residues on the working edge, such as tissue, blood and greasy film may contribute significant information for functional interpretation.

4.8.6 Hard Dense Materials

Some experiments involving working marine shell with obsidian were conducted by Fullagar (1986:189), Kamminga (1982:141-142) and Kononenko (1986) in this section sawing and scraping experiments of cockle shell (*Katylesia* spp.), cowrie shell (*Cypraeidae spp.*) and half-dry white clays are examined (Table 4.1; Figure 4.10) in order to obtain comparative use-wear and residue data for functional interpretation of some obsidian tools.

**Sawing shell** for the first 1-2 minutes results in intensive bending and less feather scarring with poor definition of flake scar boundaries because the edge is crushed. The use fractures occur on both sides of the edge and, as a consequence, the working edge of the tools is thickened and becomes very irregular in both plan and profile views from the very start of the use (Plate 104A). Pronounced, intensive rounding and well developed, smoothed polish quickly appear as a continuous thick line along the edge, but the polish does not extend into surface depressions (Plates 104B and 105A-B). Initially deep intermittent and rough bottomed short striations (Plate 105A) were flattened by abrasion. Irregular and deep cracks oriented perpendicularly to the edge occur on some parts of the surface (Plates 105B and 107A). After 15 minutes of use, the edge becomes blunt but subsequently continuous microscarring and autoabrasion processes prolong the useability of the edge to some extent. However, after two hours of sawing, the tool completely loses its efficiency (Plates 106A-B).

**Scraping shell** results in intensive, dense, stepped and bending scars and crushing. The thick profile of the edge is damaged by scars and is highly rounded and polished (Plates 108A-B). Crossed and diagonal striations of all types appear but rough bottomed and intermittent striations dominate (Plate 109A). Rounding, polish and
striations are formed on prominent areas and scar intersections and do not extend into surface depressions (Plate 109B).

Thick, intensively abraded and rounded edges with well developed smoothed polishes covered by a dense net of shallow striations, as well as the presence of all types of striations on the surfaces closest to the edge, are very distinctive wear variables for scraping shell that can be relatively easily detected on prehistoric artefacts.

**Scrapping clay** with thin flakes which have acute edges is a highly productive operation but only for the first 5-10 minutes. After 15 minutes, intensive rounding, abrasion and polish dramatically thicken and dull the working edge ending its ability to be used efficiently (Plates 110-111). The texture and distribution of polishes on the working edge of tools used for working half-dry clay have some common characteristics with shell working tools, but the abrasive nature of clay results in a more smooth and flattened appearance. There are obvious differences in the prevalent types of striations. Clay produces mostly thin, long sleeks with rare occurrences of deep rough bottomed striations oriented perpendicularly and slightly diagonally to the edge. Because of the very fine abrasive properties of clay, the surface within scars often contains similar types of striations.

A very distinctive wear patterns on obsidian tools, used either for working shell or clay, forms after a short period of use. This suggests that prehistoric artefacts with similar wear variables were probably used for about 10-15 minutes and then discarded. Wear features on prehistoric shell working tools and artefacts used to process clay may be relatively easily recognised using microscopes with low magnification.

4.8.7 Summary

Use-wear patterns on obsidian tools obtained through my task-oriented experiments with hard and soft wood, palms and bamboo, grasses such as sugar cane, tubers, skin and shell are comparable with previous use-wear data provided by Davenport (2003), Fullagar (1986, 1991), Hurcombe (1992) and Kamminga (1982). However, a series of experiments related to the processing different parts of palms, species of siliceous and non-siliceous soft and hard wood, coconut meat, pandanus leaves, banana, aibika, croton, ginger, chicken skin and clay introduces a new set of wear which occurs on obsidian tools in the course of their use in a variety of actions. Moreover, overlapping patterns of wear variables observed on the tools used for
processing some materials which are similar in density and silica contents, for example, palms, bamboo and soft siliceous wood, indicate that the identification of the material which was worked by prehistoric tools can be made in a broad sense, with further residue studies possibly allowing the further definition of the precise species of plants processed.

4.9 Residues

My experimental program was designed to investigate particular wear patterns and associated residues. The aim was to gather valuable information about the accumulation of residues, their types and distribution on the working edge of tools used for processing a diverse range of materials. Accordingly, all residues on experimental tools were fully recorded and photographed before cleaning (e.g. Plates 2A and 3A). They include oily film, plant and animal tissue, starch granules, needle-like residues (raphides), resin-like residues, blood-like residues and white-coloured residue. My experiments support the conclusion that residues accumulate in abundance usually several millimetres away from the working edge (Fullagar 2006b:199; Shafer and Holloway 1979:396). However, since some residues are also compacted into microfractures and other small cavities and depressions immediately on the edges, they are difficult to remove by cleaning procedures (e.g. Plates 58A, 77A, 78A, 88A, 36B, 53C, 64B, 99B, 101D, 106B, 109A, 110B, 111C and 112A).

The most common plant residues observed on experimental tools before cleaning are oily films, tissue, starch granules and, to a lesser extent, needle-like residues. Films may be deposited on the surface along the edge as colourless (Plates 5A, 24A, 26A, 28A, 29A, 37D, 58A, 63A, 69A, 71A and 77A) or yellow (Plates 3A, 14A, 50A, 62A, 72A and 81A) smears which often incorporate other plant residues (Plates 17A). The texture and distribution of films may sometimes indicate the mode of use (Plates 17A, 24A, 26A, 29A, 79A and 84A). This means that some artefacts may contain film residues before cleaning which can indirectly indicate the mode of use. Plant tissues may be diagnostic of the type of palm, wood and non-woody species. Unidentified flaky red, yellow and white tissue (Fullagar 1986:177) can be attached to any surface which was in close contact with the worked plants (Plates 3A, 14A, 16A, 17A, 23A, 37A, 40A, 45A, 60, 63C, 71A, 80A, 88A and 89). However, more commonly, tissue, often with cell wall structures deposits, are embedded into scars and other surface depressions (1A, 2A, 18A, 19A, 28A, 29A, 31A, 36A, 45A, 53D, 54A, 57A, 78A, 86, 90A and
Plant tissue trapped within small scars is able to survive intensive cleaning by sonification.

Experiments demonstrate that starch residues contained within the tissue are commonly found on tools used to work palms (Plates 3D, 8A, 14D, 20D, 24C, 26D and 26E, 31C), some species of soft and hard wood (Plates 40C, 41C, 46C, 57C, 58C, 116 and 117), and non-woody plants (Plates 74B, 75B, 77D, 83B, 85A, C, 88C and 93B). Starch granules have shapes that are often taxonomically distinct and, unless they have been heated or otherwise damaged, they have a distinct dark extinction cross visible under cross polarized light (Barton and Fullagar 2006:50; Fullagar 2006a:217). Starch residues extracted from experimental tools were placed on microscope slides (Plate 26E) and stored for further detailed analysis and taxonomic identification by specialists.

In my experiments there were three species of palms (*Cocos nucifera, Metroxylon spp, Calamus spp.*), *Pandanus sp.*, one species of wood (*Hibiscus tiliaceus*) and two species of non-woody plants (*Bambusa spp.* and *Colocasia esculenta*) which produced needle-like residues (Plates 1D, 12B, 23A, 30A, 30C, 41B, 63C-D, 65B and 85D). These residues probably relate to crystalline forms of calcium oxalate which are called raphides. Raphides are particles formed in plants to provide a defensive mechanism. Their shapes can sometimes be taxonomically distinct and able to be determined by specialists (Crowther, in press; Loy 2006:136, Robertson 2005:59-61). The size and morphology of raphides, in association with starch grain morphology and in combination with wear patterns observed on experimental tools, comprise exciting possibilities for functional assessment of artefacts and for obsidian collections in particular.

Resins from the breadfruit tree (*Artocarpus altulis*) were used in my experiments as fixatives for hafting some stemmed tools (Plates 115 and 132A). Resins that do not dissolve in water have adhesive properties and are widely used by indigenous peoples as glue or rubber cement (Parr 2006:186; Robertson 2005:65-66). Resins on experimental tools are distributed as thick patches or smeared areas and have a glassy and highly reflective appearance with a range of colours (Plates 115A-D). Because of charring during the hafting process, some resin deposits are blackened and slightly greasy. Cellulose tissue, starch grains and needle-like residues are observed within resins (Plates 115A and 115E-F). The resistance of resins to decomposition results in their relatively good preservation on artefacts and allows comparison with experimental data.

White-coloured plant residues with cell structure can be observed on some experimental tools involved in processing *Pandanus spp.* (Plates 25C and 27B), some
wood species such as erima (Plate 36C), hibiscus (Plates 40A and 42A), ton (Plate 54A), an unidentified species of soft wood (Plate 53C), and the non-woody plant aibika (Plate 84C). These residues have a bumpy texture with no clear form and shape. No similar residues have been recorded in previous experimental studies of obsidian tool use, and thus further analysis of these types of residues is required. The determination of the chemical composition of residues is especially important for further artefact identification. The patterned distribution of white-coloured residues near the used edges and their association with the surface microtopography, imply that their occurrence is definitely linked to the use of plant processing tools.

Non-plant residues on experimental tools consist of proteinaceous films, fleshy tissue, blood and hairs. During the performance of tasks, people using obsidian tools cut their hands occasionally and non-intentionally with the sharp edges. These results in blood residues being left on the surface of tools and these were later detected by use-wear analysis. Blood residues appear microscopically as thinly smeared, highly reflective films (Plate 44C and 112A), or as a thicker film with polygonal cracking (Plates 44D and 51C-D), often termed "mud-cracking" which is due to shrinkage of the drying residue (Fullagar 1986:184, 2006a:219; Loy 1983; Robertson 2006:70-71). Sometimes blood residue has a droplet-like appearance embedded within scars (Plate 112A). The colour of blood on the tools ranges from black to dark-red and yellow. Red blood cells of mammals have no nucleus and appear as circular biconcave discs which are best observed on glass slides (Plates 44E-F, 51E-F, 112B and 113A-B) at high magnifications using darkfield incident illumination. Some blood and animal tissue residues embedded into the microscars are also observed on tools used for cutting/piercing chicken skin (Plates 99A-B).

Residues from gutting/cutting fish consist of proteinaceous films, black and rainbow coloured tissue and blood (Plates 94B, F, 95D, and 96A-B). Individual red cells of fish blood, in contrast to human red cells, have a nucleus (Plates 114A-B) that generally indicates a non-mammalian origin (Fullagar 1986:185-186).

A coloured mixture of skin tissue, hairs and blood residues is formed in 1-2 minutes on tools used for shaving the human face (Plates 100A, 101A and 102A,C). This suggests that some artefacts, if used for the same tasks, may preserve similar residues in addition to generally weak wear development. The structure of human hairs can be differentiated from animal species (Fullagar 2006a:219). Further analysis of these residues on experimental tools may contribute a great deal to the functional interpretation of some artefacts.
Working shell produces white coloured smears and granular powdery materials on the edge (Plates 104A, 105B, 106B, 107B, 108B and 109A). These kinds of residues represent a major component of shell material which consists of a calcium carbonate mineral with an identical chemical composition to calcite (Fullagar 1986:189; Robertson 2005:81-82). Embedded into altered surfaces, these residues are difficult to remove by cleaning procedures, unless chemicals are applied.

Tools used in my experiments for scraping clay also contain white coloured smears and powdery grain residues (Plates 110A-B and 111C). This clay was obtained from limestone deposits and consists of carbonate of lime and magnesium. These residues are also difficult to remove from the working edges and this suggests that similar carbonate materials may well survive on artefacts.

The range of residues extracted from experimental tools and stored on glass slides represents significant reference material for further study. Some of these residues, for example, white-coloured plant residues, were not recorded in previous studies of experimental tools and prehistoric artefacts made of obsidian. Further study of these types of residues may assist in the functional interpretation of artefacts containing such residue.

4.10 Hafting Wear

Holding patterns of experimental tools include hafting (if a tool inserted into or attached to a handle) and prehension (if a tool is hand-held) which can produce forms of wear and residues (Keeley 1982; Rots 2003, 2005). Hafting wear is usually located on the surfaces opposite the working part of the tool. Two distinguishable features of hafting use-wear are scarring and isolated polish spots on the surface (Rots 2003:809-810; Fullagar 2006a:226). For obsidian tools the pattern of hafting wear is slightly different and also includes abrasion and striations.

The obvious signature of any types of wooden handle is seen on experimental stemmed tool as both (1) patches of an intensive abrasion and light polishes on the surface, and (2) patches of scars on some isolated parts of the hafted stem (Plates 132A-E). Spots of rough abrasion with obvious striations of all types are more common on the surface (Plates 26F, 27F, 118B-C and 119A-B) than are patches of very light polishes with isolated, long and deep striations (Plates 117A and 120). Scarring on the edges is usually accompanied by closely packed, rough bottomed, intermittent, and rarely flaked striations, which are slightly angled or perpendicular to the edge (Plates 27E and 118A).
These wear variables are similar to the abrasion, polish and striations which were observed on the woodworking tools.

Sometimes scars, striations and abraded spots on the surface are covered by tissue with starch grains and resins adhering to the tool surface (Plates 23A, 23C, 26F, 115, 116A-B, 117A-D and 118B.) The presence of resin is a potentially good indicator that tools were hafted because resin was often used in the construction and attachment of a handle (Hurcombe 1992: 74; Kealhofer et al. 1999; Keeley 1982:799).

The identification of tool use was my major priority with the way in which the tool was held or was hafted as a lesser important goal of the study. In my experiments flake tools were wrapped with plant leaves or string (Plates 133A-F). The wear resulted from wrapping includes very small scars or microscars irregularly distributed along the edges. Using string produces more pronounced scars with bending terminations. Very light abrasion may be seen on some surface spots. Sometimes a few long and thin striations can randomly occur in association with abraded spots. However, such light abrasion and randomly distributed striations in the archaeological context would be difficult to isolate from "the background noise of striations" (Hurcombe 1992:73) which could be associated with post-depositional effects. In this case, the presence of residues from wrapping materials is significant for understanding hafting patterns. For example, the tool used for gutting/cutting fish was wrapped in banana leaves and this is evidenced by starch grains preserved on hafting areas.

Experiments with hafted and hand-held tools revealed that the time consuming procedures involved in the manufacture of wood handles and the fastening of stemmed tools was not efficient. Relatively short stems with thick cross-sections begin to move quickly, and fall out from the handle in 5-10 minutes of use. However, the retouched stems were very comfortable to hold in bare hands and this, probably, gives a plausible reason why small stemmed tools were used for various activities during the middle Holocene period.

On the other hand, a highly efficient holding mechanism was produced by wrapping sharp flake tools in green leaves, such as banana and pandanus. This suggests that artefacts could have been wrapped in leaves whilst processing a range of materials in order to protect the hands. Residue analysis of some artefacts from FAO found that the surface of tools often contain phytoliths from pandanus and bamboo (Kealhofer et al. 1999) and this further supports the suggestions made on the basis of experimental data.
In my experiments, most of flakes were wrapped during use (Plates 133A-F) although some small stemmed tools were inserted and tied to a wooden handle (Plates 132A-F).

4.11 Non-Use Wear Experiments

The purpose of these experiments was, firstly, to observe how soil processes and weather conditions may alter the patterns of use-wear and residue accumulation on experimental tools used for processing plants. Secondly, they examined the degree of mechanical and chemical damage on both unused and used flakes. Experiments were conducted in two environment conditions in Newport, Australia: surface exposure (plate 121A) and shallow burial (plates 121E, F). The samples including 9 flake tools and 15 unused flakes were divided into two groups. The first group was left on the ground surface of a light slope with no vegetation cover and was exposed to wind, rain, and biological activity. The second group was buried about 10 cm beneath the surface of a brown loam soil with some rough grains of gravel. These samples were protected from wind erosion but exposed to the effects of rain and biological decomposition by insects and micro-organisms. After 22 months flakes and tools were excavated and re-examined under low and high power microscopes.

The size of flakes and tools left on the ground surface varied from large (5.5 x 4 x 1 cm) to small (2 x 1.5 x 0.5 cm) (Plates 121A-D). Before the experiments, the flaked surfaces of samples were photographed from both ventral and dorsal sides near the edge (Plates 125A and 126A) and typical surface features were recorded microscopically. This process allowed the observation of any physical or chemical surface alterations which occurred after 22 months.

The results show that residues on the tools which were left on the ground were essentially reduced in abundance and dramatically altered in appearance after 22 months (Plate 123). A similar trend in the survival of residues was observed on the surface of buried artefacts used for processing plant materials (Plates 86, 93A-B and 124). The difference between the groups of experimental samples, however, is that residues on buried tools were better preserved when embedded within scars (Plates 78A and 124E). This may be explained not only by the limited impact of natural factors (rains and wind) on artefacts buried in the soil (Lu 2006:81), but also because the dense residues were trapped in the depressions, pits and cracks of the natural obsidian surface that protected them from intensive movement and alteration.
I noted that during the first two days, samples which were left on the surface were re-deposited by rats or bandicoots and moved 10-15 cm down the slope from their initial location. Such kinds of physical movements over time resulted in the formation of randomly distributed, isolated, long and deep sleeks and short intermittent striations (Plate 127). In contrast, the surfaces of the buried flakes do not have striations with the exception of rarely occurring single sleeks (Plates 126A and 126B).

The most important result of these experiments is that the traces of initial chemical damage occur on the surface. Chemical etching appears on the ventral surface of the flake as a series of small, shallow pits and shallow, slightly concave channels with relatively rough bottoms and irregular sides in plan view (Plates 125B and 125C). It can be expected that over a much longer period of time the chemical environment of the soil will alter the shiny obsidian surface and influence wear preservation. The effect of etching was experimentally studied by Hurcombe (1992:75-75) who proved that chemical damage is able to destroy polish and alter the type of striations. For example, sleek striations were altered to the intermittent type after chemical etching (Hurcombe 1992:50). These facts should be taken into account when experimental wear patterns are compared with wear variables on artefacts.

4.12 Discussion

My experimental results were analysed in terms of the categories of materials which were processed for specific use time periods in order to examine the stages of formation of the main types of wear on obsidian tools. This also allowed the determination of a set of diagnostic wear variables within each use-material category and the assessment of how the particular set of wear variables can assist in the study and interpretation of use-wear patterns on prehistoric artefacts.

From a use-wear perspective, however, this grouping of experimental results clearly indicates some common features in the sets of wear produced by different materials. These overlapping patterns are especially relevant to plant species used in experiments. For example, all palms, pandanus, species of soft wood such as malas and Calophillum, and some grass species including bamboo and cane are characterised by high silica content (Fullagar 1991) which results in similarities of wear variables on experimental tools used for their processing (Plates 2B, 45B, 64B). In an archaeological context such similarities in wear patterns on prehistoric artefacts will be difficult to attribute to particular plant species worked, unless residue identification is involved.
This was emphasised by Fullagar in his analysis of obsidian artefacts from West New Britain (Kealhofer et al. 1999:541). All plant processing tools were divided by Kealhofer et al. 1999 into groups of (1) hard non-siliceous wood, (2) starchy and siliceous woody plants (e.g. palms) and (3) soft siliceous plants (e.g. bamboo).

Both Fullagar's data (e.g. Kealhofer et al. 1999:541) and my experimental results show that, on the basis of wear patterns, the identification of plant material worked can be made in terms of broad categories which include several families or genera of plants. My data clearly demonstrate that the grouping of used plants into palms and pandanus, soft wood, hard wood and non-woody plants is appropriate for my experimental purposes, but it cannot be fully applied to the explanation of wear patterns observed on prehistoric artefacts. The main reason for this is that wear characteristics produced by working either medium or light density palms, siliceous species of soft wood, or siliceous bamboo are so close that it is not possible to distinguish these materials on the basis of scarring, striations, rounding and polish. A similar situation is encountered with hard siliceous black palm and hard siliceous wood (e.g. mango).

This means that the sets of wear detected on prehistoric artefacts can be compared with those experimental categories of plants and other materials which produce distinctive and diagnostic wear patterns. On the basis of experimental wear patterns these categories include: (1) siliceous soft wood, palms and bamboo; (2) non-siliceous soft wood; (3) siliceous hard wood and hard palms; (4) non-siliceous hard wood, (5) non-woody plants including greens, such as leaves, stems and grasses, and tubers; (6) soft elastic materials; (7) dense, hard materials. This grouping of use-material will be employed in the interpretation of the function of prehistoric artefacts in Chapter 7.

The rate of formation of diagnostic wear traces on the tools within each of the categories of use-material also depends on the duration of use and the mode of use. As a general trend, siliceous species of plants produce identifiable wear much quicker than non-siliceous samples (Fullagar 1991). Palms, bamboo and highly siliceous species of wood may form diagnostic polish, rounding and striations during the first 5-10 minutes and, after 15 minutes of use, the efficiency of tools usually drops significantly. Non-siliceous soft and hard woods show reliable diagnostic wear on the tools after 15-20 minutes and they can be used further with slightly less productivity up to 30 minutes. The whittling action usually requires a slightly longer duration of use to form identifiable wear patterns than the scraping and sawing modes of use.
Processing non-woody plants by obsidian for 15-30 minutes generally does not demonstrate intensive wear in the same way as is seen on palm and wood working tools. However, the nature of scarring patterns, types and distribution of striations, rounding and polish characteristics form a diagnostic combination of wear which can be a more reliable indicator if the tool was used for more than 30 minutes. After 30 minutes of use, most of the tools still preserved relatively sharp and useable edges which could be involved in the further performance of the same or different tasks. Similar trends in the formation of wear variables are observed on tools used for processing soft elastic material. The build up of wear with increased duration of use and retention of sharpness of the working edge after 30 minutes suggest the opportunity for further use of the tool. In contrast, working dense hard materials, such as shell and half-dry clay, leads to the appearance of diagnostic wear in 5-15 minutes, after which the efficiency of the tool dramatically decreases so that it is more likely to be discarded.

Since these experimental data indicate the relationship between wear formation and duration of use, they provide an opportunity for a general assessment of the duration of use of prehistoric artefacts. This assessment can be divided into three groups: (1) short term and intensive use for less than 15 minutes which can generate an identifiable wear patterns resulting from working palms, wood and hard dense materials; (2) moderate use which may be associated with a time interval of between 15 and 30 minutes of use during which time, well developed wear variables are formed on palm and woodworking tools and identifiable wear occurs on the tools involved in processing non-woody plants and soft elastic materials; and (3) long-term use which can be determined by the presence of relatively developed wear patterns in association with sharp and still useable working edges, as observed on the tools used for 30 and more minutes for processing soft elastic materials.

In conclusion, the experimental work has made a number of significant contributions both to my specific study of tools from FAO and to the understanding of use-wear patterns in general. In the description of my experiments, I specified a set of use-wear variables for each category of organic and non-organic material involved in this study. My experiments prove that there are some peculiarities in scarring, striations, rounding and polishes which have diagnostic characteristics for identifying different obsidian tools involved in processing different substances. Comparison between the sets of wear produced by plants, however, showed that distinguishing precisely the worked
species on the basis of use-wear can be made only on a broad level. This inference is in part related to the fact that some groups of soft and hard species of wood, palms and tall grasses have high silica content, whereas other soft and hard wood and non-woody plants which consist of green leaves and tubers are non-siliceous. The relative differences between the wear variables produced by each of these groups of plants can be strongly supported by the analysis of residues recorded on the tools. At this stage of my study, the suggested classification of use-materials, built up on the basis of wear characteristics, can be applied to the analysis and interpretation of functional data obtained from archaeological assemblages.

The stages of formation of diagnostic sets of wear, for each category of use-material identified on experimental tools, provide a valuable approach for the assessment of the use-life history of prehistoric obsidian artefacts and the discard behaviour of people. This type of experimental data may contribute important information necessary to understand archaeological assemblages consisting of tools resulting from expedient technology.

Finally, the description of use-wear patterns on obsidian experimental tools illustrates some general trends and relationships between function and worked material and can be used as a working guide in the further examination and functional determination of artefact collections. Moreover, the detailed photographic record of use-wear and residues presented in this research provides valuable comparative sources for other scholars working on obsidian artefacts. In addition, although my experimental results provide sufficient background data for the analysis of other obsidian industries in the Pacific, these studies may also stimulate the planning and performance of new sets of specific experiments.

My experimental program was designed to investigate wear formation on obsidian tools using mostly local resources from the area under investigation. This approach has provided comparable data that allowed an identification of tool function and a comprehensive interpretation of the stone tool assemblages in the wider context of subsistence and settlement patterns. The range of resources that were available to the human populations on Garua Island during the middle and late Holocene and the environmental changes over time are the subject of examination in Chapter 5.
Chapter 5

Garua Island and the FAO Site: an Environmental and Geological Background.

5.1 Introduction

The prehistory of human occupation of Garua Island during the Holocene is a consequence of the interaction of environmental and cultural changes that occurred as the result of both natural and human phenomena. The behavioural response of human populations to the environment in which they found themselves generated the archaeological evidence which is the subject of my study. The relevant archaeological evidence, in this case, consists of assemblages of stone tools from FAO.

From the theoretical framework inherent in the evolutionary ecology and behavioural optimisation models (e.g. Aldenderfer 1998:299, 2006; Cashdan 1992; Jochim 1989, 1998:13; Smith and Winterhalder 1992), people react to and adapt to their physical environment and, in turn, modify that environment to meet their needs over time. This interaction between people and the natural environment is very direct and obvious and that is why the most compelling approach to understanding human behaviour is one that stresses the relationship between behaviour and the natural environment. The behavioural strategy of people within the landscape, which is considered as a set of economic resources, would rationally produce: (1) the optimal placement of residential sites with respect to sought-after and prized resources; (2) the exploitation of small catchment areas having convenient access to available and accessible resources located within a short distance; (3) low levels of residential mobility within the landscape and short distances between residential relocations; and, (4) the embedding of non-subsistence resource procurement (i.e. stone raw material) within subsistence activities (e.g. Aldenderfer 1999, 2006; Binford 1996; Jochim 1998:13; Jones 2005:88; Kristiansen 2005:155; Lepofsky 1988; Smith and Winterhalder 1992; Zubrow 2005).

The examination of the extent to which past subsistence practices and site functions correspond to their environmental setting allows an interpretation of the dynamic relationship between environment, economy and social structure of those communities which occupied particular landscapes. The ecological structure of the regional landscapes in which prehistoric culture used stone tools can provide a source of important information on the use of available materials and provide evidence as to the
activities associated with the processing of resources. Use-wear/residue analysis of stone tools gives insight into this relationship by providing evidence of day-to-day activities and this is especially so when combined with an understanding of the likely environmental factors and behavioural processes operating.

Unfortunately, due to poor organic preservation, very little is known about how and what resources were used in the past from the current archaeological investigations on Garua Island and the immediate region. Functional identification of tools may provide a substantial amount of environmental data because prehistoric tools indicate the type of activities undertaken by the inhabitants at that time. Equally, environmental reconstructions can assist in better understanding the use/wear residue patterns and the range and nature of the materials worked by the tools.

The purpose of this chapter is to provide the background data needed to reconstruct the nature of potential resources which were available and used by humans on Garua Island in the middle and late Holocene. What was the environment on Garua Island like during those times? How did it change and under what conditions? How did human populations adapt to these new conditions and what changes occurred in their culture, technology, life style and social organisation? How did humans modify their environment? To answer these questions three different types of data were used: (1) modern data on the current environment and available resources together with ethnographic information on the nature of human exploitation of resources in the region; (2) some paleoenvironmental materials; and (3) data from archaeological sites of the same period from neighbouring regions. On the basis of these data, I discuss geological history, changes in sea level, volcanic activity which changed and formed landscapes, the range of natural resources available, physical and geographical features of the study area, climate, flora and fauna.

5.2 Geological History

Garua Island sits within the seascape of Garua Harbour and Kimbe Bay and the maritime and land environment of the island offered a range of opportunities for human subsistence in the past (Figures 5.2 and 5.3). Has the natural physical environment of Garua Island changed so very much over the last 6,000 years? The answer to this question is both complex and simple. In simple terms the environment, though not stable, is that of a tropical equatorial island area subject to periodic volcanic activity. The climate has not changed significantly during the Holocene and is characterised by
very high rainfall, flooding and periodic long droughts (Allen 1997). The soils are rich volcanic loams resulting from tephra falls. The sea level was about the same as today or perhaps one metre higher with a tidal range of between 0.7 of a metre and 0.885 of a metre, or between 2.3 and 2.9 feet (Royal Australian Navy Hydrographic Chart Aus 1992:676).

The large New Britain Island (Figure 5.1) is young in geological terms, having emerged from the sea some 10 million years ago in the late Miocene. This was as a consequence of uplift processes and volcanism occurring along an island arc system between the Bismarck and Solomon plates (Ryburn 1975; Tregoning, McQueen, Lambeck, Jackson, Little, Saunders and Rosa 2000). A central mountain chain separates the north and south coast of New Britain. The volcanic north coast (Talasea) is composed of volcanic (acidic) soils with some limestone. Garua Island is even younger than the main island of New Britain having been created by a volcano in the late Pleistocene and is probably several hundred thousand years old (Machida 1991).

Garua Island and three other smaller islands Garala, Langu and Kaula near the Talasea mainland area are of volcanic origin (Anderson et al. 2001; Pain and Specht 1985; Specht and Torrence 2007). They are associated with the large New Britain Island, that comprise a well developed "continental" or "island-arc" type of Pacific island (Specht, Hollis and Pain 1981:10-11; Specht and Torrence, 2007; Summerhayes 2000:15). This type of large island has a complex geological history that involves seismic and volcanic activity, subsidence, erosion, formation of marine limestone and other sedimentary deposits. Large in scale, such islands exhibit varied habitats with a unique aspect of the biota and a wide range of lithic resources resulting from complex geological formation (Kirch 2000:44). In the Talasea area and on Garua Island, rhyolite, various andesitic rock, tuffs, flinty, volcanogenic sandstone, agglomerates and hornfelses are found, in addition to high quality obsidian sources (Machida 1991; Specht, Hollis and Pain 1981:48; Torrence et al. 1992; Summerhayes 2000:15).

Garua (Talasea) Harbour is a volcanic field that consists of a group of mostly rhyolitic lava domes and ash cones that ring the harbour on the west (mainland) and form Garua Island (Global Volcanism Program 2000). Garua Island is a remnant of two rhyolitic and obsidian-bearing lava domes now named Mt. Hamilton and Mt. Baki. These are truncated by fluvial and marine processes suggesting a very old age and strong uplift of this island. The island stands on the edge of an old caldera that forms Garua Harbour (Machida 1991; Machida, Blong, Specht, Moriwaki, Torrence, Hayakawa, Talai, Lolok and Pain 1996). Geomorphological and stratigraphical studies
of a number of sections along the Malaiol Stream walls by Machida (1991; Machida et al. 1996), Webb (Torrence and Webb 1992:10-14) and Boyd (Torrence and Boyd 1997:19-20) reveal a sequence of artefact-bearing soils and geological layers, including tephra and uplifted coral limestone. The presence of two or three marine-cut bench-like terraces on the island suggests higher sea levels and uplift during the Pleistocene (Machida 1991).

The complex volcanic and depositional history of the island has created a series of different topographic settings with a range of primary and secondary sources of obsidian. Several primary rhyolothic flow exposures at Mt. Hamilton are intensively altered and have been used very rarely for the manufacture of tools in the past (Torrence et al. 1992). The hills and ridges of Mt. Baki contain the high quality obsidian found in both the primary and secondary contexts. Exposed obsidian is now visible at beach level, along gullies and on the ridges some 40 metres above sea level (Specht, Fullagar, Torrence and Baker 1989:23; Torrence et al. 1992). There are a number of fluvially-exposed secondary sources in association with high densities of flaked debris in the bed of Malaiol Stream (Machida 1991; Specht et al. 1989:23-25; Torrence and Webb 1992:11; Torrence and Boyd 1997: 19-20). Also the presence of both extensive sources of exposed obsidian and archaeological deposits of flaked artefacts in situ indicates that Malaiol Stream on Garua Island was one of the important sources of obsidian raw material during the Middle – Late Holocene (Torrence and Summerhayes 1997; Torrence et al. 1992).

The mainland coast line around Garua Harbour sits on the western and southern edge of an old caldera. Rhyolitic flows and secondary deposits of high quality obsidian are known to the north and south of the harbour and are associated with Mt. Kutao, Mt. Bao and Mt. Gulu (Torrence et al. 1992). It has been suggested that the obsidian lava flow surrounding Mount Kutau was the result of a late Pleistocene eruption of the Kutau volcano (Machida 1991). The Pleistocene pyroclastic flow deposit associated with Mt. Gulu is different from Mt. Kutau suggesting a separate large-scale eruption (Machida 1991; Torrence et al. 1992). The exposed high quality obsidian sources around Talasea area have been exploited by human for more than 20,000 years (Torrence et al. 1992; Torrence et al. 2004).

In addition to volcanic islands, there are three other small islands (Boduna, Lagenda, and Depa) within the harbour and they are coral reef platforms covered with sand, tephras and soil between 1-3 m above sea level. These coral reef platforms may be
associated with the change in sea level over time or with local uplift (Ambrose and Gosden 1991; Specht and Torrence 2007; White et al. 2002).

5.3 Sea Level Change

The coastline of both the mainland and nearby offshore islands has a complex history due to two interrelated factors which occurred during the Holocene: eustatic sea level changes and tectonic movement resulting in uplift. Of course, the characteristics of Holocene sea-level change were consistent throughout the Pacific region (Chappell 1982, Lambeck, Yokoyama and Purcell 2002). The most precise and geologically persistent indicator of sea level changes is coral reef systems. Other sea-level indicators relate to geomorphological features, such as paleoshoreline notches, paleoreef flats and beach deposits. These types of indicators have wide indicative range but also have large error terms associated with any reconstructions (Woodroff and Horton 2005). Also, tectonic activity resulting in uplift complicates the task of sea-level reconstruction.

On Garua Island and the coast of the Talasea mainland, such indicators as the exposure of coral limestone, a raised coral platform with a single radiocarbon date, oyster shells on rocks with two radiocarbon dates near Talasea wharf and bathymetric data for the Garua Harbour have been used to reconstruct Holocene sea levels (Boyd and Torrence 1996; Machida 1991; Specht and Torrence 2007; Torrence and Webb 1992; Torrence, Specht, Fullagar and Summerhayes 1996).

The "remnant of well-preserved coral-reef limestone" above the Malaiol Stream described by Machida (1991) is much older than the coral reef platform at FYS site described by Torrence on the south side of the island which is some 6,400 years old (Torrence and Boyd 1996, 1997). The formation of coral limestone or coralline aragonite is a long sedimentary process and as suggested by Machida (1991) is evidence of tectonic uplift in the late Pleistocene. According to Machida (1991) the top of the limestone stands about 15 to 20 metres above present sea level and about 500 metres from the northern shore (Specht and Torrence 1991:4). Geological work by Machida, Webb and Jackson describes the coral limestone as a remnant of a coral reef overlayed by tephra layers and other materials (Machida 1991; Torrence and Webb 1993; Torrence and Boyd 1996, 1997).

On the other side of the island, the southern side, a more recent coral platform was found and investigated. Coral found at the base of test pit FYS I was dated. The date is 6420±80 BP (Beta 72857). Cultural material was on the top of this coral platform and
that material was subsequently sealed by the W-K2 tephra. The coral is currently 1.42 m above sea level and represents the higher sea level at that time and/or tectonic activity (Torrence, R., pers. comm. 12 July 2006). When the sea level was higher, Garua Island was somewhat smaller and, therefore, there was less opportunity for beach, inter-tidal (stilt houses) and coastal settlements during the middle Holocene. The occupation of a smaller area means that "inland" areas would be more likely to be occupied.

There is evidence of a relatively recent phase of uplift between 430 – 120 cal BP in the form of oyster shells on rock and small pinnacles of coral at about 1.1 m above present high tide at Point Mondu, near Talasea (Boyd and Torrence 1996; Specht and Torrence 2007). On Garua Island this uplift is evidenced by raised coral at about 0.75 m above present high tides at the scoria pit on the northern side of the island, and a raised beach on Garala Island (Specht and Torrence 2007; Torrence and Webb 1992:14).

On the basis of generalised bathymetric data and an article on volcanoes and caldera of Talesea (Lowder and Carmichael 1970, cited in Torrence et al. 1996), Torrence suggests that, during the Late Pleistocene and until about 6,000 BP, Garua Harbour would have been dry land (Torrence et al. 1996:217) and, consequently, that Garua Island was joined to the Talasea mainland. This proposition contradicts the statement that "at least part of the coastal plain sits on the coral platform which is about 1.5 metres above current sea level and dated by radiocarbon to around 6,400 years ago" (Torrence and Boyd 1996:15, and Torrence pers. com. 12 July 2006). It appears that by the late Pleistocene and certainly long before 6,000 years ago the land had already experienced significant uplift of some 15 to 20 metres as is demonstrated by the coral limestone (coralline aragonite) found in Malaiol Stream. Simply put, if the land was lower, the harbour would have been deeper and, similarly, if the sea level was higher and the land is at about its present level, the harbour would have been deeper and not dry land at all. On this basis, it is difficult to support the proposition that "the current harbour would have been dry land with the result that the Kutau/Bao, Baki, and Hamilton subgroups were landlocked" (Torrence et al. 1996:217).

At the beginning of the Holocene, the sea level was some 35 metres below its present level (Woodroff and Horton 2005, fig. 4). At that time only a small part of Garua Harbour would have been dry and Garua Island would have been joined to the main island of New Britain (Figure 5.4). Royal Australian Navy Hydrographic Chart (1992:676) shows the present depths of Garua Harbour, although they are indicated in fathoms (Figure 5.4). A fathom is approximately 1.83 metres. The present-day depth of water between Observation (Boduna) Island and Garua Island is 21 to 22 fathoms or
38.43 metres to 40.26 metres (Figure 5.4). Only the narrow channel on the western side of Garua Island would have been dry land when the sea level was 35 metres lower.

The rise in sea level of some 35 metres during the Holocene was not at a constant rate. Indeed, for the first half of the Holocene, the sea level rose so rapidly that the entire 35 metre rise occurred in the first 3,000 years of the early Holocene. An analysis of recent sea level data (Woodroff and Horton 2005, fig. 4) indicates that during the first 1,000 years of the Holocene, the sea level rose approximately 15 metres or some 1.5 metres every 100 years. The sea rose 10 metres during the next 1,000 years, an average of 1 metre per 100 years, in the period between 9,000 and 8,000 years BP. Between 8,000 and 7,000 years BP, the sea rose a further 12 metres, or about 1.2 metres every 100 years, so as to be some 2 metres above its present level and stands at this level until at least 5,000 years BP. This Holocene sea level data contradicts the suggestion that Garua Harbour was dry land around 6,000 years ago. Moreover the data demonstrates the slow fall of the sea level from its high stand some 5,000 to 7,000 years ago to about 1.3 metres above present level at around 4,000 years ago and to about 0.6 metre above the present sea level at 2,000 years ago (Woodroff and Horton 2005, fig. 4).

The area of Garua Island is about 7.2 square kilometres. This has been about the same for at least the past 2,000 years when present sea levels were reached. It appears that it took between 2,000 years and 4,000 years for the sea level to drop some 1.5 to 2 metres, or, a lowering of sea level of between 7.5 centimetres and 10 centimetres every 100 years. At the time of the Mid-Holocene High Stand, sea level Garua Island would have had slightly less land area and less coastal area available for occupation and the length of coastline would also have been proportionally less. The inland area as it is today would have been marginally closer to mean high water mark (MHWM) and any subsequent occupation as the sea receded would still be very close to the MHWM.

With the higher sea level, the area of active coral reef immediately around Garua Island would have been considerably more extensive and biotically more productive that at present with some islands now built up on dead coral (e.g. Boduna Island).

5.4 Volcanic Activity

West New Britain Province is a volcanically active region. A large number of volcanoes are distributed along the north coast of the island and the Willaumez Peninsula. A series of catastrophic Holocene eruptions had a major impact on the environmental and human history of the region (Boyd et al. 2005; Jago and Boyd 2005;
Lentfer and Torrence 2007; Machida et al. 1996; Torrence et al. 2000). The most recent volcanic activity in the central part of New Britain involved Pago-Witori Volcano near Hoskins, where eruptions occurred in the period 1911-1933, and a new eruption started in August 2002, and also Gabuna volcano near Kimbe which erupted in 2005. Dakataua Volcano at the northern end of the Willaumez Peninsula was last active in the late 19th century (McKee, Patia, Kuduon and Torrence 2005:1).

During the Holocene, the whole of the West New Britain region experienced at least 19 major eruptions (Machida et al. 1996). Garua Island has in the past been affected by eruptions from nearby volcanoes, Witori and Dakataua. The major eruptions resulted in widespread airfall tephra deposition which formed the distinctive sedimentary history of the island with which is associated four cultural phases of occupation (Boyd et al. 2005; Lentfer and Torrence 2007; Machida et al. 1996; Torrence et al. 2000). One of the major volcanic events is associated with the W-K1 eruption. The W-K1 tephra horizon was identified in a re-deposited context within Malaiol Stream but it is not preserved in the stratigraphic sequence at FAO suggesting a period of erosion following its deposition (Lentfer and Torrence 2007:92-93; Torrence et al. 2000:230-231). An ashfall tephra layer of up to 60 cm thick is present at FAO some 2 metres below the present surface. This tephra deposition is related to the largest W-K2 eruption which was occurred about 3600 cal. BP (Boyd et al. 2005:388; Torrence et al. 2000:235) or between 3480 and 3150 cal. BP as it is suggested by Petrie and Torrence (in pres.). Subsequent tephras observed in the deposit at FAO are W-K3 and Dakataua (Lentfer and Torrence 2007).

The immediate impact of Holocene volcanic eruptions on the environment and human populations depends on the magnitude, scale and frequency of these events. The W-K2 eruption was one of the largest in the Holocene that produced the most widespread pyroclastic flow, plinian pumice deposits and phreatomagmatic ash fall extended more than 40 km from the volcano (Machida et al. 1996). Such scale and magnitude of this event would have destroyed all vegetation and killed all animal and human inhabitants. The effect of such a cataclysmic event would have lasted for a long period of time. The process of successive regeneration of vegetation might have occurred at several stages when enough time had elapsed for soil to develop and would depend on the availability and distribution of seed sources, pre-existing plant communities and soil formation characteristics associated with ash fall (Lentfer 2003:13; Thornton 2000; Thornton, Cook, Edwards, Harrison, Chipper, Shanahan, Singadan and Yamuna 2001). The time required for full vegetation recovery and the
composition of species would have varied. The recovery of the forest on Long Island took more than 350 years and the regrowth still does not include many typical rainforest species (Thornton et al. 2001:1394). The first pioneer plants that colonized sterile ash beds are ferns, club mosses, grasses such as *Imperata cylindrica*, *Saccaharum spontaneum* and widely distributed woody species with broad ecological tolerance such as *Ficus sp.* (Boyd et al. 2005; Jago and Boyd 2005; Lentfer 2003:13, Thornton et al. 2001).

On the basis of fossil phytoliths, fossil starch grain and sediment analyses of the FAO 1000/1000 test pit, the overall picture of Holocene environmental change on Garua Island in association with impact of major volcanic eruptions has been reconstructed (Boyd et al. 2005; Lentfer 2003; Lentfer and Torrence 2007; Therin et al. 1999). It has been stressed that there have been lengthy periods of environmental stability between volcanic events which were characterised by the vegetation fluctuating between early pioneer and regrowth forest (Boyd et al. 2005:390). Both the W-K1 and W-K2 ashfall caused severe defoliation and damage by deposition of these ashes leading to severe disturbance of the closed forest. The consequential recovery from such events was dominated by grasses and pioneer regrowth at the beginning and followed by increase in forest regrowth. An environmental devastation caused by catastrophic volcanic eruptions implies that people would not be able to re-occupy the island which was covered by "dusty, sterile ash beds until a reasonable vegetation cover was re-established" (Boyd et al. 2005:390).

The time period for regeneration of vegetation is important in the consideration of the process of human re-occupation of the region. Apart from the devastating effect of volcanic ash falls and the fact that the tephra initially renders the land incapable of human habitation, the volcanic ash falls had a long term positive effect by boosting soil fertility and, in the longer term, stimulating plant growth from pioneer species to a closed-canopy forest. Once the process of revegetation commences, animals start to return. As phytoliths and sediment analyses at FAO establish, following after the W-K1 eruption people occupied the site when vegetation was dominated by grasses and forest regrowth. The consequential process of forest development at the site was interrupted by human activity that is reflected in deliberate forest clearance and burning (Lentfer and Torrence 2007:100). However, this environmental modification of FAO itself did not preclude the continuous and further development of a closed rainforest environment throughout the island's landscape where the process of regeneration continued. This is
supported by the presence of undisturbed forest identified in the area surrounding the site (Parrera et al. 2001:127).

As previously proposed by Torrence et al. (2000:240), people returned to Garua Island and the Talasea region some 1600 years after the W-K1 event, when the forest would have completely recovered. Recently, the length of abandonment following the W-K1 volcanic events was shortened on the basis of the Bayesian modelling and new radiocarbon dates (Petrie and Torrence in press). Despite this change, the period of abandonment was long enough to allow the suggestion that the landscape of Garua Island, during the middle Holocene, would be characterised by a typical lowland rainforest with mature diverse vegetation. However, there would be some small pockets or sites that were partly modified by human activities as it observed at FAO.

Similarly, following the W-K2 eruption people occupied FAO when the landscape was covered by grasses and pioneer regrowth forest (Lentfer and Torrence 2007:97). Later in the sequence there was a break in the vegetation recovery process at this particular site which was caused by human activity associated with clearance and burning. The human re-occupation of the island following the W-K2 event caused similar forms of disturbance related to human activity, would probably unevenly distributed across the landscape. The period of abandonment of Garua Island is now estimated 140 years (Petrie and Torrence, in press) although previously Torrence et al. (2000:240) suggested that the length of abandonment was 250 years. This lengthy period of abandonment and data from FAO suggest that the late Holocene landscape on Garua Island experienced a similar process of vegetation recovery, from grasses through pioneer regrowth to closed forest, as had occurred after the W-K1 eruption.

Despite the long-lasting environmental impact of the W-K1 and W-K2 volcanic eruptions which occurred during the middle and late Holocene, marine and land resources of the wet tropical region of West New Britain at a macro-level did not experience dramatic changes (Boyd et al. 2005; Jago and Boyd 2005; Lentfer and Torrence 2005). This suggests that the environmental conditions and resources that recovered after each volcanic event were generally similar on Garua Island. In both middle and late Holocene periods of human occupation of the island, the environment was relatively stable and free from life-threatening volcanic activity. At the time people returned to Garua Island and FAO after the cataclysmic effects of the W-K1 and W-K2, the environment would have been mainly that of wet tropical lowland rainforest and associated woodlands (Floyd 1954:3). Coral fringe reefs would have formed on shoals.
around the island in both periods. The pristine terrestrial and marine environment of the middle and late Holocene periods would have potentially been attractive to humans.

5.5 Geographical Setting

Garua Island, which forms the southern foreshore of Garua Harbour, is on the western side of Kimbe Bay adjacent to the Willaumez Peninsula in the province of West New Britain in Papua New Guinea. Willaumez Peninsula runs roughly due north as an extension of the main island of New Britain. The main concentration of population and the two main towns of West New Britain Province, Kimbe and Hoskins, are located in the central north coast area of New Britain Island (McKee et al. 2004:1; Seeto 2000). Kimbe Bay is in the south Bismarck Sea and the depth of the sea increases dramatically to over 36.6 metres (20 fathoms) only 600 metres from the north eastern shore of Garua Island. Garua Harbour is a natural deep-water safe haven for shipping (Royal Australian Navy Hydrographic Charts 1979:545; 1992:676; Royal Australian Survey Corps 1975:8987). Extinct and active volcanoes, geyser fields, boiling mud pools, and volcanic lakes are characteristic of both Hoskins and Willaumez Peninsulas, and adjacent islands. In the Talasea region, which is situated in the central part of Willaumez Peninsula, there are several active geothermal areas that form hot mud pools, hot springs, steam vents and sinter beds at beach level and on slopes around the Garua Harbour (Seeto 2000; Specht and Torrence 2007; Summerhayes 2000:16).

The major industry in West New Britain Province is the production of palm oil and palm plantations have largely displaced lowland tropical rainforest along the coast. There was little contact with Europeans until the 1960s and, today, English and Tok Pisin (PNG Pidgin) are the dominant languages (Seeto 2000).

From 1884 until 1914 New Britain was a German protectorate. German influence in the region is evident from current geographical names of which the Bismarck Archipelago is such an example. The area became the Territory of New Guinea under Australian administration until 1949. In 1949 it was merged with the Australian Territory of Papua and became part of modern Papua New Guinea in 1975. During the Second World War, New Britain was occupied by the Japanese Imperial Army. By April 1942 they had occupied Talasea and the surrounding plantations. In March 1944 United State marines landed and commenced the Volupai – Talasea operations against the occupying Japanese force. Prior to the landing at Volupai, Bristol Beauforts of the Royal Australian Air Force bombed the Volupai – Talasea area for three days and also
conducted a further last minute strike before the operations began. The final phase of
the fighting consisted of securing Garua Island for American use. Garua Island had been
abandoned by the Japanese and was secured by March 9, the same day that Bitokara
Mission became a regimental command post. Garua Island was secured by troops who
landed on the western side of the island and split into two forces which met on the other
side of the island at Garua Plantation village. Landing barges used the jetty at Talasea
Point to supply the troops. Garua Harbour and its shores provided recreational
opportunities in the form of hot springs, fishing and swimming. The Americans
occupied and patrolled the area until 25 April 1944. During their retreat from Talasea,
Japanese troops subsisted on taro, birds, fish, and vegetables from garden plots

The establishment of plantations, erosion, road construction from coral (Floyd
1954:1) and fairly extensive defensive and offensive military activities have greatly
disturbed the surface of the study area. From one perspective activities such as
excavation for road construction allow archaeologists to find sites (Specht and Torrence
such activities create difficulties in the interpretation of surface finds (e.g. obsidian
stemmed tools or marine shells on high elevation (Torrence et al. 2000:230). FAO site
was also partly destroyed by erosion and road construction (Torrence and Webb

Garua Island is separated from the Willaumez Peninsula by a channel which is
only 800 metres wide at the two closest points. The channel is 3 metres deep at low tide.
Obviously, if either the land and sea bed were lower or the sea level higher, as in the
past, this channel would have been even deeper. The size of the island is approximately
seven square kilometres, about 3.8 km across from north-east to south-west and 3.2 km
across from north to south measured at the greatest possible distance (Royal Australian
Navy Hydrographic Charts 1979: 545, 1992:676, Royal Australian Survey Corps 1975:
8987). The island is irregular in shape and if one was to stand in the middle of the island
so as to be as far as possible from the sea, one would only be a maximum of 1.5
kilometres from the shore (Figures 5.3 and 5.4).

The island is dominated by Mount Hamilton which rises to a height of some 240
metres (784 feet) above sea level. There is another hill known as Mount Baki which is
only 130 to 140 metres high. The area between these two volcanic cones forms a saddle
of land which is some 50 metres above sea level at its lowest seat. Malaiol Stream has
cut deeply into the valley running north from the saddle. Two catchment areas are
created by this east-west saddle such that approximately half the run-off is to the south and half to the north. There are at least another 12 stream catchments on the islands (Torrence and Boyd 1996, fig. 2b). Some of these streams provide a permanent or semi-permanent source of fresh water and other streambeds carry water only after rain (Specht and Torrence 2007:133-135; Torrence and Boyd 1997:14; Torrence and Webb 1992:4).

Torrence and Boyd (1996) designated the physiographic zones of Garua Island as including coastal plains, coastal escarpments, coastal cliffs, upland plains and inland steep slopes. These zones include such topographical features as hills, ridges, saddles and valleys (Torrence 2000; Torrence and Boyd 1996, fig. 2b; Specht and Torrence 2007). The eastern side of the island is fringed in parts by a narrow coastal strip about 10 m wide. On the western and southern sides of Garua Island are coastal flats which are generally not wider than 100 to 150 metres. There are only two relatively large coastal plains (about 500 m wide) both of which are associated with their main catchment areas. The coastal flat area on the northern side of the island is drained by Malaiol stream. (Specht and Torrence 2007; Torrence 1993:8-9; Torrence and Boyd 1996:15-16). Coastal slopes mostly rise directly from the sea or beach, or are located within a few hundred metres of the beach. (Specht and Torrence 2007).

5.6 Climate

The climate of New Britain has been generally the same throughout the Holocene and its characteristics are that of a wet tropical climate with a drier period between May and August (Seeto 2000). The wet tropical climate of West New Britain is a consequence of its near equatorial location in the middle of the hot wet tropical zone (Boyd et. al. 2005:387)

There is a stronger seasonality between trade wind and monsoon seasons in the western Pacific which is influenced by the cyclic heating and cooling of the nearby Asian and Australian land masses (Kirch 2000:52-53). El Nino and the Southern Oscillation (ENSO) influence patterns of rainfall or drought. An ENSO event reverses the normal aridity of the western-central Pacific which is broken by periodic heavy rainfall episodes, trade winds decrease in intensity, and there is a significant eastward flow of warm water. There are dramatic consequences for particular islands, including droughts in the western and central Pacific and heavy rains, floods, and increased cyclone frequency in the eastern Pacific. Fish populations are sometimes devastated as
are the seabird colonies that depend on them for food and ENSO presumably had serious impact on Pacific island populations in the past.

It has been argued that the Bismarck Archipelago, as an area of light variable winds and untroubled by cyclones formed a 'voyaging nursery' (Irwin 1992:24, 31; Anderson 2000:16). Evidence for the transportation of Talasea obsidian to New Ireland and other places (Specht 2002; Summerhayes 2000:9, 2004; White et al. 1991) establishes the fact of the use of watercraft taking advantage of calm cyclone-free waters in a climate conducive to short sea passages and inter island voyaging.

The average daytime temperature range is from 28° to 32°C, with temperatures at night being only slightly cooler at 25° and 27°C. The sea temperature averages between 28° and 31°C. The mean annual rainfall is around 4000-4500 mm (Specht and Torrence 2007:134). Rainfall on the north coast, including Kimbe Bay, is lowest during May to August, the average total during those four months being 635 mm, or 25 inches. Humidity is variable, but usually high, averaging between 75% and 95% (Seeto 2000).

5.7 Vegetation History

Garua Island lies in a biogeographic zone of wet tropical lowland rainforest and is naturally a closed forest. The present landscape has been greatly modified by coconut plantations that were established in the 1920s (Boyd et al. 2005:387). However, ethnobotanical data from New Britain, and particularly Willaumez Peninsula and West New Britain (Floyd 1954; Lentfer 1995; Seeto 2000; Powell 1976), available paleoenvironmental information from Garua Island and the Isthmus region (Boyd et al. 2005; Kealhofer et al. 1999; Lentfer 2003:301-303; Lentfer and Torrence 2007; Parr et al. 2001) and archaeological remains from the middle and late Holocene sites in Bismarck Archipelago (e.g. Gosden et al. 1989; Kirch et al. 1991, 2000:109; Specht 2003; Spriggs 1991, 1997:79, 117) all allow the reconstruction of past vegetation regimes that existed in the study area up until the more recent past before the advent of modern palm oil plantations.

Wet tropical lowland rainforest generally consists of up to five layers of vegetation, including numerous species of tall trees with buttressed trunks that form a dense canopy, palms and lianes. Aroids, fern, gingers, ginger-like herbs, climbing bamboos, rattan vines, cordylines and an abundance of epiphytes are common in the ground layer. (Boyd et al. 2005:387; Lentfer 2003:279; Seeto 2000). The variations in this rainforest occur in response to local factors, such as soil, drainage, and differences
in elevation. Near the coastline and on tidal flats there are mangroves that sometimes merge into littoral woodland forest with tall (Casuarina equisetifolia) and large spreading trees (Calophillum inophyllum, Terminilia catapra, Inocarpus fagiferus) and other dominant trees such as Hibiscus tiliaceus, Ficus spp., Syzygium. Several species of shrubs grow beneath the canopies of these trees. Where the soil is waterlogged or covered by freshwater for at least part of the year, freshwater swamp forest establishes itself near the mouth of rivers or areas where underground streams appear on the surface. This type of forest is characterised by widely spaced trees of irregular height with dense undergrowth that is generally matted with lianas, vines and lawyer cane. Sago palm (Metroxylon rumphii) and occasionally nypa palm (Nypa fruticans) are associated with this plant formation (Floyd 1954:3-9; Powell 1976:112-115).

Lush rainforest called "the big bush" by local people (Floyd 1954:4) covers the mountains behind the littoral or swamp formations. The common feature of this type of plant community is the relatively open nature of the forest under the canopies of the large trees. Shrubs, herbaceous plants, lianes and epiphytes are not numerous and dense and so provide for relatively easy access through the forest. Many species of trees are used by local peoples as good quality timbers for canoes, shelter building and flooring. There are some important food trees in this forest such as Canarium sp, Syzygium spp., Diospyros sp., Pandanus sp. (Floyd 1954:4-6). Secondary growth occurs in the vicinity of local villages where clearings for gardens have been abandoned and are reverting to forest and a dense tangle of young trees, brush and vines is created. Traditional practices of abandoning a garden after three or four years of cultivation means that this type of vegetation is relatively extensive around large villages. Grassland occurs naturally in a few small areas near the coast and plant species include mainly blade grass (Imperata sp.), kangaroo grass (Themeda spp.) and wild sugar cane (Saccharum spontaneum) (Burcham 1952; Floyd 1954:3-11; Lentfer 2003:279).

The rainforest biome has the largest crop biomass due to the high rate of solar radiation, abundant moisture and the twelve-month growing season. Both growth and flowering are periodic, but independent of any particular season because of relatively constant external conditions. This means that a rainforest has no definite flowering season and a wide variety of trees are always in bloom. However, this presents a particular problem for tropical animals and humans who depend on forest resources for survival because edible fruits and nuts occur in the canopy and can be difficult to locate. Continuous, but dispersed, resources within rainforest forced both humans and animals to maintain a relatively high level of mobility over a wide area which supported a

The wild plant resources of lowland rainforests are available to the local peoples of New Britain and provide them with the raw materials for building houses and shelters, making canoes, rafts, tools, weapons, containers and clothing. Many plant species are widely used as staple or supplementary food. Plants are also used as medicines and in ritual and ceremonial events (Floyd 1954: Appendix II; Powell 1976:107-117; 134-179). Food plants include coconut, breadfruit, sago palm, fruit and nut trees such as *Pandanus sp.*, *Syzygium spp.*, *Canarium sp.*, sugarcane (*Saccharum officinarum*), banana (*Musa spp.*), tubers (taro, yam) edible ferns, seeds and pith (*Cycas spp.*), edible leaves of woody species (*Ficus spp.*), and a number of herb species (Lentfer 1995; Powell 1976:174-181).

The gathering of plant foods is associated with the seasonality (wet and less wet) of the tropical rainforest. People have engaged in concentrated gathering efforts during the drier season when products are available and travelling is much easier. Seasonal mobility is required especially for the exploitation of fruits and nuts (Moran 1979:257). Forest plants make an important contribution to the diet, although their nutritional significance is less for the total calories they provide than for the mineral, vitamin, and micronutrient content (Moran 1979:263; Powell 1976:182). There is a tendency to gather and eat some of the edible plant food on the spot thus limiting the volume of products that need to be transported to the camp (Moran 1979:263).

At present the staple plant food in West New Britain is provided by the cultivation of several types of crops (taro, yam, sweet potato, and bananas) that are grown in mixed gardens and sequentially cropped from the garden using the system of shifting cultivation widely known in tropical regions (e.g. Bellwood 2005:128-145; Kirch 1997:203-212; Moran 1979:267-270; Spriggs 1997:31-35). This system involves the clearing and short-term use of a piece of land for crop cultivation followed by its abandonment after only a short period of use. This process is necessary for the soil to recover. As a result, extensive areas of land are required in order to provide a relatively small population with food because only a few gardens are in cultivation at any one time. Many abandoned garden plots are in various stages of regrowth. Often gardens are 5 to 10 kilometres from the village and in such cases people need to build a temporary hut in the garden to provide shelter while they are working there (Parkinson 1999:341). Until relatively recently, both gardens and associated settlement consisting of a series of
small hamlets, moved regularly within the interior of West New Britain. For example, modern stable villages with their associated gardens started in the Arawe Islands only about 100 years ago (Gosden and Pavlides 1994:167-168). Prior to this traditional gardening was associated with regular mobility.

Plant remains recovered from some archaeological sites in the Bismarck Archipelago indicate that many of the most frequently used species today were known and gathered by humans since the late Pleistocene (Spriggs 1991, 1997:61-64; Loy et al. 1992). There are at least 15 species of plants that were involved in subsistence and other activities of the late Holocene populations on Mussau, Arawe, and Watom Islands during the Lapita period (Table 6.1). These include a wide variety of tree crops producing fruits and nuts (Canarium and Terminalia almond, Tahitian Chestnut (Inocarpus fagiferus), pandanus (Pandanus sp.), starchy fruit such as breadfruit (Artocarpus altilis), fleshy fruits (Vi Apple Spondias dulcis, Malay Apple Eugenia malaccensis), coconut (Cocos nucifera), root or tuber crops such as taro (Colocasia esculenta) and yams (Dioscorea alata), and bananas (Musa spp.) (Gosden et al. 1989; Kirch 1991, 2000:109; Specht 2003; Spriggs 1991, 1997:79, 117).

Charred fragments of Canarium, coconut and other nutshellss were found during excavation on Garua Island and the nearby mainland (Specht et al. 1991). This evidence suggests that nut bearing trees were widely spread throughout the region and could be intensively used by middle and late Holocene populations. Also some significant data about plants that grew on Garua Island in the middle and late Holocene have been obtained through phytolith and starch analyses of the sediments and residues found on obsidian tools at FAO. These are represented by palms including the fishtail palm, Caryota rumphiana, which is one of the major starch producing species, figs (Ficus spp.), Syzygium, Canarium nuts, bamboo, banana, gingers, fern and other diverse arboreal and herbaceous plants (Boyd et al. 2005; Kealhofer et al. 1999; Lentfer 2003:301-303; Lentfer and Torrence, 2007; Parr et al. 2001).

Comparative analysis of plant remains found at the middle and late Holocene sites on the Arawe Islands, Mussau Islands, Watom Island and Garua Island, and modern plant communities of lowland rainforest in New Britain (Table 5.1), demonstrate that the general structure and distribution of vegetation has not changed dramatically over time, although on Garua Island periodic destruction of vegetation by volcanic eruptions probably resulted in some differences in composition of subsequent replacement plant communities (Lentfer 2003:13). This allows one to suggest that many economically useful species of plants were widely accessible during the middle and late Holocene on
Garua Island and could have been involved in subsistence and other daily activities of the island's inhabitants in much the same way as such resources were used by local people in New Britain relatively recently (Floyd 1954; Lentfer 1995; Powell 1976).

5.8 Fauna and Marine Resources

The lowland rainforest habitats in West New Britain support a diverse fauna including marsupials, rats, fruit bats, land birds, reptiles and insects which are the subject of hunting and provide fat and protein for the diet and supplement food from domesticated pigs, chicken and dogs (Seeto 2000). The natural resources of the reefs and the sea were also important sources of food for the coastal population (Kirch 1997:31; O'Connell and Allen 2004).

The protected waters of Garua Harbour and part of Kimbe Bay encourage luxuriant coral growth to occur on reefs with hard coral formations and masses of crinoids creating a marine environment which support a staggering diversity of fishes comprising more than 800 species. Kimbe Bay contains large coral pinnacles and seamounts that rise to within a few metres of the surface. The peaks of reefs are covered by masses of carpet anemones with their requisite anemonefishes, with dense schools of barracuda, trevallies (jacks) and other pelagic fishes attracted to the crests of reefs. Atolls, large barrier reefs, patch reefs, spur-and-groove systems, and shallow shoals with their crests rising to less than one metre beneath the surface are other reef structures where soft corals and sea fans give way to steep walls which fall to significant depths. The sheerest drop-offs to deep water are found further offshore (Seeto 2000).

There are no sea wasps (Chironex fleckeri) and other dangerous stingers in Kimbe Bay and only a few of the milder jellyfish species are ever encountered and are not found in any abundance in the Bay. However there are other stinging animals present in the waters of Kimbe Bay, including scorpaenid fishes. Sea snakes and saltwater crocodiles (Crocodileus porosus) are infrequent visitors with crocodiles being found only in rivers in unpopulated parts of the area. The grey reef shark (Carcharhinus amblyrhynchus) is the most common species followed by the placid whitetip reef shark (Triaenodon obesus), scalloped hammerhead (Sphyra lewini), silvertip (C. albinarginatus) and blacktip reef shark (C. melanopterus). Silky sharks (C. falciformis - usually seen there with schools of tuna) make rare appearances and there has been one sighting of a mako (Isurus oxyrinchus). Whale sharks (Rhiniodon typus) are
occasionally seen in Kimbe Bay and Tiger sharks (*Galeocerdo cuvier*), although commonly caught at night by fishermen further out in the Bay, are very rarely seen by divers. Spinner dolphins, killer whales, sperm whales, pilot whales, and other toothed whales are frequently seen in Kimbe Bay (Seeto 2000). Green sea turtles inhabit the coral reefs and are still sold as seafood in the local market in Kimbe (author’s observation).

The abundance and accessibility of aquatic resources actually encourages both relative sedentariness and increased dependence on horticulture within the coastal area because the alternative of semi nomadic hunting of wild game represents a poor return on labour invested in hunting within the rainforest with its scattered hard-to-find animal resources (Moran 1979:263-264).

Archaeological data from some coastal sites in the Bismarck Archipelago provide significant information related to the use of animal and marine resources by humans during the Holocene. This information is able to be used as an indirect analogy for the reconstruction of subsistence lifeways of people on Garua Island in the middle and late Holocene.

Rich faunal remains associated with the early Holocene subsistence patterns are found at some caves and rock shelters in New Ireland, Buka and Manus Islands (Marshall and Allen 1991; Spriggs 1991, 1997:51-82; White *et al.* 1991). The inland cave Panakiwuk had remains of marine shellfish, crabs, salt water crayfish, fish, crocodile and turtle. The importance of marine resources in the diet is evidenced by the deliberate transportation of a range of shellfish and fish species from the sea to the sites in New Ireland over distances of between 3 to about 10 kilometres (Marshall and Allen 1991; Spriggs 1997:52; White *et al.* 1991).

The diverse terrestrial fauna in New Ireland includes phalangers, bats, rats, birds, reptiles, fresh water shells and land snails (Marshall and Allen 1991). Five species of shellfish collected from coastal rocks and corals, remains of three species of sharks that inhabit coastal waters of the open sea and which sometimes enter lagoons and five families of fish, all dwellers of coastal reefs were identified at Balof 1 and 2. In addition to local bats, rats and reptiles, introduced phalangers and wallaby were hunted by inhabitants of this rockshelter (White *et al.* 1991).

There is relatively limited information about middle Holocene subsistence practices in the Bismarck Archipelago. However, the composition and quantity of shellfish, animal and fish bones on some sites on Manus (Kennedy 1983), Nissan (Spriggs 1991; Spriggs 1997:80-81) and New Britain (Gosden *et al.* 1989; Spriggs
1997:77) demonstrate an importance of marine resources in subsistence, in addition to hunting and plant exploitation.

A very diverse range of marine resources has been used by Lapita people during the late Holocene in the Bismarck Archipelago. The excavated sites on the Mussau Islands produced substantial vertebrate faunal assemblages, the majority of which consists of fish bone of more than 26 families (Kirch et al. 1991). The abundance of fish remains representing inshore reef species suggests that Lapita fish procurement did not focus heavily on hook and line techniques. The early Lapita sites also demonstrate an active exploitation of marine turtles. Large quantities of marine molluscs, both gastropods and bivalves were collected from a variety of habitats including reef edge, sandy bottom and mangrove (Kirch et al. 1991). Bones of marine fish, teeth of sharks and shellfish have all been identified at the Balof shelter in New Ireland (White et al. 1991). At the Lasigi open site, an abundance of marine shells, bones of inshore species of fish and turtles were found (Golson 1991; Spriggs 1997:125). A concentration of reef fish including pelagic species has been recovered at the shelter and open sites on the Nissan Islands (Spriggs 1991; Spriggs 1997:80-81). On Watom Island, waterlogged deposits at the SAD and SAC sites produced a number of shell middens, bones of fish and of turtle (Specht 2003; Spriggs 1997:124-126). The earliest Lapita sites in the Arawe Islands (Magekur and Apalo) contain dense deposit of shells and a large amount of bone that include dugong, fish and crocodile (Gosden et al. 1989; Spriggs 1997: 120-121).

In most Lapita sites the dominant shellfish are represented by gastropods (Turbo, Trochus, Cerithium, Cypraeidae, and Strombus) and by bivalves (Arcidae, Tridacnidae, and Cafrarium) (Ono 2003). Some shellfish species such as Turbo, Trochus and Conus were collected from reefs, and from the lagoon floor, both as an important food resource and as a raw material for the manufacture shell adzes, fish hooks, scrapers, and ornaments (Smith 2001). The maritime-based diet also included a wide variety of inshore and bottom-dwelling fish, the most important of which were parrotfish (Scaridae), wrasses (Labridae) tangs (Acanthuridae), squirrellfish (Holocenturidae), jacks (Carangidae), groupers (Serranidae), open sea pelagic fish tunas (Scombridae), barracudas (Sphyraenidae) and turtles, especially the green sea turtle Chelonia mydas (Kirch 2000: 56; Ono 2003).

Bones of domesticated pigs were found on all the above mentioned sites while chicken and dog were identified at the site on Mussau Island and chicken at the SAC site on Watom Island (Kirch et al. 1991; Specht 2003; Spriggs 1997:124-126). The most
common bones of wild terrestrial fauna found are phalangers, rats, fruit bats, reptiles and birds (Golson 1991; Kirch et al. 1991; Spriggs 1997:125; White et al. 1991). Wallaby and cassowary are known at the earliest Lapita sites in the Arawe Islands (Gosden et al. 1989; Spriggs 1997:120-121) and bandicoot was identified at SAC on Watom Island (Specht 2003; Spriggs 1997:124-126).

Both faunal and plant remains from archaeological sites demonstrate that the diet of human populations in the Pacific heavily relied upon sea resources for meat and protein and, to a lesser degree, these seafoods were in addition to forest game and domesticated animals. The staple carbohydrate basis of the diet was comprised of starchy plants such as taro, yams and bananas seasonally supplemented by breadfruits. The sources of vitamins were provided by nuts, fruits and greens which occur widely in the lowland rainforest environments (Kirch 1997: 212-217)

The spectre of marine resources involved in the subsistence of the population of the Bismarck Archipelago during the middle and late Holocene allows the suggestion that Garua Island would have been an attractive place for human occupation because it was surrounded by reefs and the deep waters of Kimbe Bay which contained a rich diversity of marine life. The subsistence of island's inhabitants would have been oriented towards the exploitation of the predictable aquatic resources. An abundance of, and relatively easy access to, shellfish, crabs, octopus, fish and marine turtle would have greatly contributed to the necessary calorie and protein intake and augmented the nutritionally poor starchy diet obtained through plant gathering and probably gardening. Protein deficiencies could be partly compensated for by hunting of scattered forest game on the island and mainland and probably by the keeping of domesticated pigs, chickens and dogs that were part of the economy of the late Holocene inhabitant of the island.

5.9 Summary

The basic elements of the seascape and landscape of Garua Island and of the Talasea mainland, which are relevant to reconstructing prehistoric settlement and subsistence systems, have not changed dramatically since the middle Holocene despite some fluctuations in sea levels and the impact of tectonic and volcanic activity.

Firstly, geological formations in the Talasea/Garua Island area provided a wide range of easily accessible lithic resources including high quality obsidian and other useful raw materials such as ochre and clay throughout the entire Holocene period (e.g.
Secondly, little change occurred as a consequence of the Mid-Holocene High Stand sea level. When the sea level was higher, Garua Island was somewhat smaller and, therefore, there was less opportunity for beach, inter-tidal and coastal settlements during the middle Holocene. With the higher sea level, however, the area of active coral reef immediately around Garua Island would have been considerably more extensive and the seascape would have been biotically richer and more productive than it became.

Thirdly, the airfall, redeposited tephras and slope-wash materials emanating from the W-K2 catastrophic eruption would change, to some extent, the micro-topography of the island by in-filling low-lying areas and changing the shape of slopes and the coastal plain (Specht and Torrence, 2007:134). However, the main landforms on the island, such as coastal escarpments, coastal cliffs, hills, ridges, slopes, foothills, saddles, valleys and ravines generally did not undergo dramatic change.

Fourthly, the environmental conditions and resources that recovered after each volcanic event were generally similar on Garua Island throughout the Holocene and there have been lengthy periods of environmental stability between volcanic events (Boyd et al. 2005:389). Comparative analysis of plant remains from archaeological sites with modern plant communities of lowland rainforest in New Britain (Table 5.1), demonstrates that the general structure and distribution of vegetation has not changed dramatically over time ((Boyd et al 2005; Jago and Boyd 2005; Lentfer 2003:13). This botanical data allows one to suggest that many economically useful species of plants were widely accessible during the middle and late Holocene on Garua Island and could have been used in subsistence and other daily activities by the island's inhabitants in a similar way to that which local people in New Britain used available resources until relatively recently (Floyd 1954; Lentfer 1995; Powell 1976).

Finally, the availability of predictable and diverse aquatic resources is one of the more significant features of the marine environment surrounding Garua Island throughout the Holocene. The abundance and accessibility of aquatic resources and the relatively small catchment area containing terrestrial resources provided by the island would encourage a low level of mobility and increased dependence on gardening and some domesticated animals. The temporal consistency in basic marine and terrestrial resources would, necessarily, result in there being common features in the dynamic relationship between subsistence strategy, tool-use behaviour and settlement patterns.
Garua Island possessed a number of highly desirable natural attributes and provided resources which attracted human populations from the middle Holocene up until the present. The attractive features of Garua Island were:

- the strategic advantage provided by islands, including security;
- shelter and safe access to deep water provided by Garua Harbour allowing access to the trade routes across and around the Bismarck Sea, given that it is well established that obsidian has been transported by sea;
- the availability of flat waterfront land to the west of Malaiol Stream and on the southern and western sides of the island;
- the presence of volcanic soils which support diverse plant resources including edible species and timber and the abundance of lithic resources in the form of accessible obsidian sources;
- the existence of permanent or semi-permanent sources of fresh water associated with Malaiol Stream and springs as well as other lesser watercourses on the island;
- its accessible topography providing arable land for garden plots; and
- the close and fringe coral reefs providing access to rich marine resources including seafood, *Tridacna* or *Terebra* shells and other materials.

It is apparent that Garua Harbour provided a comfortable, resource rich and safe focus for human settlement along its foreshores (Talasea) and on Garua Island. The nature of the existing landscape and ethnohistorical material suggest that tool use activity, subsistence and settlement strategy on Garua Island and at FAO particularly, were closely associated with the exploitation of the diverse range of productive plant and marine resource that were represented within the occupied landscape during both middle and late Holocene periods. The extent to which use-wear/residue data is able to provide reliable information about the interaction between human activities and the natural environment is examined in Chapters 7 and 8. The following chapter describes the archaeological context of the middle and late Holocene obsidian tool assemblages at FAO which were studied in this project.
6.1 Introduction

The methodological approach adopted in this thesis was designed specifically to assess the middle and late Holocene obsidian assemblages found at the FAO site on Garua Island and is described in Chapter 3 and Chapter 4. The artefacts chosen for my use-wear/residue analysis are from seven excavated test pits (Figures 5.3 and 6.2). This chapter briefly describes the location and excavation of the site, its depositional history and the chronology of human occupation of the site. The spatial distribution of the artefacts recovered by the excavations is also outlined.

6.2 Site Excavation

The FAO site is situated on a relatively flat area of a hilltop and has commanding views of the Talasea mainland to the west, Kimbe Bay and two smaller neighbouring islands (Garala and Kaula) to the north-east. Steep north, west and east slopes rise to terminate at the flat crown of the hill (Figure 6.1) and this elevated area would have been an ideal place for a small hamlet (Gilkes 1993; Torrence 1993). Sources of obsidian can be found in several outcrops around the base of the hill as well as on the beach some 40 metres below (Torrence and Webb 1992: 6).

The site was first discovered by Richard Fullagar and Robin Torrence in 1989 when small pottery sherds were found on the road surface next to a cutting. In order to clarify the extent of the site and the depth of deposits, three auger holes were dug across the crest of the hill down to a depth of 2 metres. Following up on this work, a road section was cleared about 20 metres downhill and a 50 cm × 1 metre test pit was excavated by Jim Specht, Neville Baker and Francis Wadra. The section revealed a five-layer sequence containing two tephra layers separating the cultural deposits (Specht et al. 1989). The two tephra layers were later determined as being the W-K2 and Dk tephras (Machida et al. 1996; Torrence et al. 2000). It was later confirmed that these two tephra layers sealed cultural deposits between identifiable volcanic events for most of the site. However, the stratigraphy became less clear on the southern extent of the
site, where W-K2 tephra deposits were not observed within test pits (Gilkes 1993, Torrence 1993).

Extensive excavations at FAO were undertaken by Torrence in 1992 and 1993 (Torrence, 1993; Torrence and Webb 1992) and additional test pits were dug in the surrounding area in 1997 (Torrence and Boyd 1997). The 1992 excavation, supervised by Glenn Summerhayes and Laurie Victor comprised only a single test pit 100/100 measuring 1 metre × 1 metre. The pit was located on the apex of the hill. Seven strata were identified, including Layer 4 which is associated with post W-K2 deposits (obsidian and pottery are common throughout the layer) and Layer 6 underlying the W-K2 tephra (obsidian artefacts were concentrated in the top 10 cm) (Torrence and Webb 1992:6-7).

In 1993 a grid was set up across the site taking 100/100 as a central survey point but changing the coordinates to 1000/1000. Test pits were identified by the north-east corner survey points. Test pits measuring 1 metre × 1 metre were located at 10-metre intervals along north-south and east-west transects (Figure 6.1). In all, a total of seventeen (17) test pits were excavated. Three extra test pits were dug on the southern slope of the hill and these were identified as A, B and C (Figure 6.2). They were not part of the original grid.

The need to determine the earliest period of occupation was a priority in 1992. Consequently, pit 1000/1000 was extended to become a 2 metre × 2 metre test pit. By taking down the quadrants in steps, it was intended to safely extend the 1000/1000 depth until bedrock was reached. To achieve this objective as fast as was possible, only half of 1000/1000 (1 metre × 0.5 metre) was excavated below the level reached in 1992. At 3.1 metres bedrock had not been reached and it was considered unsafe to go any further although worked obsidian was still being found (Gilkes 1993; Torrence 1993). Pit 970/1000 was excavated to about 2 metres in depth ending at the red/brown clay layer. In contrast, other pits were excavated no deeper that 20 cm below the W-K2 tephra deposit (Torrence 1993:5; Torrence and Webb 1992:6-7).

Test pits were excavated stratigraphically following natural strata. Each natural layer was arbitrarily subdivided into 10 cm thick spits. The unconsolidated airfall tephras which did not contain artefacts were removed in bulk. All sediments from each excavated unit were dry sieved through 3 mm mesh screens. When sediments became too clayey and thick, they were carefully hand sorted. Most artefacts were washed in the field, bagged in clean plastic bags and transported to Australia for Laboratory analysis. Some obsidian artefacts from each spit within the excavated pits were specifically
sampled for residue and use-wear analysis. Carbonised material was collected and placed in clean plastic bags either during the excavation or retrieved from the sieved material (Torrence 1993; Torrence and Webb 1992; Barton et al. 1998). Samples of the sediments from test pit 1000/1000 were taken for starch and phytolith analyses (Boyd et al. 2005; Lentfer 2003:287, Parr et al. 2000, Therin 1994:70; Therin et al. 1999)

6.3 Stratigraphical Sequence at FAO

FAO contains well stratified assemblages which have become the most studied on Garua Island. The full sedimentary sequence of the site was obtained through the stratigraphic profile of the north face of the FAO 1000/1000 test pit that reached a depth of 3.1 metres (Figure 6.3). The sediments in this profile indicate several layers of buried soils alternating with tephras (Boyd et al. 2005:387; Lentfer 2003:280; Lentfer and Torrence 2007:86; Therin et al. 1999:443-444; Torrence et al. 2000:230-231). The basal deposit (Layer 1) is represented by stiff orange/brown kaolinitic clay that is associated with a weathered buried soil (Figure 6.3). Layers 2, 3, and 5 are characterised by light colour, coarser texture and contain pumice fragments allowing them to be identified as airfall tephras. Layer 4 consists of grey/brown sticky kaolinitic clay and was interpreted as being poor soil development resulting from rapid tephra accretion.

In contrast, Layer 6 was comprised of homogenous red/brown silty clay associated with well-developed buried soil and probably sub-layers that might represent a slow process of tephra accretion. However, there was no evidence indicating the presence of the W-K1 tephra in this layer (Lentfer and Torrence 2007:91).

Layer 7 consisted of thick deposits of unconsolidated brown/yellow W-K2 airfall tephra above which was the buried soil of Layer 8 that comprised a chocolate brown clay loam. This was overlaid by orange/brown gravelly loam representing an accretion layer of airfall tephra from the W-K3 eruptions (Layer 9). The orange/brown sediment of Layer 10 with a large sand and gravel components is associated with an unconsolidated Dk airfall tephra. This is covered by an orange/brown sandy loam with a black/brown topsoil (Layer 11) (Lentfer 2003:280, Lentfer and Torrence 2007).

The middle Holocene cultural deposit at FAO is associated with stratigraphic Layer 6 which was dug and documented as level 6. The late Holocene cultural deposit at the site corresponds stratigraphically with Layer 8 excavated within level 4.
6.4 Chronological Sequence at FAO

The Holocene tephras, which are stratigraphically preserved in situ within test pits at FAO and other locations on Garua Island and Talasea area, represent important sources for relative dating of archaeological deposits (Machida et al. 1996, Torrence 2002a, 2004a, Torrence et al. 2000). As emphasised in Chapter 2, the correlation of the Holocene tephras with the Witori and Dakataua volcanic eruptions outlined the five chronological phases of human occupation which are widely accepted for the region (Pavlides 2006, Torrence 2002c, Torrence et al. 2000). However, re-assessment of the date for the W-K2 volcanic event from 3600 BP to the modal date 3315 cal. BP (Petrie and Torrence in press); necessitate the reconsideration of the relationships between the middle and late Holocene occupations of FAO and volcanic eruptions. There are four radiocarbon dates and a series of obsidian hydration determinations available for the site (Lentfer and Torrence 2007:87; Torrence and Stevenson 2000:329; Torrence et al. 2000:228-229):

Table 6.1 Radiocarbon dates from the FAO archaeological site (Torrence and Stevenson 2000; Lentfer and Torrence 2007; Petrie and Torrence in press).

<table>
<thead>
<tr>
<th>Pit/layer/spit</th>
<th>Material</th>
<th>Lab. number</th>
<th>Radiocarbon date</th>
<th>Calibrated BP</th>
<th>Bayesian modelling date, cal. BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000/1000, Layer 6, spit 1</td>
<td>nutshell</td>
<td>NZA 2901</td>
<td>3532±66</td>
<td>3990-3630</td>
<td>3990-3640</td>
</tr>
<tr>
<td>1000/1010, Layer 8, spit 2</td>
<td>nutshell</td>
<td>NZA 3738</td>
<td>2439±64</td>
<td>2720-2350</td>
<td>2720-2350</td>
</tr>
<tr>
<td>990/990, Layer 8, spit 4</td>
<td>nutshell</td>
<td>NZA 3729</td>
<td>2452±67</td>
<td>2720-2350</td>
<td>2720-2350</td>
</tr>
<tr>
<td>1001/999, Layer 11</td>
<td>nutshell</td>
<td>Beta 72139</td>
<td>1100±60</td>
<td>1180-920</td>
<td>1150-910</td>
</tr>
</tbody>
</table>

The dates summarised in Table 6.1 confirm the chronological sequence apparent in the stratigraphy. Moreover, radiocarbon and calibrated dates from the upper part of Layer 6 (1000/1000 pit) correspond with the widely expected date for the W-K2 event (Machida et al. 1996; Pavlides 2006; Torrence 2002a, 2004a; Torrence et al. 2000) indicating that the occupation of FAO was directly interrupted by the devastating volcanic eruption.
6.5 Stratigraphical and Spatial Distribution of Obsidian Artefact at FAO

The density of obsidian artefacts within the buried stratigraphic layers at FAO varies and indicates some differences in discard behaviour and activities of inhabitants in each of the two chronological period of occupation which are the subject of my investigation. My physical examination of 3,340 artefacts includes 2,043 specimens (61 percent of the total collection) from the middle Holocene deposit and 1,297 specimens (39 percent of the total collection) related to the late Holocene deposit. Artefacts are unevenly distributed within each excavated unit with marked differences between spits. This indicates variations in the accumulation of cultural material over time in both middle and late Holocene periods (Table 6.1).

6.6 Layer 6 (Middle Holocene Period)

Only two excavation units (1000/1000 and 970/1000) present the full depth profile of obsidian artefact distribution in the middle Holocene deposit because other test pits were excavated to only 20 cm below the W-K2 tephra deposit (Torrence 1993:5; Torrence and Webb 1992:6-7). Both 1000/1000 and 970/1000 show two distinctive concentrations of artefacts within their distribution throughout Layer 6 (Table 6.2). One concentration is observed in the lower part of the deposit: spit 4 in 1000/1000 and spits 3 and 4 in 970/1000 (Table 6.1). The second occurrence of increased density of artefacts is found in the upper part of the deposit excavated by spit 1 (Table 6.2). This pattern of distribution of discarded artefact throughout the stratigraphic profile of Layer 6 in two test pits indicates that FAO was sporadically and repeatedly occupied by humans during the middle Holocene (Lentfer and Torrence 2007:100).

The excavation of the twenty (20) test pits occurred within an irregular-shaped area which extended some 90 metres from north to south and about 40 metres across from east to west (Figures 6.1 and 6.2). Torrence (1993:5) noted that obsidian artefacts in the middle Holocene deposits at FAO were spatially more evenly spread over the hill although there was a slight tendency for them to be more abundant at the highest elevation. A high percentage of artefacts in all excavated units (58.6 percent of the total of 2,043 artefacts) occurred in the top 10 cm (spit 1) directly beneath the W-K2 ashfall (Torrence and Webb 1992:7). There are three areas of the site that show obvious concentrations of artefacts at this level.
The first concentration is marked by a thick layer (20 cm in depth) of obsidian waste in 1000/1010 test pit which is located about 10 metres to the north of the centre of the site. The technological analysis of flaked debris provided evidence that this area of the site was used during the last stage of occupation prior to the W-K2 eruption as a workshop for the knapping and manufacture of obsidian artefacts (Symons 2001:56-82; Torrence 1993:5). The second concentration of finds is revealed in 1000/1000 pit which is considered as the central part of the site (Torrence and Webb 1992:6-7). Finally, numerous artefacts were found in 970/1000 test pit that has been interpreted as a refuse area or dumping ground (Torrence 1993:5). This test pit is situated on the edge of the relatively flat terrace of the hill, about 30 metres west of the central 1000/1000 pit.

The distribution of artefacts throughout the middle Holocene stratigraphic profile at FAO clearly indicates some variations in human behaviour and intensity of occupation over time. Moreover, the spatial pattern of discarded artefacts observed in the upper part of Layer 6 provides some information about the intra-site structure through indications of spatially organised activity areas used by the inhabitants who occupied the site in the period that immediately preceded the W-K2 eruption.

6.7 Layer 8 (Late Holocene Period)

Artefacts from the late Holocene deposit, in Layer 8, are relatively evenly distributed within stratigraphic profile in each excavated test pit, although it has been noted by Torrence (1993:5) that obsidian artefacts and sherds of pottery occur less frequently on the east and south sides of the hill throughout the stratigraphic profile (Gilkes 1993, Torrence 1993:5).

Layer 8 comprises the lower, middle and upper parts of the late Holocene deposit which was excavated by spits 3, 2, and 1 respectively (Torrence 1993:5; Torrence and Webb 1992:6-7). The density of stone artefacts in the lower part of Layer 8 (spit 3), the first depositional material following the W-K2 eruption, is significantly less than the numerous finds in the upper part of the middle Holocene deposit terminated by the W-K2 ashfall: 396 artefacts from Layer 8, spit 3 versus 1198 artefacts from Layer 6, spit 1 (Table 6.2). The presence of artefacts immediately below the W-K2 tephra (spit 1 of Layer 6) and their virtual absence from spit 4 of Layer 8, the first 10 cm of depositional material following the eruption, clearly suggests that the site was occupied before the event and abandoned after it. The distribution of obsidian artefacts in the middle and
upper parts of Layer 8 indicates their slightly increasing number over time: 434 finds are recovered by spit 2 and 427 finds are excavated by spit 1 (Table 6.2).

The lower part of Layer 8 indicates an obvious concentration of artefacts in 970/1000 pit which has been interpreted as a dumping ground (Torrence 1993:5). A number of artefacts were also recovered from the centre of the site: four square metres excavated by 1000/1000, 1001/1000, 1000/999 and 1001/999 pits (Table 6.2). The middle part of Layer 8 reflects some changes in the pattern of artefact distribution: the density of finds essentially increases in the northern (989/1010 pit) and southern (990/990 pit) parts of the site and the number of artefacts in the refuse area drops dramatically from 199 to 54 (Table 6.2). This trend in the distribution of discarded artefacts continues in the upper part of Layer 8 indicating a gradual spatial reorganisation of activities from the central part of the site to the southern and northern edges of the hill. Moreover, the refuse area identified by 970/1000 pit apparently stopped being used: only 32 artefacts are found at this level (Table 6.2).

The comparison of the distributional patterns of artefacts within the late Holocene stratigraphic profile at the site shows that the density of artefacts within the lower, middle and upper parts of the deposit is generally low and relatively equal and that this is probably the result of a similar intensity of use of the site over time. Spatial patterns of discarded artefacts within each stratigraphic part, however, reveal some changes associated with the relocation of activities from the central part of the site at the beginning of occupation to the southern and northern parts of the habitation area in the late period. These changes indicate that FAO was repeatedly re-used during the late Holocene.

Previous general examination of patterns of artefact discards, together with phytoliths and starch analyses of sediments and residues on the tools, allowed the proposal that FAO was a domestic or consumption site during both middle and Holocene periods of occupation (Fullagar 1992; Therin et al. 1999; Torrence et al. 2000). This suggests that the site had been generally used in a similar way and with similar intensity in both chronological periods. This is supported by my detailed analysis of the spatial distribution of artefacts within each stratigraphic unit (Table 6.2). During both the middle and late Holocene, the site was repeatedly re-occupied for a relatively prolonged period of time reflecting similar strategies in settlement patterns.
6.8 Summary

The excavation strategy at FAO involving a number of 1 metre × 1 metre test pits located at 10-metre intervals did not produce sufficient data for a comprehensive study and interpretation of FAO. Large open area excavation of the site would be required for a more complete picture of past human activity to emerge. However, well defined stratigraphic and chronological sequences of cultural deposits sealed by the tephra layers and the abundance of obsidian artefacts with an uneven spatial and temporal distribution allow the examination of some aspects of human behaviour at the site over time. Applying the use-wear/residue methods of study on the numerous obsidian artefacts found at FAO provides the opportunity for the identification of actual tools and their relationship with the structure and spatial organisation of activities undertaken by site's inhabitants, their strategies of exploitation of available resources, and the degree of mobility during the middle and late Holocene periods of occupation on FAO and Garua Island.

The interpretation of FAO as a consumption site (Fullagar 1992; Therin et al. 1999; Torrence et. al. 2000) assumes that a wide range of activities were undertaken by the inhabitants of the site. In order to test these assumptions about middle and late Holocene activities and settlement patterns at FAO particularly, and Garua Island generally, I have conducted a detailed use-wear/residue analysis of numerous obsidian artefacts in conjunction with a description of their morphological and technological features as these are related to the patterns of use. Chapter 7 presents the results of these analyses.
Chapter 7

Middle and Late Holocene Tool Assemblages at the Site: Results of Functional Analysis.

7.1 Introduction

The functional study of obsidian artefacts from FAO builds knowledge essential for the reconstruction of, firstly, the range of activities undertaken by its middle and late Holocene inhabitants and, secondly, the relationship between human activities on Garua Island and the resources available within the surrounding landscape. It is possible through the identification of tool function to obtain data on the resources that were used and manipulated in each particular chronological period. Moreover, evidence for the actual use of prehistoric artefacts provides important information about the strategy of tool selection based on the technological and morphological attributes of those tools (e.g. flakes, blades or formal tools, their size and their shape). Actual tools with their specific technological and morphological features are significant for considering the degree to which assemblages were curated or expedient as a way of investigating settlement patterns and mobility (Torrence 1992; Torrence et al. 2000).

The purpose of this chapter is to investigate the patterns of wear on prehistoric obsidian tools and to determine their function using methodological approaches outlined in Chapter 3 together with the experimental data presented in Chapter 4. To achieve this, 563 middle Holocene artefacts and 832 late Holocene artefacts, recovered from seven test pits at FAO, were microscopically examined. The microscopic analysis followed four major strategies: (1) separating used artefacts from unused samples, (2) examining wear characteristics on used artefacts, (3) describing residues on the tools, and (4) comparing my experimental results with the observed wear on artefacts. This four-fold approach provides the basis for assessment and verification of the function of actual tools and their association with the particular use-material and mode of use.

The study of wear patterns observed on tools from FAO was enhanced by comparative data obtained through microscopic examination of obsidian artefacts from three additional regions. These include 148 Late Holocene artefacts from the Makue site on Aore Island, Vanuatu, dated to about 3,000 years ago (Galipaud and Kelly 2007; Kononenko and Fullagar 2006); 29 artefacts from the Zara site, Primorye region, Russia, dated between 3,700 and 3,300 BP (Cassidy and Kononenko 2006); and 98 microblades, cores and tools from the Hopyeong-dong Upper Paleolithic site Korea,
dated between 24,000 and 16,000 years ago (Hong and Kononenko 2005). These data allow the examination of the extent to which differences in natural environments and time periods influence the preservation of wear variables and residues on obsidian artefacts and, as a consequence, the reliability of use-wear/residue analysis for the study of lithic assemblages.

In the first part of this chapter, I describe the strategies of sampling and organisation of functional and related morphological data obtained through analysis and then I characterise the surface preservation of obsidian artefacts from different chronological periods. Next, the range of identified tools at FAO used to process a variety of plant and non-plant materials during both middle and late Holocene periods is summarised. Finally, similarities and differences in functional and morphological characteristics of tools and their relationships with particular activities at the site in each chronological period are discussed.

7.2 Sampling Strategy

Obsidian artefacts were found in all of the 20 excavated units at FAO. In this project 3,340 specimens were physically examined by me (Table 6.2). The number does not include numerous flakes from test pit 1000/1010 that are associated with a "workshop" for the knapping and manufacture of obsidian artefacts (Symons 2001:56-82; 2003; Torrence 1993:5). This material is now being analysed by Pip Rath and is temporarily unavailable. Also, some artefacts have not been included in my analysis because they are being used for PIXE-PIGME analysis.

Use-wear/residue analysis was conducted with all of the artefacts (1,395 specimens) found within seven test pits: 1000/1000, 1000/999, 1001/1000, 1001/999, 990/1000, 980/1000 and 970/1000. Test pits are located 10 metres from each other in a grid extending from the centre of the site to the west end of the terrace (Figure 6.2). Of the total of 1,395 artefacts found in these pits, 832 (or 59.6 percent) belong to the middle Holocene period, and 563 (or 40.4 percent) to the late Holocene period.

The stone assemblage at FAO is generally characterized by flake technology. Morphologically and technologically, there are only a few well defined classes of artefacts, such as stemmed tools, retouched flakes and blades, which are associated with the middle Holocene period. Late Holocene artefacts at the site are mostly represented by flakes and, rarely, cores (Torrence 2002a). In this project all of the examined artefacts were initially grouped into categories according to their morphological
The main criteria used to distinguish cores from flakes are that cores have one or more negative flake scars while flakes have one or more positive conchoidal flake scars (Hiscock 2007). Flakes and blade-like flakes were divided into groups according to their size: (1) microflakes (less than 1×1×0.1 cm); (2) small flakes (1×2×0.1-0.3 cm); (3) medium flakes (2×3×0.1-0.5 cm); (4) and large flakes (more than 4×3×0.3-0.5 cm).

The first stage of my analysis mainly focussed on flakes with macroscopic scars and retouched flakes. They were initially selected for use-wear/residue analysis because I assumed that retouch and/or the macroscopic scars on the surface of obsidian flakes might potentially relate to their use. However, it should be stressed, that the definition of "retouched flakes" and "flakes with macroscopic scars" is complicated. In many cases there are no reliable criteria to distinguish morphological features of intentional retouch from scars which might result from the use, non-use edge damage, or as micro-components of deliberate retouch (Boot 1987; Hiscock 1985, 2004; Hiscock and Clarkson 2000; Hurcombe 1992:10; Kamminga 1982:4; Keeley 1980:24; McBrearty et al. 1998; Vaughan 1985:11-12). Hiscock (2007) suggests that the interpretation of scars may rely on the features of the last surface of the flake: if this surface is a positive scar then the artefact is an unretouched flake. Retouched flakes are those from which further flakes have been struck (Hiscock and Attenbrow 2005:34). Both retouch (and pseudo-retouch) and scars might appear on the brittle obsidian surface as a result of use, manufacturing or post-depositional effect. From the morphological point of view, edge damage caused by these factors often has some similarities. Use-wear analysis in many respects, however, may differentiate non-wear damage from those created by use on the basis of striations and light polish observed within the negative surface of scars or their intersections (e.g. Plates 147B, 151A and 154A).

In this project retouched flakes are defined as flakes with continuous, relatively regular (in shape and size) macroscopic negative of scars patterned along the edges (Hiscock and Attenbrow 2005:32-34). There are only two flakes in the late Holocene assemblage that can be considered as retouched flakes: M325 (Figure 7.6: 1) and M1921 (Figure 7.9: 5). Both tools were probably intentionally re-sharpened by retouch during the use. Middle Holocene artefacts include five retouched stemmed tools (Figures 7.6: 2; 7.10: 2 and 7.12: 5). Intentionally retouched flakes were not found within the samples examined (Table 7.17).
Flakes with scars are defined as flakes with visible small chips or micro-chips on the ventral or dorsal, or both, surfaces. The random distribution, irregular shape and size of these scars often corresponded with use-wear traces (e.g. Plates 171A, 172C and 176A). Most of the used obsidian artefacts at FAO have scars of small to medium size which are visible to the naked eye. But micro-scars, which can only be observed under magnification, are also very common, particularly on more acute-angled edges. Different types of scars on artefacts and their distribution on the working edge were examined in my study and were compared with experimental data in order to verify their relationship with use-material, use-action and use-duration.

Before the next stage of my study, involving all stone artefacts from seven excavated pits, it is necessary to describe the procedures undertaken to prepare the specimens for examination under both low and high power microscopes.

### 7.3 Preparation Procedures

The sequence of procedures for preparing artefacts for use-wear/residue study was largely determined by the way the artefacts were handled in the field. Most of the artefacts were washed in the field but some samples were carefully collected for organic residue studies (Barton et al. 1998) during excavation and were not washed. The washed and unwashed artefacts required different treatment before analytical procedures were undertaken.

Before microscopic examination, surfaces of washed artefacts were lightly swabbed with alcohol in order to remove remains of grease from recent handling and other loosely adhering contaminants like dust. Next, all surfaces of the sample were scanned under a stereomicroscope with low magnification and an external light. At this stage certain features such as scars, surface alteration, visible residues and the most developed wear, were noted on a prepared recording sheet (Figure 3.1). Then, the tool was set aside for further analysis under higher magnification using a metallographic microscope with vertical incident lighting, brightfield/darkfield and polarizing filters. Those artefacts not exhibiting signs of use-wear were also recorded and were scanned under the high power microscope for residues. If artefacts without use-wear indicated the presence of any residues, these were recorded photographically, and sometimes samples were extracted and mounted on microscope slides for further investigation.

More complicated preparation procedures were involved for non-washed artefacts. For a residue study, it is important to preserve the diagnostic structure of residues on the
tool surface. This requires that initial observations of the artefact make note of the presence of residues before they are be extracted and prior to any cleaning procedure (Fullagar 2006a:213).

All non-washed artefacts were processed using a technique developed by Fullagar (2006b; Loy and Fullagar 2006). Non-washed specimens were slightly cleaned by a soft, dry nylon brush in order to remove loosely adhering, thin, sandy films and soils from the surface. Sometimes the artefact was gently rubbed inside a plastic bag to remove thick blocky lumps of sediment. The sediments were then bagged separately for further analysis. After this preparation, each artefact was drawn, and the surface was scanned under both low power and high power microscopes to locate residues. Starch and needle-like residues were sometimes visible directly on artefact surfaces under a high power microscope with reflected light. However, detailed analysis of these residues requires the removal of small samples of residue from the artefact surface by peels or pipette extraction (Barton et al. 1998; Kealhofer et al. 1999; Fullagar 2006b).

In this project both peels and pipette extraction were used for sampling of the residues from the recorded location on the surface of artefacts. Peels taken from the surface of the tool were useful in the study of use-wear especially when the large size of an artefact did not allow its analysis directly under the metallographic microscope. The material used for peels was a two-part compound called “Polyvinyl-siloxane” (PVS) often used by dentists to take tooth impressions. A small amount of the mixed components was applied to the surface or the edge of the artefact. After 5-7 minutes, peels about one centimetre square and a few millimetres thick were removed and placed in a clean plastic bag with a separate label. These peels are easy to mount on the stage of a reflected light microscope for further analysis of both use-wear and residues.

Peels were taken from each non-washed artefact at the locations where any concentration of residues was noted during preliminary microscopic observation of surfaces. These locations were recorded on drawings. The peels were then scanned by Dr. Parr at 200× magnification for phytoliths, starch grains and other microfossils and these data were used to interpret tool function.

Because an identification of starch and phytoliths residues requires the use of a transmitted light microscope, the best way to sample is by pipette extraction (Barton et al. 1998; Kealhofer et al. 1999; Fullagar 2006b). To achieve this, about 10-20 microlitres of purified water were delivered by a nylon-tipped pipette onto the previously recorded location of residues on the artefact. Then, the residues were agitated with the nylon tip and the liquid was drawn back into the tip. The solution was then
transferred to a microscope glass slide. When the water evaporated from the glass slide, the dried sample was then sealed with a glass cover slip, and purified water was added for transmitted light microscopy.

After initial observation and pipette extraction, further residue and sediment removal from selected artefacts was undertaken in the laboratory. To do this, each artefact was placed into a separate clean plastic container, and purified water was added to just cover particular surfaces (or, in some cases, the entire artefact). The container was then suspended for between 30 and 60 seconds (depending on the amount of sediment adhering to the surface) in an Ultrasonic bath to remove residue by sonication. The artefact then was removed from the container, air dried and placed in a clean, labelled, plastic bag. The remaining residue-containing solution was poured and washed from the container into a 50 ml centrifuge tube and spun at 1500 rpm for 5 minutes. After all the procedures related to residue extraction and sonic washing, the tool edges were additionally cleaned with alcohol prior to scanning for use-wear analysis.

Similar procedures were used for the preparation of experimental tools. They were initially scanned for use-wear/residue before cleaning and all features of residue and wear were recorded on a recording sheet and by digital images (e.g. Plates 3A, 5A,). Each sample was then washed in an Ultrasonic bath, air dried and additionally cleaned with alcohol before microscopic examination for use-wear. Solutions with residue were stored in centrifuge tubes for further analysis.

7.4 Data Systematisation

Use-wear/residue information obtained from obsidian tools and their morphological features are organised in the functional classifications made for each studied test pit (Tables 7.1 – 7.11). The morphological attributes of the artefacts, which I predicted as being significant for the performance of particular tasks, are presented in the first half of the functional classifications (e.g. Table 7.1:A-H). The second part of the classification (e.g. Table 7.1:I-S) presents the characteristics of wear variables determined on artefacts and their function. Each table includes the following data:

A – Catalogue number of the artefact.
B – Number of the excavated spit indicating the position of the artefact within the stratigraphic layer.
C – Tool type: flake, blade-like flake, stemmed artefact and core.
D – Size of tools: large, medium or small.
E – Shape of the edge: irregular, straight, concave and convex. In the case of a tool having two edges they are distinguished as edge a, edge b and edge c. The relationship between the shape of the edge and the function of a tool may be considered as a very general trend because any used edge on an artefact is modified to a different degree by the particular worked material and mode of use.

F – Edge angle of artefacts was classified based on the measurement of the edges which had been modified by use: 1 – very thin; less than 15°; 2 – medium: between 15° and 55°; and 3 – thick, more than 55°.

G – Cortex ("present" or "absent") on the surface of tools which is indicative of technological choice and preference for flakes for the performance of particular functions.

H – Surface preservation (low pitted, medium pitted, heavy pitted) which is an important factor in indicating the relationship between the degree of surface alteration and the level of confidence in the identification of wear patterns on prehistoric artefacts.

The second part of the table lists the use-wear variables that are the main criteria for the functional interpretation of prehistoric artefacts:

I – Scar type: bending; feather; step; continuous and discontinuous.

J – Striations: parallel; diagonal; perpendicular; crossed; dense; or isolated (a – edge a, b – edge b).

K – Edge rounding: slight; medium; and intensive (a – edge a; b – edge b).

L – Polish development: very light; light; developed; and well developed.

Columns M to S describe phenomena that are interrelated. A combination of wear variables provides the data for the identification of the mode of use (M, a – edge a; b – edge b) and the material worked (N). The level of confidence (O) in the assessment of a tool function is determined as definite use (d), probable use (p) and uncertain use (u). The duration of tool use (P) is measured on the basis of wear characteristics observed on artefacts and experimental data and is graded as short-term, moderate, and long-term. The hafting pattern, if observed, is also recorded in this column: wood handle or wrapped. Residue types (Q) found on the working edges include plant and animal tissue, starch granules, needle-like residues, phytoliths, white and black residues, resin, blood and blood-like residues. Residues on some artefacts were identified by specialists and this is indicated as: B (Barton et al. 1998), F (Fullagar, personal comm.), K (Kealhofer et al. 1998), P (Parr, personal comm.). Wear patterns observed on prehistoric
tools are documented by references to the plates (R). The pattern of wear on experimental tools is also presented by plates (S).

The association of tools with material worked for each test pit is represented by Tables 7.12 and 7.13. The relationship between the material worked and the mode of use of tools within each chronological period is described in Tables 7.14 and 7.15. In addition, technological and morphological characteristics of tools used for the working of a variety of materials and the duration of their use are presented in Tables 7.16 and 7.17. These tables provide the basis for the summary in Table 7.18.

7.5 Surface Preservation

Variation in the properties of obsidian, even from a single source, may affect wear characteristics and patterns of modification, including the degree to which an artefact microflakes, striates, polishes, abrades and absorbs amino acid (Hurcombe 1992:24; Schiffer 1979:17). Obsidian from the Talasea region on the Willaumez Peninsula, West New Britain, is composed mainly of silica, is homogeneous and relatively isotopic, and is excellent for flaking. However, the homogeneity of blocks, boulders and cobbles at the Talasea sources depends upon the number of air bubbles, density of small phenocrysts and thin fractured layers included within them (Specht et al. 1988; Torrence et al. 1992). Our knapping experiments showed that these inclusions may affect the predictability of fracture paths during flaking and may cause unexpected breakage of tools during their use. Some broken artefacts with wear traces found at FAO (e.g. Table 7.2) may support this observation.

Freshly flaked surfaces of obsidian from Talasea sources are very smooth and bright but usually contain crystalline irregularities created by crystals within the amorphous silica, ripple marks and stress fissures (Plates 260C-D and 262). These features are clearly visible on prehistoric artefacts from both rhyolithic and basaltic obsidian (Plates 261B, 290A-D and 300A, E) and can be easily distinguished from wear or damage traces their characteristic shape and direction.

In relation to use-wear analysis of prehistoric obsidian artefacts, there are two major problems which are associated with physical damage and chemical alteration of the surfaces. Physical damage on the edge and the surface of obsidian artefacts is the most common and visible feature. This often makes it difficult to distinguish non-use wear scars, abrasion and striations which occurred as a result of post-depositional damage or manufacture, from those produced by human use. In order to assess the
damage and modification of obsidian surfaces due to non-use factors, three criteria were involved in this project: (1) the distribution and shape of edge scarring; (2) the comparison of the surface with the flaked surface within scars; and (3) the abrasion and striation patterns on the surface.

Depositional edge damage on flakes at FAO is usually characterised by the sporadic distribution of scars as well as their irregular shape and size. Often irregular and step scars are associated with the crushed edge reflecting a random impact on the surface. Some damaged edges have very fresh flaked surfaces that clearly contrast with other parts of the artefact surface because of the intensity of smoothing and brightness (Plates 264-266 and 271-272). Most such fresh scars on the obsidian artefacts have occurred recently, perhaps due to recovery, transportation, bagging and storage (Plates 275B-F, 290E-F and 300C). Unintentional abrasion and striations which appear on the surface as a consequence of natural or post-depositional factors normally are not patterned in their distribution and are clearly visible (Plates 262B, 267A, 290A and 300A). Sometimes, however, if they are distributed close to the edge (Plate 266), they may mask some use-wear variables (e.g. striations or polish).

Chemical alteration of obsidian surfaces, in the form of numerous, roughly hemispherical pits which are unequally distributed on the surface, was observed on all artefacts from FAO (Plates 262A and 267-269). In some cases, the flaked surface of obsidian exhibits flowing aspects (Plate 263). Similar damage can be observed on both rhyolitic (Plates 275, 290 and 297) and basaltic (Plates 300A-C) obsidian from other geological sources. This indicates that some natural combination of chemicals has etched the original flaked surface over time, although the degree and speed of these processes varies and depends on many environmental factors including local climate and soil formation processes.

The acidity of the ground conditions causes etching of obsidian surfaces. My experiments demonstrate that the traces of initial chemical damage can occur on the surface relatively quickly and be observed in only 22 months (Plate 125). As a result of the chemical damage, use-wear features on the working edge can be destroyed or greatly altered. Experiments conducted by Hurcombe (1992:81) demonstrate that some sleek striations can be altered to intermittent form, and, crescent cracks widened to crescent-shaped depressions and, sometimes, the intermittent striations can become oval depressions. In contrast, pits resulting from use-wear are arranged in lines and may indicate the direction of etched striations and may assist in the functional definition of the tool.
My analysis of obsidian tools from FAO supports the observation by Fullagar (Kealhofer et al. 1999) that some artefacts with heavily altered surfaces have edges with well preserved and distinctive use-wear characteristics (Plates 158, 188, 201, 204, 212, 217 and 219). This may be explained by the nature, distribution and preservation of residues. My experiments demonstrate that a dense deposition of residues is often trapped and compacted into microfractures, small cavities and depressions of the natural obsidian surface (Plates 3A, 23C, 29A, 40A, 51A, 78A, 85A, 88A, 89, 94B, 100A, 105B and 115A). Firstly, the residues are protected from intensive movement and alteration of the tool so that they were difficult to remove by cleaning procedures. Secondly, residues which were attached and embedded into the surface could act as mechanisms providing protection against chemical etching. These suggestions are supported by some prehistoric artefacts with embedded and preserved residues at FAO (Plates 224B, 225B, 245, 247, 249, 257F, 259B and 274), Makue (Plates 286B and 287D), Zara (Plate 300F) and Hopyeong-dong (Plate 297).

Although the degree of chemical damage may vary on each artefact, there is a general relationship between degree of surface alteration and age. The absence of preserved organic material throughout the stratigraphic sequence at FAO suggests that the soils were strongly acidic. The surfaces of most late Holocene tools (77.3 percent) are low pitted (e.g. Plates 147 and 150) and about 16 percent of tools are medium pitted (e.g. Plate 169), although there are some tools (6.8 percent) with heavily pitted surfaces (e.g. Plate 256). In contrast, tools with heavy (43.6 percent) and medium (37.6 percent) pitted surfaces dominate in the middle Holocene (e.g. Plates 158, 159 and 225, 229 accordingly). It should also be stressed that there is a relatively high percentage (18.8) of tools with low pitted surfaces (e.g. Plates 221 and 222; Tables 7.7-7.11) in this chronological period. These data obtained from FAO indicate that the surface alteration may act as an additional chronological indicator for stone assemblages found in similar environmental conditions such as elsewhere on Garua Island and in the Talasea region.

In contrast, the surfaces of middle Holocene tools from the Makue site, Vanuatu are mostly low pitted (e.g. Plates 278 and 279) and this has resulted in well preserved wear patterns comparable with middle Holocene tools from FAO site. On the other hand, most obsidian microblades and tools from the Hopyeong-dong Upper Paleolithic site in Korea, dated between 24,000 and 16,000 years ago, are also characterised by a low degree of chemical damage (e.g. Plates 290-295 and 298). The artefacts from Vanuatu and Korea were much better preserved because of depositional factors and hence use-wear on the surface of obsidian tools is able to be more easily identified.
Wear patterns on some of these tools were used in this project as an analogy for the verification of data obtained from middle and late Holocene tools at FAO site. Similarly, some use-wear data on tools made of basaltic obsidian (the Zara Late Neolithic site, Russia) were used in my comparative study of wear variables on obsidian raw material.

In addition to the physical and chemical damage, weathering processes contribute to the surface alteration of obsidian artefacts. A combination of these factors affected the use-wear/residue features to some extent. Sometimes the surface may be so greatly altered as to render any use-wear definition impossible (Table 7.2). Fortunately, since the number of artefacts with completely altered surface is relatively small at FAO, productive use-wear/residue studies can be made.

In the following part of this chapter, I outline the range of use-wear and residue patterns recognised on the middle and late Holocene tools. Following the carrying out of the experimental program discussed in Chapter 4, the prehistoric artefacts with wear patterns are grouped according to their association with categories of worked materials which include: (1) siliceous soft wood, palms and bamboo; (2) siliceous hard wood and hard palms; (3) non-siliceous soft wood; (4) non-siliceous hard wood, (5) non-woody plants including greens and tubers; (6) soft elastic materials (skin, fish); (7) dense, hard materials (shell, clay). Within each use-material category, the types of use actions and the suggested duration of use are presented with characteristics of the main forms of wear variables including scarring, striations, rounding, polish and residues (e.g. Table 7.1).

7.6 FAO Late Holocene Assemblage

From a total of 563 artefacts recorded from the stratigraphic level between the W-K2 and Dk tephras within seven test pits under study, 88 tools (16.0 percent of the total artefacts) were identified. The largest number of artefacts was recovered from the 970/1000 test pit which also contains most of the tools (54). Four square metres located at the centre of the site (1000/1000, 1001/1000, 1000/999 and 1001/999 test pits) produced 19 tools which were mainly concentrated within the 1000/1000 and 1001/999 pits (Figure 6.2, Table 7.18). Of the 15 artefacts from 1001/1000, no tools were identified.

According to the use-wear data generated (Table 7.18), most Late Holocene tools were used to process siliceous soft wood, palm and bamboo (35 artefacts or 39.8
percent) and the rest were involved in processing non-siliceous soft wood (20 artefacts or 22.7 percent) and non-woody plants (17 artefacts or 19.3 percent) including tubers (11 artefacts) and greens (6 artefacts). A relatively high percentage of tools (8 artefacts or 9.1 percent) were used in the working of soft elastic material such as skin (5 artefacts) and gutting/cutting fish (3 artefacts). A small number of woodworking tools were used on hard siliceous (3 artefacts) and non-siliceous (3 artefacts) wood and palms. A single tool was used for sawing shell.

7.6.1 Siliceous Soft Wood, Palm and Bamboo

Artefacts used for processing siliceous soft wood, palm and bamboo at FAO are mainly represented by medium and small flakes with straight or irregular edges in plan view and edge angles between 15° and 55° (Figure 7.1). There are 6 small flakes with thin, (less than 15°) edge and 7 large and medium flakes that have an edge angle of more than 55°. Some tools are characterised by convex (5 artefacts) or concave (3 artefacts) edge profiles. Twelve tools have cortical surfaces (Tables 7.1-7.6). Of the total of 35 artefacts involved in this activity, 9 have two working edges and one large flake with four working edges was intensively used (Figure 7.1: 8; Plate 155).

The mode of use indicates the preference for scraping (10.2 percent), whittling (8.0 percent), sawing (4.5 percent) and whittling/sawing (4.5 percent) actions in the processing of siliceous soft wood, palm and bamboo (Table 7.14). My experimental results show that straight, irregular, concave and convex profiles of edges are equally effective in the performance of sawing and whittling actions, although straight and irregular edges are more convenient for sawing and whittling. One exhausted core was used for scraping and three tools were broken during use.

This group of tools are characterised by relatively intensive edge damage consisting of small and medium scars (Plates 147, 148 and 151). As a result, medium and intensive edge rounding, as well as developed and well developed polish, has a patchy distribution along the working edge. Usually patches of polish are located at the intersection of micro-scars and at the higher peaks of surface topography along the edge (Plates 148B, 148D, 150, 153A and 54B). Well defined striations on the surface are common and dense and are often observed within scars (Plates 147A, 148C, 149, 150B, 151, 153A, 152B, 155A-B, 156 and 157).

Within this category, the sawing mode of use on artefacts is represented by small and medium scars with bending and feather terminations continuously or, rarely,
discontinuously distributed along the edge (Plates 147 and 151A). Dense striations are parallel to the edge and extend from the higher peaks down to the lower surface and sometimes spread inside the micro-scars (Plates 147A, 151A and 155A-B). Smoothed polish is generally found on the best preserved edge areas (Plate 151B). This polish does not extend from the highest peaks into the surface depressions and it is usually more widespread on one side of the edge than on the other.

**The scraping motion** results in mostly stepped and bending scar terminations that have a continuous distribution along the edge, but are usually restricted to one surface. The scars vary from very small to medium in size (Plates 148A). The scraping motion is associated with perpendicular and sometimes diagonal striations (Plates 148C and 154A-B). Sometimes scraping motion is also indicated by flaked striations (Plate 148C). A few patches of well developed polishes on the edges may be observed (Plate 148D).

**Whittling actions** on artefacts is characterised by both continuous and discontinuous bending and feather scars which are oriented slightly diagonal to the edge and generally restricted to one face of the tool (Plates 150 and 152). Edge rounding varies from light to intensive and has a patchy distribution along the edge and dense striations are mainly diagonally oriented (Plates 150B and 152). Because of intensive edge damage, a few patches of developed and well developed polishes are usually preserved (Plate 150C).

A combination of wear patterns reflecting two or more modes of use (whittling/sawing, scraping/whittling, scraping/sawing, cutting/whittling) were found on a single tool with two working edges (Plates 147A-B) or on the same edge of the tool (Plates 149 and 155A-C). There is one large flake (Figure 7.1: 8) with four working edges which were intensively used for whittling/sawing siliceous plants. In addition to well determined wear patterns, some parts of the working edges preserve resin-like residues (Plates 155A-B). These residues, and their distribution are possibly related to the working of resinous plants, such as breadfruit (*Artocarpus altilis*) or *Calophyllum*, which were widely used for various activities including the procurement of hafting resin (e.g. Parr 2006; Robertson 2005:69). Another interesting aspect of this particular tool is a very high percentage of palm phytolyths which were probably associated with the wrapping of the tool in palm leaves during use (Kealhofer *et al.* 1999:544). The hafting area of this tool also includes some spots with striations, tissue and starch residues (Plates 155E-F) which were possibly related to the wrapping of the tool.
Pointed ends of a few flakes were used for carving items by cutting motions, as in the use of a burin with occasional whittling, scraping or sawing actions (Figure 7.1; Plates 156A-B). One large, pointed flake with an irregular longitudinal profile indicates a rotational mode of use which is associated with drilling (Plates 157A-D).

The working edge of tools involved in processing siliceous soft wood, palm and bamboo often preserved tissue (Plates 154 and 155), some small starch grains (Plates 153B, 154C and 155F) and white plant residues (Plates 148A and 157C-D).

In summary, the scarring patterns, the intensity of edge rounding, the level of polish development and the patterns of dense sleeks, rough-bottomed and intermittent types of striations observed on this group of late Holocene tools are comparable with my experimental tools which were used for processing highly siliceous soft wood, palm and bamboo.

7.6.2 Siliceous Hard Wood and Hard Palm

There are three large flakes in the assemblage which were used for sawing, scraping and whittling siliceous hard wood and hard palm (Figure 7.8: 1 and 4). The first one has three concave working edges with an edge angle of more than 55°. One edge was used for sawing (Plate 171C) and the other two were involved in scraping actions (Plate 171A). Both irregular and straight edges of the second flake have wear indicative of sawing (Figure 7.8: 1; Plates 170A-C). The working edge of the third flake was used for both sawing (Figure 7.8: 4; Plate 173A) and whittling (Plate 173B) actions.

The most recognisable and frequent wear feature on these tools is intensive edge scarring. Scars are irregular in shape and medium to large in size. Whittling and sawing resulted mainly in bending and feather scars (Plates 171C and 173A-B), whereas scraping produced more step scar terminations (Plate 171A). Continuous scars generally occurred on one side of the edge. This intensive edge damage partly removed other wear features from the working edge, such as striations, rounding and polish. The areas close to the edge are often characterised by light attrition that contrasts against the natural surface of obsidian (Plate 171C). Attrition on obsidian tools occurred more often on hardwood tools as also noted by Hurcombe (1992:41).

In addition to intensive scarring and light attrition, the common trend in wear characteristics for tools used for processing hard wood is the constant occurrence of isolated, rough, intermittent striations in association with prevalent dense, rough
bottomed and sleek striations (Plates 170A, 171C and 173A-B). The peculiarities of striations on the highly fractured edges in association with patches of rounding (Plate 170B) and polish (Plate 170C) are significant indicators for this category of tools. Plant tissue (Plate 171B) and starch grains (Plate 173C) are also common on these tools.

In relation to the assessment of use-duration of these artefacts, I conclude that most were used only for a short time. As emphasised in Chapter 4, the formation of diagnostic wear on experimental tools involved in processing highly siliceous wood, palm and bamboo occurred very quickly. Tools can be most effective during the first 5-15 minutes of use, and after 15 minutes of work, the efficiency of tools usually dropped significantly, although some were relatively efficient for up to 30 minutes. The comparison between wear patterns on artefacts and experimental tools supports the suggestion that the prehistoric tools used to process hard wood were only used for a short amount of time. Exceptions are two artefacts (M1925 and M336) with intensive wear patterns on two or four working edges which may be considered as tools used for a moderate length of time.

7.6.3 Non-Siliceous Soft Wood

A total of 88 late Holocene tools (or 22.7 percent) were involved with the processing of non-siliceous soft wood (Table 7.18). Medium sized flakes with straight or irregularly shaped edges and edge angles between 15° and 55° were mainly used in this activity (Figure 7.4). One tool was broken during use and eight tools have two, three or four working edges. Most flake tools are without cortex.

The dominate mode of use of these tools is associated with whittling actions: 11 artefacts or 12.5 percent (Plates 175 and 182-186; Table 7.14). A few artefacts were used for carving (Plate 179-181) and scraping (Plate 178) activities. There are five artefacts with a single working edge indicating two actions performed by the same edge: scraping/sawing (Plate 174), scraping/whittling (Figure 7.4: 7; Plate 177) and whittling/sawing (Figure 7.4: 5; Plates 172 and 176).

Whittling soft wood resulted in continuous or discontinuous scarring patterns with bending scars or feather terminations (Plate 182, 184 and 185). Small bending, feather and step scars are distributed mainly in a continuous manner on tools used for sawing actions (Plate 176A). Mixed scar patterns with stepped, bending and feather terminations on one side of the edge are common on tools involved in scraping and carving actions (Plate 181A). Due to the relatively intensive edge damage consisting of
many scars, some areas with wear have been destroyed. As a result, edge rounding and polish mostly have a patchy appearance (Plates 174A-B, 175B, 177, 178, 180C, 183 and 187).

In addition to scarring patterns, the mode of use is well demonstrated by the orientation of striations and the polish arrangement. Relatively isolated, long, shallow or deep sleeks as well as rough bottomed and intermittent striations generally have a slightly diagonal orientation due to whittling motions (Plates 175A, 176B and 182-186), are parallel from sawing (Plates 174C and 187) and perpendicular and slightly diagonal resulting from scraping actions (Plates 174A-B and 178). Carving, as a combination of cutting, scraping and whittling motions, demonstrates relatively complicated patterns of distinctive long and deep striations oriented in parallel or slightly diagonal directions (Plates 179-181). Polish does not extend deeply into surface depressions and its distribution is restricted to the highest points of the surface microtopography and the scar intersections (Plates 174B and 175B).

The processing of soft non-siliceous wood resulted in long, mainly deep striations, well separated from each other despite their relatively high frequency of occurrence (e.g.175A, 176B, 179 and 185), in contrast to highly siliceous plants, which usually produced closely-packed, short, deep and shallow striations with dominate rough bottomed types (e.g. Plates 148C, 151A and 155A). This difference in striations on the tools used for siliceous versus non-siliceous soft wood is well supported by my experiments. The experiments also demonstrate that there are some differences in the intensity of edge rounding and polish characteristics which form on tools during the same duration of use in the processing of siliceous or non-siliceous species of plants. Polished areas on tools used for working palm for 5, 15 and 30 minutes are usually very smooth and more intensively flattened than on woodworking implements used for the same time intervals (Plates 9-11 and 38-40). This suggests that the formation of identifiable wear variables on artefacts used for the working of non-siliceous soft wood would probably require slightly longer periods of use: for example, more than 15-20 minutes. Based on the criteria of use-duration defined from the experiments, the woodworking tools at the site were mostly used for short time periods.

7.6.4 Hard Non-Siliceous Wood

There are three flakes of medium size with an edge angle between 15° and 55° and a fourth with more than 55° edge angle and all of these flakes were used for
scraping and scraping/sawing hard non-siliceous wood (Table 7.14). Scraping/sawing actions were performed by flakes with multiple working edges (Tables 7.1-7.2). The tools are characterised by intensive and continuous scarring patterns (Figure 7.7: 1; Plates 197A-B and 199A), patches of pronounced rounding and developed polish (Plates 197C, 198A and 199A) and as well as by well-separated, diagonal (Plates 197A, 198A and 199A-B) and parallel (197B), long and deep striations.

Plant residues are common on woodworking implements. They are represented by tissue and in some cases starch grains (Plates 174D, 197D, 198B and 199B). On a few artefacts unidentified white plant residues were observed (Tables 7.1-7.4).

The fact that the differentiation between woodworking implements used for processing siliceous soft and hard wood, palm and bamboo and those which were used for working non-siliceous soft and hard wood can be made is supported by data from other sites. For example, a similar differentiation in wear patterns is identified on the Lapita tools from the Makue site, Vanuatu (Plates 276-280), the Late Neolithic artefacts from Zara, Russia (Plates 300D-E) and the Upper Paleolithic tools from Hopyeong-dong, Korea (Plates 291-296).

It is important to emphasise that tools from Makue often preserve dense needle-like residues (e.g. Plate 281) in addition to starch grains and other plant tissue. In some cases, needle-like structures extracted from the tool and placed on glass slides disappeared after adding diluted acetic acid (10 percent) probably indicating a calcite composition (Crowther in press). However, on some glass slides needle-like crystals did not dissolve in the acid and changed their appearance (Plates 276C and 280B) probably indicating the presence of raphides (Kononenko and Fullagar 2006). Starch grains did not change after the addition of acetic acid (Plates 282A-B). The association of these residues with use-wear patterns demonstrates that the tools were used for working soft wood, palms and bamboo.

7.6.5 Non-Wood Plants: Tubers and Greens (Leaves, Stems and Grasses)

The processing of non-wood plants was one of the important activities at the site. Seventeen artefacts (or 19.3 percent) were associated with this activity out of a total 88 tools (Table 7.18). Among these 17 tools, 11 (12.5 percent of 88) were used for scraping, cutting and slicing tubers (Figure7.9), as well as and cutting, slicing and, in rare cases, scraping greens (leaves, stems and grasses) (Table 7.14). There was no preference as to flake size: large, medium and small flakes were equally involved in this
activity. An exception is a large flake (Figure 7.9: 5) with four working edges, one of which was resharpened by retouch. This tool had intensive and long-term use for scraping/slicing tubers (Plates 211A-B). There are also five tools with two working edges and one tool with three used edges. The shape of the working edges is generally slightly convex or concave, but irregular and straight edges were also used regularly. Tools with multiple working edges often combine concave, convex and irregular shapes. The edge angle of most tools varies between 15° (7 artefacts) and 55° (6 artefacts). Based on the measurement of edge angle for tools modified by use, it is reasonable to suggest that flakes with more acute edges were preferred for processing tubers and greens.

In contrast to woodworking implements, tools used for cutting, slicing, scraping and peeling relatively soft plants like tubers or greens exhibit small to very small irregular scars. These scars have a discontinuous or, in the case of very intensive use, continuous distribution along the edge. The scars are more numerous on the face (ventral or dorsal) which has had stronger contact with the use material and only occasional scars are found along the edge of the opposite face. Most of the scars are oriented in a perpendicular or slightly diagonal aspect to the edge and have bending and feather terminations (Plates 208, 209, 213 and 226). Scraping actions demonstrate more stepped scars (Plate 210A) which are usually restricted to one face, although a few isolated scars may be observed on the opposite face indicating "forward" and "back" motions during scraping.

The profile of the edges may have slight (Plate 226), medium (Plate 208) or intensive (Plates 209, 211, 213, 214 and 216) rounding indicating short-term, moderate or long-term use of a particular tool. This wear variable is well correlated with polish development: light (Plates 226C), developed (Plate 208B) and well developed (Plates 209D-E, 211B, 213B, F, 214C and 216A-B). In the case of moderate and intensive use, a clearly defined line of relatively merging and continuous polish along the utilised edge is observed. This polish is very distinctive and strongly contrasts with the unused surface (Plates 209B, 211B, 213 and 214).

The polished areas contain a few to a moderate number of slightly diagonal (Plates 208A and 212A), parallel (Plates 213E, 226B and 227A) or, more often, a combination of crossed striations (Plates 209, 211B, 213A-B and 226A, C). Scraping actions usually produce a number of perpendicular striations (Plates 214 and 216). Most striations are clearly separated from each other and are mainly deep and shallow sleeks and intermittent types, although rough bottomed types may be observed as well.
Wear patterns on tools used for working greens (Figure 7.11: 1) have some peculiarities in comparison with those involved in processing tubers. Firstly, there is less intensive edge damage usually in the form of small scars and microscars on tools used on greens. Secondly, for greens a few to a moderate number of striations of shallow, sleek types are prevalent and, much more rarely, rough bottomed or intermittent types may be present. Finally, the surface alteration by polish on tools is less extensive for greens and the polish rarely has a merging appearance (Plate 226). The comparison with experimental tools which were used for scraping/slicing and cutting/slicing coconut meat suggests that some prehistoric artefacts could have been involved in the performance of similar tasks (e.g. Plates 5-6 and 226).

In general, the set of wear variables observed on tools which were used for processing non-woody plants includes: (1) less intensive edge fracturing by small and very small bending and feathered scars; (2) low and moderate density of long, deep and shallow, and well separated striations; (3) medium and intensive edge rounding and (4) developed and well developed merging polishes distributed relatively continuously along the edge. These variables are comparable with my experimental data which also demonstrate that a diagnostic combination of wear variables can form on tools after more than 30 minutes of use. Because most of the tools examined have identifiable wear variables, it is reasonable to propose that they were used for much longer time periods than the woodworking implements. The wear patterns of only three flakes of this category of tools are associated with short-term use, while nine tools indicate moderate use, and five artefacts represent long-term use.

All tools involved in processing tubers have starch grains and plant tissue residues (Plates 208D-F, 209F, 212B and 213D). Of particular interest is a large flake with a slightly concave working edge (Figure 7.9: 3; Table 7.2), that was probably used for scraping/slicing over a relatively long period of time. A number of large starch grains preserved on the surface of the tool were preliminarily identified as yam (Dioscorea) (Kealhofer et al. 1999:543). My microscopic examination of this tool also revealed some needle-like residues on the edge (Plate 210B). In addition, phytoliths of bamboo leaves were found on the surface of this artefact indicating that this tool was possibly wrapped during the performance of tasks (Kealhofer et al. 1999:543). Arboreal phytoliths were also found on tools M313 and M317 (Kealhofer et al. 1999:542) which probably also related to the mode of hafting by wrapping. Tools which were used for working greens also preserved tissue and occasionally starch grains on the working edge.
Similar patterns of wear in association with residues were observed on some tools from Makue, Vanuatu (Plates 283 and 284). Cutting/slicing and scraping/slicing non-woody plants, like tubers, produced visible residues on the surface that include starch grains and needle-like particles (Plates 283B-D). Extracted residues were tested with acetic acid in order to distinguish between needle-like calcite crystals, (soluble in 10 percent acetic acid) and calcium oxalate raphides (insoluble in 10% acetic acid) (Crowther in press). The result clearly indicates the presence of raphides and starch on some tools from this site (Plates 283C and 284B).

7.6.6 Soft Elastic Materials: Skin and Fish

According to my use-wear/residue studies, a relatively small number of flakes (8 samples or 9.1 percent) were involved in processing soft elastic material (Table 7.14). Piercing and cutting skin (5 artefacts) was performed by small and medium flakes with pointed tips (less than 15°) formed by thin, straight or irregular edges (Figure 7.12: 4 and 7). As a result of use, two of these tools have snapped tips.

The piercing action reveals a common pattern of use-wear. The working edge has small scars and microscars which are discontinuously distributed. In some cases, patches of continuous, small scars are observed (Plates 234, 237). The profile of the working edges is medium rounded or relatively intensively rounded (Plates 234A-B and 235A). Developed and merging polish is present as more or less smooth patches along the edge (Plates 235A-D, 236A-B and 237C). Some isolated, deep and shallow sleek striations and, more rarely, rough bottomed and intermittent types are orientated slightly diagonally (Plates 234 and 237) or are perpendicular to the tip (Plates 235 and 236), reflecting penetrating, rotating (Plate 235C) and cutting (Plate 237C) motions. Small numbers of discontinuous scars and a low density of mostly thin and shallow striations in conjunction with smooth merging polish suggest that these tools were used for piercing soft skin, possibly for body tattooing. In this context it is important to emphasise the presence of blood-like residues on two of these tools. These dark-red and black residues (Plates 236B and 237B, D) gave a weak positive reaction to Hemastix (a presumptive blood test) (Loy 1983:1269) indicating the presence of mammal blood. The wear patterns and residues on these artefacts are similar to those of the experimental tools which were used for piercing/cutting chicken skin (e.g. Plates 97-99, 112A and 114A-B).
It is possible to suggest that the tools identified as having been used for piercing and cutting soft skin and which also preserved mammal blood residue could have been involved in the performance of some special tasks related to the human body or soft animal skin. From ethnographic records in West New Britain, Papua New Guinea, it is known that sharp obsidian pieces were used for shaving, blood-letting by skin cutting, trephination, hair cutting, circumcision and for manufacturing personal adornment (Specht 1981).

Additional important information about tools which were related to prehistoric skin processing was obtained through use-wear/residue examination of obsidian artefacts from Makue, Vanuatu and Hopyeong-dong, Korea. Small and medium sized flakes with pointed, thin edges from Makue have many common features of wear patterns with late Holocene tools from FAO (Plates 285-289). Blood residues have been observed on the surface of these tools (Plates 286B and 288). One Makue tool preserved residues of a mixture of blood and a bright red clay-sized mineral like ochre (Plates 287B-D). Of particular interest is black coloured blood residues on one tool used for piercing skin (Plates 285B-C). Microscopic analysis of this blood residue extracted on to a glass slide revealed the red cells with nuclei which are usually associated with non-mammals but similar to those of birds, fish or reptiles (Kononenko and Fullagar 2006). Consequently, I propose that some of these piercing tools could have been used for the manufacture of items from skin derived from turtles, fish or birds.

Similar wear patterns were found on retouched and non-retouched microblades from the Hopyeong-dong site (Plates 297-299). One of the retouched awls (Hong and Kononenko 2005:27-28, Figure 24) preserved dark red residues (Plates 297A-D) which probably also represent a mixture of blood and minerals like ochre. The abrasive nature of ochre may also explain the frequency of long, deep, sleek striations on some tools (Plate 298). On the other hand, some rough intermittent striations, relatively intensive edge damage by scars, and merging polish (Plate 299) observed on a few awls might be associated with the processing of thick skin or hide.

There are three flakes of medium size with edges of angle between 15° and 55° which were used for gutting/cutting fish (Figure 7.13:1-3). These tools have more intensive edge scarring on their straight, irregular or convex edges than with those used for piercing and cutting skin. Scars are mostly feather and bending types, small or very small in size and mainly distributed continuously along the edge (Plate 249). These scars apparently were formed as a result of contact with bone or scale. Usually medium rounded edges (Plates 247A and 259E) preserved patches of smooth, developed polish
which is visible as a thin line on both faces of the edge profile. The polish extended from the higher peaks of the microtopography into surface depressions (Plates 247B, 248C-D and 249C).

Smoothed and polished areas are associated with parallel (Plates 247C) and slightly diagonal striations (Plates 248A-B) which are often accompanied by randomly oriented, intersecting striations (Plates 247A and 249A, D-F). They are mostly represented by isolated, long, deep rough bottomed or sleek types (Plates 247 and 249) although some intermittent striations can be observed as well (Plates 248A-B and 249E). These distinctive wear patterns on the archaeological flakes correspond well with those produced on experimental tools used for processing fish (e.g. Plates 94-96).

According to my experimental data, the formation of identifiable wear patterns on tools used for the working of soft elastic materials requires at least 30 minutes of use. This means that examined artefacts from FAO with similar wear must have been used for a similar task for a relatively long period and so they should be assessed as having had moderate to long-term use-life.

In addition to wear features, distinctive residues on fish working tools were observed. They include animal tissue (Plate 248E-F), blood-like residue (Plates 247D-F and 249A, F) and white, black (Plates 247B-C and 249C) and rainbow coloured (Plates 248A and 249C) residues. Similar types of residues are also preserved on experimental tools used for gutting/cutting fish (e.g. Plate 114).

7.6.7 Dense, Hard Material: Shell and Clay

Despite its heavily pitted surface, one large flake with an edge, which was irregular in plan view, was probably used for sawing dense, hard material, probably shell. The thick working edge is intensively damaged by bending and rare feather scars with poor defined boundaries because of the crushing effect (Plate 256C). Dense, shallow and, rarely, deep, rough bottomed and intermittent, short striations are mainly oriented parallel to the edge (Plates 256A-D). Well developed polish slightly flattened the surface with striations, but this polish does not extend into the surface depressions (Plates 256D-F). Some white coloured smears are embedded into the tool surface which has been altered by polish (Plates 256B, F). This pattern of wear and residues is similar to that observed on experimental tools used for sawing shell (e.g. Plates 104-107).
7.6.8 Discussion

Although the number of tools associated with the late Holocene period is relatively small (88 tools or 16.0 percent of total assemblage consisting of 563 artefacts), there are some general correlations between (1) the material worked and mode of use (Table 7.14), (2) the material worked and duration of use and (3) the type and size of tools and function (Table 7.16).

Of the woodworking implements (61 artefacts or 69.3 percent of the total 88 late Holocene tools), most were involved in the processing of siliceous soft wood, palm and bamboo (35 artefacts or 57.4 percent of woodworking tools). These tools were mostly used for scraping, whittling and, to a lesser extent, sawing and carving actions (Table 7.14). A relatively large number of tools (20 artefacts or 32.8 percent of woodworking tools) were related to working non-siliceous soft wood mainly by whittling and carving actions. Both siliceous and non-siliceous hard wood and palm (6 artefacts or 9.8 percent of woodworking tools) were probably involved in daily activities and were mainly worked by sawing/scraping actions (Table 7.14).

Most of the woodworking tools (53 artefacts or 86.9 percent) were used for a short period of time. Flakes of medium (26 artefacts) and small (18 artefacts) sizes were preferred for these activities (Table 7.16). Tools with single working edges are prevalent (41 artefacts or 67.2 percent) within the woodworking assemblage, although implements with multiple working edges are also relatively numerous (20 artefacts or 32.8 percent). Used tools are mainly characterized by an edge angle between 15° and 55° (37 artefacts or 60.7 percent of woodworking tools) and, to a lesser extent, more than 55° (14 artefacts or 23.0 percent of woodworking tools). Thin edges (less than 15°) were also utilised (10 artefacts or 16.3 percent) probably for fine woodworking activities. These data reflect the hardness of worked materials and indirectly suggest intentional selection of flakes with strong and relatively thick edges for working hard wood.

Tools used for processing non-woody plants comprise 17 artefacts (19.3 percent of the total tool assemblage). Tubers (11 artefacts or 12.5 percent of total tools) were worked by scraping/slicing and scraping. Greens (6 artefacts or 6.8 percent of total tools) were processed by cutting/slicing or cutting. Use-wear patterns indicate that most tools involved in this activity were used for moderate (9 artefacts) or long (5 artefacts) periods of time. Flakes of all sizes were chosen for the performance of tasks although medium and small tools (12 artefacts) were preferred. Tools with single edges were mainly used for working non-woody plants (10 artefacts) although tubers were more
often processed by tools with multiple working edges (5 tools). Only two artefacts with multiple edges were used for cutting and slicing greens (Table 7.16). Thin and relatively sharp, straight and irregular edges were preserved on these two cutting tools indicating that soft plants rather than woody species were processed. Edges on scraping tools used for working tubers are slightly thicker in profile and are more likely to be convex or concave in shape than those edges on cutting and slicing tools (Table 7.16).

A relatively small number of late Holocene tools were used to process **soft elastic materials** (8 artefacts or 9.1 percent of total 88 tools), including five for piercing and cutting skin and three for gutting/cutting fish (Table 7.14). This category of tools demonstrates only moderate to long-term use and is represented by small and medium flakes with single working edges. Cutting and piercing skin was performed by thin edges which still maintained their sharpness. Tools for processing fish are characterised by relatively sharp but stronger edges (between 15° and 55°).

Sawing **dense, hard materials** such as shell was achieved by a large flake with two working edges. According to the wear patterns, a thick edge angle (more than 55°) of both working edges apparently resulted from the short-term use of the flake involved in the processing of this particular material.

In contrast to the preference for flake tools, a few implements are blade-like flakes. One Kombewa flake, which is unusual in the late Holocene assemblage, was used for gutting/cutting fish (Table 7.16). There are numerous tools with cortex preserved on the dorsal surface (29 artefacts or 33 percent of total 88 tools). This suggests that, firstly, no complex technological strategy was involved in the manufacture of these flakes and, secondly, the selection of flakes for a particular activity was based on those morphological features which were the most appropriate for the performance of that task (e.g. size of a flake, the edge shape and the edge angle). These technological and morphological peculiarities of late Holocene tools and their mostly short-term use (63.6 percent of total 88 tools) is generally associated with the nature of the expedient technology proposed for this chronological period (Torrence 1992:120-121).

### 7.7 FAO Middle Holocene Assemblage

Of the total of 832 artefacts found in the middle Holocene stratigraphic layer in the seven studied test pits (Table 6.2), 102 tools (12.3 percent) were identified (Table 7.18). The largest number of artefacts were recovered from the 970/1000 test pit which
also contained most of the tools (55 samples). The excavation of the centre of the site (1000/1000, 1001/1000, 1000/999 test pits) yielded 23 tools which were concentrated in the 1000/1000 test pit. One tool was identified among 38 flakes from the 1000/999 test pit (7.16). There were no tools identified in the 1001/1000 pit and the middle Holocene layer in 1001/999 pit was not excavated.

In contrast to the late Holocene period, a higher proportion of the middle Holocene tools were involved in processing non-woody plants (24 artefacts or 23.5 percent of the total of 102 tools) including tubers (15 artefacts) and greens (9 artefacts) (Table 7.15, 7.18). An almost equal number of tools were related to the working of non-siliceous soft wood (22 artefacts or 21.6 percent) and siliceous soft wood, palm and bamboo (19 artefacts or 18.6 percent). A much higher percentage of middle Holocene tools (15.7 percent) was associated with the working of hard siliceous and hard non-siliceous wood in comparison with the late Holocene period. Similarly, a greater proportion of middle Holocene artefacts were used for processing soft elastic materials: 18 middle Holocene tools (or 17.6 percent) versus eight late Holocene tools (or 9.1 percent). The middle Holocene set also includes two tools which were used for working shell and clay (Table 7.18).

The result of my study clearly demonstrates that during the middle Holocene period obsidian artefacts were used for processing similar categories of worked materials and involved similar modes of use to the previous period (e.g. Tables 7.14-7.15). Consequently wear patterns on late and middle Holocene tools have many common characteristics. There are major differences, however, in the degree of natural alteration of the surface of obsidian tools in the middle Holocene period. Generally, more intensive chemical damage on middle Holocene artefacts produced some peculiarities in wear features and, in some cases, reduced the level of confidence for the definition of the category of worked material (Table 7.9).

7.7.1 Siliceous Soft Wood, Palm and Bamboo

Middle Holocene artefacts which were involved in processing siliceous soft wood, palm and bamboo are mainly represented by large and, to a lesser extent, medium flakes with straight, irregular or convex edges in plan view and edge angles between 15° and 55° (Figures 7.2 and 7.3). Small flakes with thin edges were rarely used. Of a total of 19 artefacts, involved in this activity, only two tools have two working edges and one large intensively used flake has three working edges (Table 7.17).
The preferred modes of use for tools working siliceous soft wood, palm and bamboo were whittling (Plates 160 and 165) and sawing/whittling (Plates 158, 161, 162 and 164). Scraping (Plate 167), carving (Plate 169), sawing (Plate 159), or a combination of scraping/whittling, scraping/cutting (Plate 168) and whittling/scraping/sawing, are rare in the assemblage (Table 7.15).

Common features of whittling implements include dense, diagonal striations in association with continuous bending and feather scars together with medium and intensive edge rounding accompanied by patches of developed and well-developed polishes (Plates 160 and 165). Evidence of whittling/sawing actions performed by the same working edge is another common feature of middle Holocene tools (Figures 7.2: 1, 3 and 6; Plates 158, 161, 162 and 164). The wear patterns on some tools were intensively damaged by pits resulting in the alteration of striations from sleek and intermittent types (Plate 160 and 161) to mostly intermittent forms (Plates 158B, 159 and 162) which can sometimes appear as oval depressions (Plate 158C). Despite this, however, some patches of polish (Plates 158C, 164 and 169B) are preserved on the working edge and this in conjunction with other wear variables (scarring patterns, edge rounding, striations, residues) allows reliable identification of function.

7.7.2 Siliceous Hard Wood and Hard Palm

There are six large and two medium flakes and a large stemmed tool in the assemblage which were used for sawing, scraping and whittling siliceous hard wood and hard palm (Figures 7.6: 2 and 7.8: 2-3; Table 7.18). One of the distinctive features of these tools is their thick edge angle (more than 55°) caused by intensive edge scarring (Plate 201). Two of them were broken during use. The stemmed tool has two working edges: the straight edge was used in a whittling motion and the concave-shaped edge was involved in a scraping action (Table 7.8). The working edges of this tool preserved plant tissue and starch residues, while the hafting area retained palm phytoliths (Kealhofer et al. 1999) probably derived from the wood handle (Table 7.8). Plant tissue, starch and sometimes white residues often occur on this category of tools.

The highly fractured edges with patches of intensive rounding and well developed polish together with dense striations are common wear patterns on tools involved in working siliceous hard wood and hard palm. These wear variables are analogous with experimental tools used for working similar plant materials. Most of the tools in this group have damage indicating their short-term use. Exceptions are the stemmed tool
(Figure 7.6: 2) and one flake broken during use which were probably designed for a more long-term or moderate use but broke prematurely.

7.7.3 Non-Siliceous Soft Wood

Tools associated with processing non-siliceous soft wood (22 artefacts or 21.6 percent of 102 middle Holocene tools) comprised large flakes (14 artefacts) and some flakes of medium size (6 artefacts) with edge angles of between 15° and 55° (Figure 7.5; Table 7.17). Tools with a single working edge are prevalent within this group (19 tools of total 22 artefacts). There are only three flakes with multiple working edges (Table 7.17).

The dominate modes of use are whittling (9 artefacts) and scraping (5 artefacts) actions (Plates 188-190), although carving (Plate 192), sawing (Plates 195-196), scraping/whittling (Plate 191), scraping/sawing (Plate 194) and whittling/sawing were occasionally performed (Table 7.15).

Both whittling and scraping soft wood resulted in continuous or discontinuous scarring patterns with bending, feathered and stepped terminations (Plate 190 and 194). Slight, medium and, to a lesser extent, intensive edge rounding, as well as very light to well developed polishes, have a mainly patchy appearance on the working edge (Plates 188B and 191). Striations are relatively isolated, long, shallow, or deep sleeks, rough bottomed and intermittent types (Plates 189A, 191, 195 and 196). Carving, as a combination of cutting, scraping and whittling motions, demonstrates relatively complicated patterns of distinctive long and deep striations oriented in parallel or slightly diagonal directions (Plate 192). Only one tool (Figure 7.5: 3) was used for carving soft wood (Plates 192A-B) for a relatively moderate period of use. All others artefacts were only used for a brief time.

Used edges often preserved plant tissue and sometimes starch residues (Plate 189B). There are some tools with "white" residues (Plate 190) and one tool has black residues which are probably associated with processing resinous woods.

7.7.4 Non-Siliceous Hard Wood

The middle Holocene tool set includes five large and two medium flakes with thick edges which were used for the working of non-siliceous hard wood (Figures 7.7: 2-5 and 7.8: 2-3; Table 7.18). Scraping (Plate 202) and scraping/whittling (Plates 200,
203 and 205) are the prevalent modes of use whilst scraping/sawing (Plate 204) and cutting/whittling motions (Plate 207) were rarely associated with this category of worked material. Tools with a single working edge are prevalent (5 artefacts). One tool (M2124) has two working edges: the straight edge was used for sawing and the concave edge was involved in a scraping action (Plate 203). Signs of intensive use are observed on the tool M1905 (Tables 7.7 and 7.13) with use-wear present on each of its four working edges. Two straight edges of this tool were used in scraping actions (Plates 200A-B) and two convex edges are associated with scraping/whittling motions (Plate 200C).

Wear patterns on the tools are characterised by intensive scarring which is continuously distributed on the edge, patches of pronounced rounding (Plates 200C and 206A) with developed polish (Plates 200B, 204A-B and 206B-C) and isolated diagonal (Plates 200C, 204B and 207B), parallel (Plate 204A) or perpendicular (Plate 203), long, deep and shallow, sleeks and intermittent striations. All the tools were used for a short duration of time. Plant tissue and starch residues can often be observed on the working edges of these tools (Plates 200D and 205).

7.7.5 Non-Wood Plants: Tubers and Greens (Leaves, Stems and Grasses)

Processing non-woody plants is represented by 15 artefacts used for scraping, scraping/slicing and, to a lesser extent, slicing/cutting and cutting tubers, and nine artefacts used for cutting, slicing and scraping greens (leaves, stems and grasses) (Table 7.15).

Tools for working tubers (Figure 7.10: 2-6) are mostly represented by medium sized flakes with an edge angle between 15° and 55°. An exception is a medium sized stemmed tool with a thin, convex working edge. Despite its heavily altered surface, some spots on the edge preserved identifiable wear patterns (Plates 219A-C) which are comparable with wear variables on both late Holocene tools with well preserved surfaces (e.g. Plates 209A and 218A) and experimental tools (e.g. Plate 88, 90 and 92B). The edge and surface of the stem have some spots with light polish and isolated striations which indicate that the tool was hafted into a wood handle (Figure 7.10: 2; Plate 219E). This indirect and interesting evidence of hafting wear may be seen in the difference in the surface alteration between the stem, which was presumably covered by the wood handle and the exposed working part of the tool (Plate 219D).
Tools with wear patterns in this category do not reflect preferences in the shape of the edge: straight, irregular, convex and concave edges were almost equally used to achieve the tasks (Table 7.17). There are no tools with multiple working edges in this group and only three artefacts have acute edge angles (less than $15^\circ$).

Working relatively soft plants like tubers leads to small or very small bending, feather and, rarely, step scars which have a discontinuous or, in the case of intensive use, continuous scar distribution along the edge (Plates 219A-C, 221A, 222 and 224A). The profile of working edges is characterised by light (Plates 220A and 222), but mainly medium and intensive rounding (Plates 217A, 218C, 219A, 221B, 223 and 225A). As with the edge rounding, light (Plates 218B and 221A) and developed polish (Plates 217B, 218C, 219C, 220B, 222 and 223) may have a slightly patchy distribution. Relatively merging polish, however, is often seen as a thin, continuous line along the utilised edge under higher magnification (Plates 217A-B, 218C, 222, 223 and 225A).

A small or moderate number of striations, clearly separated from each other, may have slightly diagonal (Plates 218, 223 and 225A), parallel (Plates 222 and 224A) and perpendicular orientations (Plates 217, 219C and 221B), or they can cross each other (Plates 218C, 220A and 223) reflecting a flexible mode of use.

On the basis of both diagnostic wear patterns observed on the tools and comparative experimental data, I suggest that most of the tools from the middle Holocene layer reflect moderate use in processing tubers. The function of these tools is also supported by the more frequent presence of starch residues on the working edges (Plates 218D, 219F, 224B-C and 225). Plant tissue and white residue (Plate 221B) are also common (Tables 7.8-7.11). Phytoliths found in the hafting area of artefact M367 suggest that this tool was wrapped during use (Kealhofer et al. 1999:543).

Medium flakes with straight and acute edges were involved in processing greens (Figure 7.11: 2-8; Table 7.17). The modes of use were cutting/slicing, cutting and, very rarely, scraping actions (Table 7.15). The acute edges of the tools preserved small scars and microscars with bending and feather terminations which are often discontinuously distributed along the edge (Plates 227A, 228A-B, 229A, 230A, 231A, 230 and 233). Long, shallow and occasionally deep, sleek striations, accompanied by some rough bottomed and intermittent types, are rare (Plates 227, 228, 229 and 232) or moderate (Plates 230A) in number and are well separated from each other. A slightly, or medium, rounded edge often corresponds with light to developed polishes (Plates 228B, 230A and 231). The polish is less extensive and rarely has a merging appearance. An exception is one tool (Figure 7.11: 7) with dense and short striations in association with
intensive edge rounding and well developed polish. These wear features are similar to those which were formed on experimental tools used for processing highly siliceous plants such as pandanus leaves or the green skin from rattan (e.g. Plates 27A, 28, 31 and 134). Residues (Tables 7.7-7.11) include plant tissue, starch grains (Plates 227C, 230B and 233C) and sometimes white residues (Plates 231B and 233B). Based on the wear patterns, only two flakes of this group of tools were associated with short-term use while seven artefacts indicate a moderate period of use.

7.7.6 Soft Elastic Material: Skin and Fish

The middle Holocene tool assemblage contains a relatively high percentage of tools used for processing soft elastic materials, such as skin and fish (18 artefacts or 17.6 percent of total number of tools). The piercing, cutting and shaving of skin is represented by two small stemmed tools, one blade-like flake, seven medium and four small flakes (Figure 7.12: 5-6 and 8-13). Most of the flake tools have pointed tips formed by acute straight-sided edges (Table 7.17).

The acute edges of tools involved in this activity usually preserve microscars and, rarely, small scars which are discontinuously distributed along the edge (Plates 241F, 243A and 244A-B). The edge profile is slightly (Plates 239A-B, 241 and 242), or medium, (Plates 238A-B, 240B, 243A and 244A-B) rounded and this is associated with light and developed merging polishes (Plates 240C-D, 241B-C, 243A-B and 244B). There is a small number of isolated, deep and shallow sleek striations (Plates 238A, 239B, 241D and 242A-B) and, rarely, examples of rough bottomed and intermittent types (Plates 239B, 240B, 243A and 244A-B). Striations are oriented slightly diagonally or perpendicular to the tip (Plates 235 and 236) and indicate penetrating, rotating and cutting motions.

One small stemmed tool (Figure 7.12: 5) which was used for cutting/piercing skin has a partly broken working edge with preserved dark-red and rainbow-coloured residues embedded into the surface which has been altered by polish (Plates 240A-D). The stem of this tool contain some spots with striations, plant tissue and starch residues (Plates 240E-F) indicating that the artefact was probably hafted in a wooden handle. The second small stemmed tool with a straight and acute edge (Figure 7.12: 10) was probably wrapped for holding and used for cutting very thin and soft skin.

The tip of one piercing tool (Figure 7.12: 7) preserved a spot of black residue which changed colour under higher magnifications (Plates 241A-C). According to
Fullagar (Fullagar, R. pers. comm., 23 May 2006) these residues might represent a mixture of charred plants which could be used for pigments during piercing and cutting of skin. Similarly, some spots with red residues on the tool M2129 (Figure 7.12: 12) may indicate a mixture of blood and a bright, red mineral like ochre (Plate 243B). These residues gave a weak positive reaction to Hemastix (a presumptive blood test). In contrast, bright and coloured residues found on the hafting part of the tool M1907 are similar to resins (e.g. Plates 26D and 115C-D) and are probably associated with hafting.

There are two flakes (one medium and one small in size) with acute edges which were probably used for shaving the human face. A few bending and rare feather microscars are distributed in a discontinuous fashion on one side of the edge (Plates 245A and 246A). A thin line of light edge rounding (Plates 245B and 246E) and very rare spots of smoothed and merging polishes are visible under high magnifications (Plates 245C-D and 246B, C, F). A few perpendicular and slightly diagonal long sleeks and intermittent striations can be observed (Plates 245A and 246). Residues similar to skin tissue (Plates 245D, F) as well as red, white and black residues are observed on some spots on the edge (Plates 245C, E). Similar residues and wear variables were formed on experimental tools used for shaving human faces (e.g. Plates 100-103).

Both wear patterns and residues on artefacts involved in processing skin were used for moderate duration and have many common features with those experimental tools which were used for piercing/cutting and shaving skin (e.g. Plates 97-99, 112A and 114A-B).

Large and medium sized flakes (seven samples) are identified as tools used for gutting/cutting fish (Figure 7.13: 4-9; Table 7.18). Flakes with a single working edge were preferred for this function (Table 7.17). These tools have more intensive edge scarring in comparison with those used for piercing and cutting skin. Scars are mostly feather and bending types, small or very small in size and are continuously distributed on the edge (Plate 252A and 253A). Medium rounded edges (Plates 251A, 252 and 253B) preserved patches of light and developed polishes that extend from the higher peaks of microtopography into surface depressions (Plates 251B, 252B-C, 253B-C and 254B). Parallel (Plates 251A, 252A and 253A), slightly diagonal (Plates 250B) and intersecting striations (Plates 250A, 252B, 253B, 254A, 255A and 255B) reflect a relatively wide range of motions. Striations are mostly isolated, long, deep rough bottomed or sleek types (Plates 252A and 255A) although some intermittent striations can also be observed (Plates 252C).
These distinctive wear variables correspond well with wear patterns on experimental tools which were used for processing fish (e.g. Plates 94-96). Because the formation of identifiable wear patterns on tools used for working soft elastic materials requires at least 30 minutes of use, it is reasonable to propose that fish processing tools at the site were used for moderately long periods of time.

Distinctive residues were found on fish working tools. They include animal tissue (Plates 250D, 254C and 255C), blood-like, rainbow-coloured (Plates 250C, 252C and 254B) and white residues (Plates 252C and 253C). These types of residues are usually observed on experimental tools used for gutting/cutting fish (e.g. Plates 112A and 114).

7.7.7 **Dense, Hard Material: Shell and Clay**

The middle Holocene tool set includes two large flakes with an edge angle of more than 55° which were briefly used for scraping a dense, hard material, such as shell and probably clay (Figure 4.10: 5-6; Table 7.8). The working edge of the tool involved in scraping shell is severely damaged by bending and step scars with poorly defined boundaries (Plates 257A-D). A rough and intensively rounded edge profile (Plates 257A-D) is accompanied by well developed flattened polish which does not extend into the surface depressions (Plates 257E-F). Dense and mainly shallow and short striations are slightly diagonal to the edge (Plates 257A, C). Some white coloured smears are embedded into the surface which is altered by polish (Plate 257F and 258A-B). This pattern of wear and residue is similar to that which was observed on experimental tools used for processing shell (e.g. Plates 106A-B and 107A-B).

The second large flake has some peculiar wear patterns and was probably used for scraping clay (Table 7.8). As on the shell-working tool, the edge of this tool is extensively damaged by small, step and bending scars with poorly defined boundaries (Plates 259A, C). The intensively rounded edge profile contains patches of well developed polishes which, in contrast to the polish on the shell-working tool, have a more smooth and flattened appearance (Plates 259C-D). There are also some differences in the types of striations. They are mostly thin, long, sleeks and occasionally intermittent types (Plate 259A), indicating the working of more abrasive material than shell. White and yellow coloured residues are embedded into the surfaces (Plates 259B and D). The comparison of wear variables observed on this artefact with experimental tools used for scraping of half-dry white clay shows close similarities in wear patterns and residues (e.g. Plates 110-111).
A detailed examination of obsidian tools clearly demonstrates that similar resources were used in human activities during both middle and late Holocene occupations of the site, with the exception of the use of clay. There are, however, some minor differences in the intensity of use of particular resources, the way in which they were processed and in the selection of tools used in the performance of particular tasks. These differences are made apparent by comparing the percentage of tools involved in a range of activities in each of the middle and late Holocene phases of occupation of the site.

The efficiency of use-wear/residue identification of wear patterns and tool function depends in many respects on the surface preservation of artefacts under investigation. No soil analysis was undertaken as part of the FAO excavation and specific information on the soil chemistry at FAO is not available. As previously noted in this chapter, there is a high degree of variation in the natural alteration of the surface of obsidian tools from the middle Holocene period. Generally, more intensive chemical damage on middle Holocene artefacts influenced the level of confidence for the definition of some categories of worked material, for example, soft elastic material. However, the combination of wear variables such as scarring, edge rounding, striations, polish (if it is preserved) and residues on the tools with altered surfaces allowed the identification of the mode of use and, to a lesser extent, the material worked. For example, woodworking implements have a particular set of wear variables suggesting the processing of siliceous or non-siliceous, soft or hard species of wood and this combination leads to a relatively reliable identification of tool function even in the case of intensive surface alteration.

In summarising the results of my use-wear/residue analysis of prehistoric obsidian tools, it is necessary to emphasize the point that those artefacts which indicated the kind of wear, but did not present a reliable combination of main wear variables which would have allowed the functional interpretation of tools, were excluded from the results. This means that the number and percentage of tools and the comparative analysis of associated activities at FAO can be considered as representing a general trend pointing to the similarities and differences in human behaviour during the middle and late Holocene.

Notwithstanding the need to exclude some tools there is an obvious trend that, in contrast to the late Holocene period, a greater number of middle Holocene tools were
involved in the processing of non-woody plants: 23.5 percent of total middle Holocene tools versus 19.3 percent of total late Holocene tools (Table 7.18). This includes tubers (14.7 percent versus 12.5 percent accordingly) and greens (8.8 percent versus 6.8 percent). Tubers in both periods were processed in the same way: by scraping, scraping/slicing and cutting/slicing. Both late and middle Holocene tools had a moderate duration of use. However, only the late Holocene set includes tools with multiple working edges and evidence of long-term use (Table 7.16). This suggests that middle Holocene tools were used more expediently in this activity in comparison with the late Holocene period. Medium-sized flakes were preferred for the performance of tasks in the middle Holocene period of occupation. An exception is a single stemmed tool made of a Kombewa flake which was used as a scraping/slicing implement (Table 7.8). In contrast, in the late Holocene period, there was no preference for a particular size of flakes for processing tubers and no formal tools were used on tubers (Table 7.16).

The percentage of woodworking implements in the middle Holocene tool assemblage is smaller than in the late Holocene tool set: 55.9 percent versus 69.3 percent (Table 7.18). Moreover, middle Holocene tools were mainly used for working non-siliceous soft wood (21.6 percent) and, to a lesser extent, siliceous soft wood, palm and bamboo (18.6 percent). In contrast, late Holocene woodworking implements were mainly used for processing siliceous soft wood, palm and bamboo (39.8 percent) and fewer tools were involved in working non-siliceous soft wood (22.7 percent). In addition, hard siliceous and non-siliceous species were more widely used during the middle Holocene occupation (15.8 percent) than in the late Holocene period (6.8 percent).

Woody species of plants in both periods were worked by tools using similar modes: whittling and scraping and, to a lesser extent, sawing and whittling/sawing motions (Tables 7.14 and 7.15). A difference, however, is observed in processing siliceous soft wood, palm and bamboo. In the late Holocene period this category of plants was mainly worked by scraping and whittling actions. In contrast, whittling was a preferred mode of use in the middle Holocene period while scraping was almost non-existent (Table 7.15). Some variations are also observed in the working of hard silicious and non-siliceous wood and palm: middle Holocene tools indicate a more diverse set of actions. The carving of woody species with obsidian tools was slightly more prevalent during the period of late Holocene occupation.
Most woodworking implements in both late Holocene and middle Holocene periods were used for a short period of time: 53 artefacts of 61 late Holocene woodworking tools and 50 artefacts of 57 middle Holocene woodworking tools. However, there is an interesting pattern in the distribution of tools with multiple and single working edges within each chronological period. Within the late Holocene woodworking set, 32.8 percent of tools are characterised by having multiple working edges. In contrast, only 19.3 percent of middle Holocene tools have multiple working edges while artefacts with a single working edge are obviously prevalent (80.7 percent of the total 57 woodworking tools). This frequency pattern demonstrates the more expedient and less intensive use of middle Holocene flake tools, in comparison with that of the late Holocene artefacts (Tables 7.16 and 7.17).

One of the distinctive morphological features of middle Holocene woodworking implements is the intentional selection of large flakes for the performance of tasks. These comprised 63.2 percent of tools while medium (28.1 percent) and small (8.8 percent) flakes were less involved in this activity. There is one large stemmed tool and five blade-like flakes in this group of middle Holocene tools. In contrast, medium sized flakes (42.6 percent of total woodworking tools) were preferred for processing woody plants during the late Holocene period, although large (27.9 percent) and small (29.5 percent) flakes were also used widely. No formal tools are associated with the late Holocene woodworking assemblage although one amorphous core was used for scraping.

A higher percentage of middle Holocene tools were involved in processing soft elastic material in comparison with the late Holocene period (18 artefacts or 17.6 percent of total middle Holocene tools versus eight artefacts or 9.1 percent of total late Holocene tools). This group of tools is mainly associated with piercing and cutting skin and, rarely, with shaving human faces, an activity which is only detected in the middle Holocene tool set. (Tables 7.14, 7.15) The processing of skin in both chronological periods was accomplished by small and medium sized flakes which were only used for moderate and, rarely, short time periods. The difference between these periods is the presence of two small stemmed tools in the middle Holocene assemblage and the absence of any formal tools in the late Holocene tool kit.

Processing fish in both chronological periods is represented by a small number of tools although their percentage representation in each assemblage varies: 3.4 percent of total 88 late Holocene tools and 6.9 percent of total 102 middle Holocene tools. Gutting/cutting fish during the middle Holocene period of occupation of the site was
performed by large and occasionally medium sized flakes in contrast to medium sized flakes used for similar tasks in the late Holocene period. These tools indicate a moderate duration of use in both late Holocene and middle Holocene periods.

7.9 Summary

It is apparent, from this comparative analysis of functional and morphological data that the set of activities undertaken and resources utilised at FAO is similar for both middle and late Holocene periods. A slight change in activities undertaken and resource exploitation may be observed in the proportion of tools used for processing some materials and also in some technological and morphological preferences in the selection of obsidian flakes for the performance of specific tasks. The interpretation of these data addresses a number of questions about middle and late Holocene subsistence, settlement pattern and mobility and their relationship with curated and expedient technologies. These questions will be considered in the next chapter.
8.1 Introduction

This chapter examines those patterns of human behaviour that can be identified from data derived from use-wear/residue studies of obsidian artefacts. The interpretation of the functions of stone tools allows inferences to be made about various categories of daily activities which occurred at the site, as well as providing information as to intra-site structure, settlement pattern, technological organisation and mobility. Use-wear/residue analysis is especially useful in the study of flake assemblages associated with expedient technology because a better knowledge of the function of used flakes can be gained and significantly increase the understanding of prehistoric human activities in the Bismarck Archipelago.

The functions of obsidian tools at FAO are associated with two basic areas of human endeavour: subsistence and craft activities (Kononenko 2007). Craft activities also include some social activities which may be indicated by the particular uses of stone tools. The distinction between subsistence-related tools and those used in the manufacturing of implements (Juel Jensen 1994:48) provides important information about two major activity groups with different implications for an understanding of the lifeways of ancient populations. Tools involved in subsistence activities include all those artefacts that were involved in food procurement and food processing (Andreeva, Zhushchikhovskaya and Kononenko 1986:149-150; Fullagar 1994:213; Juel Jensen 1994:48, 166; Kononenko 1987:160, 2001, 2003:104-108; Kononenko and Kajiwara 2003:133-139). Artefacts associated with craft activities consist of functionally diverse groups of tools which were primarily employed in the manufacture and maintenance of other items made from a variety of plant and non-plant material. Tools involved in craft activities were not directly related to subsistence, although many could potentially have been used for food procurement and food processing: for example, flakes used for scraping/cutting soft wood, palm, bamboo that was being made into taro knives or fishing spears. Unfortunately, use-wear/residue analysis does not allow the precise identification of the kinds of items produced by a particular artefact. This objective limitation of the functional assessment of tools necessitates the use of the data on a

Using the data about the nature and type of activities which were undertaken at FAO, a comparison between middle and late Holocene can be made in order to explore chronological changes in both subsistence practises and craft activities during these periods on Garua Island. In a wider perspective, this may provide new insight into the relationship between Pre-Lapita and Lapita economics and cultural development in the Bismarck Archipelago.

The spatial distribution and density of identified tools and production debris varies significantly in different parts of FAO and suggests discrete activity areas. This variation permits the investigation of how activities were segregated or combined and how tasks were accomplished in each period, and allows the identification of some general trends in the internal structure and function of the site (Carr 1991; Keeley 1991; Kirch et al. 1991; Kooymen 2000:133; Kroll and Price 1991; O'Connell, Hawkes and Jones 1991). The consideration of the location of FAO in the context of the distribution of contemporary sites within the island's environment, gives insight into the broader settlement pattern and the strategies of resource use in the studied region during the middle and late Holocene period (Torrence 2002a, Torrence and Stevenson 2000).

The significance of functional interpretations of stone tools for the study of residential mobility is apparent when taken together with the behavioural reconstruction of activities, technological organisation, site function and settlement pattern (Bamforth 1986; Binford 1979; Carr 1991; Hiscock 1994; Hiscock and Clarkson 2000; Jochim 1989:106-111, Kelly 1992; Kooymen 2000:130-132; Nash 1996; Odell 1996a, 1996b; Torrence 1989a, 1989b). Based on technological studies, limited use-wear/residue examination and distributional analysis of obsidian artefacts on Garua Island and the Talasea region, inferences have been made that there was high residential mobility of human populations during the middle Holocene and a more sedentary way of life in the late Holocene (Fullagar 1992:140; Kealhofer et al. 1999:544-545; Torrence 1992:121, 2002a:773; Torrence et al. 2000:238-239). My preliminary use-wear/residue study of obsidian artefacts from FAO (Kononenko 2007) does not support the proposed distinction between mobile and sedentary lifestyles of middle and late Holocene populations and this is the subject of more detailed analysis in this chapter.
A more complete picture is drawn using the functional interpretation of obsidian tools from West New Britain, available environmental and palaeoecological information and ethnobotanic and ethnographic data, when assessed as a series of interrelated factors. The lack of organic material in archaeological sites requires that other sources of information need to be found. Only environmental, palaeoecological, ethnobotanic and ethnographic data are available to reconstruct, firstly, resource availability, secondly, the ways in which resources were procured and used and, thirdly, the extent to which obsidian tools were involved in their processing. Using these data in conjunction with tool function, it is possible to identify significant changes in the availability of natural resources through time and to examine the responses of human populations to the changed material conditions.

The use of ethnographic and ethnoarchaeological information for the interpretation of archaeological data in the Pacific region is justified where there is historical and cultural continuity between living and past societies (Allen 2000; Conte 2006; Golson 2005; Kirch and Dye 1979; Roscoe 2005; White 1967, White and Thomas 1972). It is also argued that these external sources of analogies can be used on an abstracted, generalised level in an archaeological explanation if there is a link with technological aspects of human activities (Andrefsky 1998; Conte 2006:242-244; Gosden 2005:95-97; Sillitoe 1988:11; Terrell 2003:70-74, White and Thomas 1972:276). It is also possible to extend technological analogies to the explanation of social aspects of past human behaviour, for example, ethnographic mapping of technological or social activities (e.g. cooking and the spatial structure of camp sites). It is conceded that this can provide only a range of possibilities and more realistic levels of analogy are only possible when archaeological data are associated with ecological environments and cultural contexts close in time to the living group (Conte 2006:244).

Since the basic properties of tropical environments, the physical properties of raw materials used, and the physical needs and capacities of humans restrict the potential technological solutions, analogies to recent behaviour are reasonable (Conte 2006). This proposition provides the basis for my attempts to use available ethnographic data from the Pacific region, to interpret the function of obsidian artefacts from FAO.

8.2 Middle and Late Holocene Subsistence Activities

Previous reconstructions of middle Holocene subsistence practices at FAO were based on the analysis of sediments and plant microfossils such as phytoliths and
starch granules and use-wear/residue examination of selected obsidian artefacts (Barton et al. 1998; Fullagar 1993a, 1993b; Kealhofer et al. 1999; Lentfer and Torrence, 2007; Therin et al. 1999). The study of sediments at the 1000/1000 test pit indicates a sudden rise in burning and an intensive pattern of clearance at the site during the middle Holocene (Lentfer and Torrence 2007:100). The presence of nutshell and phytoliths in soils suggests that people were harvesting Canarium nuts. Bamboo morphotypes appeared for the first time in the phytolith assemblages probably signalling the early cultivation of these useful plants in the vicinity of the occupation site (Lentfer and Torrence, 2007:100-101). Use-wear/residue analysis by Kealhofer et al. (1999:542-543) identified the presence of starch grains, possibly from taro on the working edges of obsidian tools.

According to my use-wear/residue study, 21.8 percent of a total of 101 tools were involved in food processing (Table 8.1). Most of the 22 tools were used for scraping, slicing and cutting tubers (15 tools). Some of these tools were possibly used for extracting coconut flesh and for cutting and scraping breadfruit. More precise differentiation from flakes for processing tubers requires further detailed residue study.

Tubers, such as taro, contain toxins in the outer surface that need to be removed by scraping and peeling (Fullagar, et al. 1998:50; Fullagar, et al. 2006:597; Matthews 2006:23) and these uses resulted in the preservation of starch residues on used tools with particular use-wear characteristics. On the basis of use-wear/residue studies of obsidian artefacts, Fullagar (1992, 1993a, 1993b; Barton, et al. 1998; Kealhofer, et al. 1999) proposed that a major function of obsidian flakes in West New Britain was the processing of starchy tubers. Ethnographic data indicate that tubers were scraped, peeled and sliced by stone and shell tools, though often bamboo scrapers and knives were deliberately prepared and used for this task (Hogbin 1938:151, 304; Kirch 1997:213-214; Parkinson 1999:342; Sillitoe 1988:61; Specht and Fullagar 1988:7-8). The relatively small number of obsidian tools involved in tuber processing, allows the suggestion that most food processing implements at FAO were made of bamboo or soft wood and this is consistent with finding numerous flakes used for fine woodworking activity which were involved in the manufacture of those implements (Table 8.1). In addition, some cooking and food processing activities could have been performed off site, for example, in gardens or on the beach.

The processing of fish at the site is evident by the presence of seven tools with distinctive use-wear patterns (6.9 percent of total tools). Archaeological data from some early and middle Holocene sites in the Bismarck Archipelago indicate that fish were
obtained and transported from the sea to inland sites over distances of between three to
about ten kilometres (Marshall and Allen 1991:89; White et al. 1991:56). This suggests
some processes being involved in the preparation and preservation of seafood to avoid
the effects of the tropical climate on very perishable resources. It is known from
ethnographic and historical observation that fish after capture were cleaned and scaled
(Conte 2006:251) and large species of fish were chopped into small pieces and added to
other food (Green 1986:125; Masse 1986:110). Dried or smoked fish were used as a
form of payment and for exchange between people (Akimichi 1986:16; Haddon and
Whiting and Reed 1938:182). These kinds of fish preparation and preservation
procedures would have required tools made of stone and shell. Obsidian flakes used for
fish processing at FAO are the only relatively direct evidence for the exploitation of
marine resources of the reefs and surrounding waters of Garua Island. It is reasonable
to assume that most of cleaning and scaling activities occurred on the beach and this
may explain the small number of fish processing tools at the site.

Unfortunately, with the exceptions of food processing tools related to tubers and
fish, use-wear/residue analysis does not provide straightforward information about food
gathering and food production activities at the site. In this case, archaeological data
from a limited number of early and middle Holocene sites in the Bismarck
Archipelago, as well as paleoenvironmental reconstruction, can be used as indirect
indicators of resource use activities that could have taken place on Garua Island during
this time period (see Chapter 5).

The exploitation of marine resources, deliberate introduction of animals
(phalanger, bandicoot, and some rats), plant transplantation (Canarium nut trees), the
selection and manipulation of wild plants, like taro, started during the late Pleistocene
period and these processes continued into the middle Holocene (Allen 2000, 2003;
O'Connor and Chappell 2003; Spriggs 1997:61; Summerhayes 2007). Further gradual
intensification of the use of plant resources stimulated the development of
arboretural and horticultural activities during the middle Holocene (Allen 2000;
2000). A similar range of marine and land resources was available on and around Garua
Island (Chapter 5) which, together with the results of use-wear analysis of obsidian
artefacts, indicates that subsistence activity at FAO was centred on the procurement and
processing of marine resources, harvesting and processing plant resources and possibly
gardening (Lentfer and Torrence 2007). Food production from gardening was already
developed by the middle Holocene in the Bismarck Archipelago (Kirch 2000:87) and data from FAO is consistent with general trends in subsistence practices that have been reconstructed for the middle Holocene in the Bismarck Archipelago (Allen 2000; Lentfer and Torrence 2007; Pavlides 2006; Torrence 2002a, Torrence et al. 2000).

The late Holocene prehistory of West New Britain was influenced by a natural disaster associated with the W-K2 volcanic eruption which occurred at 3640 – 3360 cal. BP (Lentfer and Torrence 2007:85) or, according to Petrie and Torrence (in press) at 3480-3150 cal. BP. It is proposed that after this catastrophic volcanic event and lengthy period of abandonment, a different social system associated with expedient technology, pottery and a higher degree of dependence on cultivated resources was introduced into the region (Torrence 2000:774-775; Torrence et al. 2000:241-243), although at the beginning of reoccupation processes on Garua Island the people "subsisted largely on marine resources" (Torrence et al. 2000:241). Torrence et al. (2000:239) propose that a gradual intensification of the use of terrestrial resources started during the middle Holocene, but this process was greatly accelerated with the beginning of the Late Holocene and this was apparently linked to the introduction of new plants and animals (Torrence et al. 2000:241-242).

Recent data, obtained through the study of plant microfossils and sedimentary history at FAO support the proposition that there were no significant differences in landscape modification and subsistence practices between inhabitants who occupied the site before the W-K2 eruption and those who arrived at the site after the W-K2 event (Boyd et al. 2005; Lentfer and Torrence 2007; Petrie and Torrence in press). However, the introduction of the fishtail palm Caryota rumphiana and the slight increase in banana phytoliths is considered as evidence of more intense gardening practices (Lentfer and Torrence 2007:100). Many charred fragments of Canarium, coconut and other nutshells at the Walindi site (FRL) and on Garua Island from the Late Holocene deposit provide evidence that nut trees were widely spread on the island and could be related to arboricultural practices (Specht et al. 1991:289; Torrence and Stevenson 2000:325-330). A few analysed obsidian tools from the late Holocene obsidian assemblage contain residues which were identified as palm, bamboo and probably yam (Kealhofer et al. 1999:543) suggesting the processing of these plants at the site.

My use-wear/residue analysis of obsidian tools indicate that the set of activities undertaken at FAO during the late Holocene period is generally similar to the set which was identified for the middle Holocene occupation of the site (Table 8.1). However, the
trend which emerges from the comparison of middle and late Holocene assemblages (Table 8.1) indicates that the percentages of tools involved in **late Holocene subsistence activities** has been slightly reduced. The tools were mainly used for processing soft starchy plants (e.g. tubers) in both periods (Table 8.1), but a smaller number of such tools in the late Holocene tool set is not consistent with the proposal for an increasing dependence on cultivated gardens (Lentfer and Torrence, 2007:101). However, the smaller number of stone tools might indicate a wider use of implements made of bamboo, wood or shell in subsistence activities (Hogbin 1938:304; Parkinson 1999:342; Sillitoe 1988:61). As indirect support for this suggestion, there is the presence of numerous and diverse woodworking implements (Table 8.1) possibly involved in the manufacture of subsistence equipment including fishing gear. The presence of tools for processing fish is significant evidence for the procurement and use of marine resources and their part in the diet of the inhabitants of FAO.

Despite the absence of direct botanical and faunal remnants, use-wear/residue examination of obsidian tools and paleoenvironmental data (Boyd et al. 2005; Jago and Boyd 2005; Lentfer 1995, 2003; Lentfer and Torrence 2007; Parr et al. 2001) allow the conclusion that subsistence activities at FAO during the late Holocene were probably equally based on the wide scale exploitation of the available sea and land resources and gardening (Boyd et al. 2005:388-389; Lentfer and Torrence 2007:101). By analogy, faunal data from some Lapita sites in the Arawe Islands (Gosden et al. 1989:583-584; Spriggs 1997: 120 -121) make it possible to suggest some domestic and wild animals were also involved in subsistence practices of the inhabitants of the site.

This pattern of late Holocene subsistence at FAO is consistent with the generalised model of the Lapita economy in the Bismarck Archipelago which includes marine exploitation (e.g. collecting shellfish and other sea products, fishing, hunting sea turtles), arboriculture, horticulture ("swidden gardening" or "shifting cultivation"), domestication of pigs, dogs, chicken and small scale terrestrial hunting (e.g. Green 2002; Gosden and Pavlides 1994; Gosden et al. 1989; Kirch 1997: 195-226; Spriggs 1997:84-87).

### 8.3 Middle and Late Holocene Craft Activities

Craft activities were involved in many aspects of day-to-day life because a variety of items made from perishable materials were required. Of the total of 101 identified obsidian tools at FAO, 79 (or 78.2 percent) were involved in **craft activities during the**
middle Holocene. Among them, the most represented category is woodworking implements (78.2 percent or 79 tools). According to use-wear characteristics, they were used for processing a wide range of woody species such as siliceous and non-siliceous soft wood, palms, bamboo, hard wood and palms (Table 8.1). This is generally supported by the analyses of phytoliths found on the tools (Kealhofer et al. 1999). Morphological attributes of tools (size and shape of the edge) and use-wear features indicate they were mainly used for a short time for cleaning, shaping and cutting off materials. These activities suggest their association with fine woodworking processes. There are no tools for chopping wood within the obsidian assemblage and no adzes were found at the site (Torrence, R., pers. comm., 20 August 2006).

Environmental reconstruction (Chapter 5), ethnographic analogy and use-wear/residue study of obsidian artefacts, together, give a good indication that woodworking implements at FAO site had been primarily employed in the manufacture and maintenance of a large spectrum of items from a variety of plant materials and this activity played an important role in the daily lives of inhabitants.

Ethnographic data demonstrate that, at European contact, inhabitants of the Pacific region performed most woodworking tasks using stone or shell tools. Stone flakes were used in the manufacture of wooden tools used for food processing, and as fishing equipment, weapons, consumption utensils and for building shelters and watercraft. A large variety of actions and tasks were performed using stone tools in similar modes of use to those identified on obsidian prehistoric artefacts on Garua Island. These include cutting off pieces of wood or bamboo by sawing, shaping and sharpening by scraping and whittling, smoothing, drilling and carving (Kaberry 1941; Nilles 1943; Parkinson 1999:347; Sillitoe 1988: 43-220; Sillitoe and Hardy 2003; White 1967, 1968; White and Thomas 1972; Whiting and Reed 1939).

Sharp obsidian was especially suitable for carving items made of bamboo, canoe prows made of wood, wooden bowls, coconut shell utensils and for scraping spear shafts and canoe paddles. Occasionally obsidian pieces were used as an adze (Nilles 1943:114; Parkinson 1999: 160, 347; Specht 1981) but no such tools were found at FAO.

The obsidian artefact assemblage at FAO includes a small number of tools (9 tools or 8.9 percent) which were used in processing greens, such as leaves, stems and grasses. Some of these artefacts probably were involved in food processing, for example, scraping coconut flesh (Kirch 1997:215; Parkinson 1999:42). However, it is difficult to differentiate these tools as a particular category without further experimental study and
detailed residue analysis. Comparative examination of use-wear patterns on experimental tools (Chapter 7) and those observed on some flakes with cutting actions indicate their probable use in manufacturing plant string, probably to make clothing and lashing materials. Ethnographically, it is known that stone flakes were used in paring rattan strand for binding and weaving (Sillitoe 1988:46-47, 503). The preparation of lashing equipment, roofing and weaving material, strings and clothing had a significant role in daily activity (Parkinson 1999:345-346; Sillitoe and Hardy 2003:561) and the presence of these tools at FAO is one important aspect in the definition of site function and its relationship with general settlement patterns and mobility on Garua Island.

Another aspect of site function is indicated by implements used in activities associated with working soft elastic material which include 11 identified tools (10.9 percent of total tool assemblage). Although there is the possibility that some tools could be used for cutting and piercing animal skin, for example, reptile skin for hand drums (Nilles 1943:116), I agree with Specht's (1981; Specht and Fullagar 1988) and Fullagar's (Fullagar et al. 1998) proposals that one of the main functions of sharp obsidian flakes was related to the human body through tattooing and scarification, medical treatment and shaving. Ethnographic and historical records are consistent with this explanation. Shaving human faces, tattooing, blood letting, incision, trephination and other surgery with obsidian in New Britain are all recorded by Parkinson (1999: 48-50, 63, 96 and 347). Relatively recent use of obsidian for similar tasks in West New Britain is recorded by Specht (1981:347-348). Widespread use of obsidian as medical and tattooing instruments is well known in other areas of the Pacific (Elkin 1935:4-5; Krieger 1932:15-16; Nilles 1943:113-116; Watson 1986:5-6). Glenn Summerhayes witnessed a man in the Arawe Islands (Maklo Island) in 1990 cutting his forehead for relief of a headache. He used obsidian (Summerhayes, G., pers. comm., 16 October 2006).

Tattooing and scarification as body decoration, as well as body painting, were often accompanied by using coloured pigments mixed with blood, for example: burned red ochre, charcoal, charred resins, plant juice, coral lime dust, rotten limestone and white clay (Nilles 1943:113; Sillitoe 1988:39, 466-467; Parkinson 1999:61-63). Pieces of ochre and white clay were crushed and probably scraped into powder which then was mixed with water, blood or plant oil and used as painting substances for decorative purposes in tattooing, scarification and body painting (Sillitoe 1988: 443 – 444). The presence of a flake used for scraping clay and a few piercing tools with residues consisting of a mixture of blood and ochre suggests that similar activities could have been performed at the FAO site.
The regional archaeological record contains evidence for the presence of shell artefacts such as fish hooks, adzes, rings, disks and points (Golson 2005; Gosden 1991b; Smith 2001; Spriggs 1997:52; Szabo and O'Connor 2004) at middle Holocene sites in the Pacific. The manufacture of shell items definitely required the use of stone implements such as grinding and pecking tools, drills and files (Akerman 1975; Allen, et al. 1997; Attenbrow, Fullagar and Szpak 1998). Shell artefacts themselves sometimes preserved traces of cutting or sawing actions performed by stone tools (Smith 2001). Scraping of the hard outer concretion covering of pearl shell by stone scrapers is known ethnographically (Sillitoe 1988:382). Obsidian in West New Britain was relatively recently employed for cutting turtle carpace (Specht 1981:348). An identified obsidian scraper at FAO indicates that shell processing activity took place on Garua Island since the middle Holocene and this may have been associated with the manufacture of both shell tools (e.g. adzes, fish hooks) and shell ornaments (e.g. armband, crescents, pendant).

Shell ornaments, the use of coloured pigments for the body decoration, tattooing and scarification are indicators of social aspects of human behaviour in Oceania (Krieger 1932). The presence of obsidian tools at FAO involved in piercing and cutting skin, scraping clay and shell provides significant insight into the social life of the middle Holocene inhabitants of Garua Island. Apart from subsistence and craft activities that satisfied the basic material needs for the settlers of the site, social activities apparently played an important role in the adaptive strategies of islanders.

The set of tools used in late Holocene craft activities at FAO is similar in many respects to those of the middle Holocene kit (Table 8.1). However, there are some differences in the proportion of tools involved in different activities that may indicate some chronological, and probably, cultural discontinuity in the organisation of tool use and the strategy of resource exploitation between the middle and late Holocene.

First, the percent of tools involved in craft activities is slightly higher in the late Holocene assemblage (84 percent) in comparison with the middle Holocene tool kit (78.2 percent). Second, most tools are represented by woodworking implements (Table 8.1) which demonstrate obvious differences in their use in processing particular types of woody plants. More than 40 percent of the late Holocene woodworking implements are associated with the processing of siliceous soft wood, palm and bamboo. A much smaller percentage of tools (23 percent) were used for working non-siliceous soft wood. Hard wood and palms were rarely involved in craft activities (6.8 percent of the total of
woodworking tools). In contrast, during the middle Holocene a larger percentage of woodworking implements (21.8 percent of the total woodworking tools) were used for working soft non-siliceous wood and a much higher percentage of tools (15.8 percent) were involved in processing hard wood and palms.

These differences are difficult to assess with the data at hand, but can be considered as a general indicator of different responses to the needs of middle Holocene inhabitants and those of the late Holocene in their daily activities. Although there is no direct evidence within the late Holocene tool assemblage, numerous woodworking implements, including an increased number of tools used for scraping, carving and drilling species of soft wood, palm and bamboo suggest that some of these tools could have been used for the manufacture of tools, weapons, consumption utensils (Sillitoe 1988) and different parts of canoes (e.g. prows, paddles, bows) and rafts (Cassidy, Raab and Kononenko 2004:118-122).

There is no doubt that the re-occupation of Garua Island after the W-K2 eruption and a long period of abandonment would have been achieved by seafarers with the cultural experience to settle small islands. Empty land with forest regrowth on an island would be occupied by people probably arriving by canoe carrying garden plants for cultivation and food production and animals in order to create the same cultural landscape they left behind (Kirch 1997:109-115). Moreover, paddling and sailing canoes and rafts were essential in the procurement of marine resources and the performance of exchange activities especially for the distant transportation of obsidian (e.g. Allen 2003; Anderson 2000, 2001; Kirch 2000:112-114; Specht 2002; Summerhayes 2003; Torrence and Summerhayes 1997). All of these factors suggest that construction and maintenance of watercraft could be one of the important activities of the island's inhabitants. The problem is how to recognise the building of watercraft as distinct from other woodworking activities within the available archaeological record. Insights from use-wear/residue analysis of woodworking tools at FAO in association with ethnographic material and the further examination of obsidian assemblages from other contemporary sites on the island could be particularly useful in the further explanation of this period of occupation.

For example, the inhabitants of New Britain used a variety of species of soft wood, palms and bamboo including hibiscus, malas, erima, breadfruit tree, coconut palm, Calophyllum, rattan, bamboo for making watercraft (Powell 1976:157-159). These species of woody plants would have been available within the closed rainforest environment of Garua Island as it gradually recovered after the W-K2 volcanic events.
It is also known that the wood for canoes obtained from the forest was usually dragged to the seashore where the initial felling and partial hollowing of the hull would have been undertaken with axes and adzes made of stone and shell blades (Haddon and Hornell 1975:152-156, 303). Suitable pieces of obsidian could also be used as adzes (Specht 1981:348) for some finishing processes on the beach where watercraft were built and this can explain the absence of tools for chopping wood at the site. Some important components of watercraft, such as canoe paddles, a canoe's prow-affix and stern-affix, strakes, washboards, breakwaters and other timber parts of a canoe would need to be replaced many times during the 20 to 30-year life of the main hull (Haddon and Hornell, volume II 1937:155 (1975 reprint) because of the propensity of the smaller canoe components to be lost, wear out or break. Consequently, it is more than possible that obsidian tools were used to work wood to create a range of timber products needed in the use of watercraft and this activity could have been performed at the site where the artefacts were found. The use of obsidian for carving canoe prows and scraping canoe paddles was observed in New Britain (Parkinson 1999:46, 347; Specht 1981:348) and this activity was obviously likely to have been undertaken at the habitation site.

Some of the late Holocene tools involved in processing non-woody plants at FAO (Table 8.1) could also be related to the manufacture of strings and ropes which were necessary as a binding material in watercraft construction. Further experimental study of tool use is needed for more reliable identification of such a category of implements.

In contrast to the previous chronological period, in the late Holocene the number of tools used in working soft elastic material decreased: from eleven to five tools from 10.9 percent (11 tools) to 5.8 percent (5 tools). These tools are associated with piercing and cutting actions performed on the skin and these small flakes and stemmed tools, given their size, shape and sharpness have only a limited number of possible uses. The presence of residues of mammal blood on two late Holocene tools and non-identified blood residues on four middle Holocene tools, in conjunction with particular wear patterns and experimental data, suggests the possibility that these tools may have been involved in tattooing and scarification of the human body. This possibility is to be the subject of further investigation and is outside the scope of this thesis. Tattooing is considered as an important symbolic component of the Lapita Cultural Complex which was identified in the archaeological record on the basis of finds of decorated stylised human faces on ceramic vessels and figurine fragments (Green 2002; Kirch 1997:141-143; Torrence and White 2001). The presence of the Late Holocene obsidian tools used
for piercing and cutting skin at FAO is consistent with this proposal. However, functionally identical tools found at the site in the middle Holocene context allow the assumption that, in addition to medical treatment of the human body, shaving the face and scarification, tattooing was possibly also practiced in the region before the appearance of the Lapita people.

The assemblage from Makue site includes one piercing tool from the late Holocene which has preserved non-mammal blood residue suggesting that in some cases obsidian flakes could be used for piercing skin of birds, reptiles or fish.

8.4 Discussion: Middle and Late Holocene Tool Function and Activities

My use-wear/residue examination of obsidian artefacts indicates that a wide range of economic and social activities were performed by the inhabitants of FAO during both the middle and late Holocene periods. Although some activities were most likely performed outside of the habitation area (for example, canoe building and fish processing on the beach, processing and consuming tubers and nuts in the gardens) the diverse functions of tools support the proposed interpretation of FAO as a consumption site which maintained its role during both chronological periods (Therin, et al. 1999:456-457). This interpretation of FAO contradicts Fullagar's (1992:140-141; Kealhofer et al. 1999:544-545) assumption that in the middle Holocene only a few tool-using activities with a limited spectrum of tasks took place at the site reflecting a high level of mobility.

The general similarities between subsistence practices, craft and social activities of the middle Holocene inhabitants and those of the late Holocene observed at FAO can be explained by some common factors. First, the physical limitations of obsidian as a raw material has restricted the number of possible technical and functional solutions in the performance of particular tasks causing similarities in the mode of use of obsidian prehistoric tools. Second, the nature of available marine and terrestrial resources, both food and non-food, in the wet tropical region of West New Britain at a macro-level did not experience dramatic changes during the middle and late Holocene despite the long-lasting impact of the W-K2 catastrophic eruption (Boyd et al. 2005; Jago and Boyd 2005; Lentfer and Torrence 2007). Finally, the subsistence needs and capacities of inhabitants living in the island's environmental conditions were broadly the same over time.
The recognition of the attributes and resources of Garua Island, and its marine environs, by humans, over time, is an element of cultural behaviour which defines the ecological context of the complex social relations of human settlement. The people who have sequentially occupied Garua Island in the past chose the place, at various times, based on their experience, living skills and cultural traditions. Their collective decision to remain or leave would have been in response to environmental factors such as periodic volcanic activity or even drought. Whatever the case may have been, those people would have had to rely on subsistence strategies which necessitate the combined exploitation of both land and sea resources. The use-wear/residue data provide insight into the diet of the island's inhabitants in prehistoric time through indirect evidence of the types of foods processed, including tubers and fish during both chronological periods. This does not support Torrence's proposal (2002a:773-774; Torrence et al. 2000:239) that plant collecting was the primary source of food in the middle Holocene.

Garua Island possessed a number of highly desirable natural attributes and resources (Chapter 5) which attracted human populations in both the middle and late Holocene. The re-occupation of FAO after the W-K2 eruption was determined by such features as (1) the location of the site on a relatively small volcanic island with a wide variety of marine and plant resources; (2) the presence of diverse topographical features around the site including slopes, flat coastal and upland areas with rich volcanic soils appropriate for gardening; (3) permanent fresh water supply associated with Malaiol Stream and its springs as well as other watercourses on the island; (4) shelter and safe access to beaches and deep water provided by Garua Harbour – the use of the trade routes of the Bismarck Sea has been well established by the fact that obsidian was transported by sea (Specht 2002; Torrence and Summerhayes 1977; Torrence et al. 1996). All of these features are consistent with the general settlement strategy which is associated with the dispersal of the Lapita Cultural Complex in the Pacific (e.g. Green 2003; Kirch 1988, 1997:165-166; Lepofsky 1988; Spriggs 1997:88-90; Summerhayes 2007).

8.5 FAO Site Structure and Settlement Patterns on Garua Island during the Middle Holocene Period

Torrence (2002), using concepts of cultural landscape and methods of distributional archaeology, has proposed a model for the middle Holocene settlement patterns and land use on Garua Island. This model is based on data obtained from 69 test pits (1×1 m) which were excavated within different topographical settings on the
island. An examination of the distribution of obsidian artefacts in the buried ground surfaces in the excavated pits revealed that during the middle Holocene period there were only two coastal locations (FCY II and FAS II) with a low number of finds while other locations on the island show a more inland orientation (Torrence 2002a:772) and this is a more common feature of the middle Holocene settlement patterns (Kirch 2000:86). Of the total 69 excavated units, 40 pits contained high densities of obsidian artefacts (more than 60 samples) and 18 pits are characterised by medium densities (between 6 and 60 samples). The pits with high densities of artefacts are continuously distributed across the island's landscape and the absence of significant clusters is considered as one of the important indicators of short-term occupation of the site by highly mobile groups (Torrence 2000a:73-774, Torrence et al. 2000:237).

In relation to the FAO site, it is proposed that there were relatively low rates of artefact discard in the excavated units (Therin et al. 1999:455-456). Starch and phytoliths studies of sediments and use-wear/residue identification of some artefacts indicate the domestic use of the site since the middle Holocene and throughout the late Holocene (Barton et al. 1998; Kealhofer et al. 1999; Lentfer and Torrence 2007; Therin et al. 1999). The structure of this consumption site is difficult to interpret for some interrelated reasons. First, with the exception of four square metres in the centre, other parts of this large site comprising about 10,000 square metres (Torrence and Stevenson 2000:326) were tested only by 17 pits located at 10-metre intervals and additional three pits south of the main area of excavations (Figure 6.2). Second, the middle Holocene deposits were only completely excavated within two test pits (1000/1000 and 970/1000, Figure 6.3) and the same stratigraphic layer in other pits was excavated no deeper than 20 cm below the W-K2 tephra deposit (Torrence 1993:5; Torrence and Webb 1992:6-7). Finally, no organic or structural remains were discovered at the site. All of these factors create serious limitations for the interpretation of intra-site structure at FAO.

However, there are two kinds of evidence which can be used for the recognition of general spatial patterns of human behaviour at the site. The first is associated with phytolith distribution in the sediments which give indications of the degree and character of the surface disturbance by human activity (Boyd et al. 1998; 2005; Lentfer 2003; Lentfer and Torrence 2007; Parr et al. 2001). The second is related to the distribution of obsidian artefacts within the excavated units.

The spatial distribution of phytoliths indicates that the central part of the site in the middle Holocene period of occupation (the lower part of Layer 6) was covered by grasses and regrowth forest. In contrast, the upper part of Layer 6 in this area is
characterised by increased grasses and burned phytoliths indicating the deliberate clearance by later inhabitants (Lentfer and Torrence 2007:101; Parr et al. 2001:132). The south part of the site was covered by palms and herbaceous regrowth while the north (1000/1020 pit) and north-western (970/1000 pit) edges of the hill were covered by grasses since the beginning of the occupation indicating deliberate clearing. The coincidence of peaks of burned phytoliths and two increases in artefact densities associated with lower and upper parts of Layer 6 of 1000/1000 pit support the suggestion that an infrequent use of the site occurred during the Middle Holocene (Lentfer and Torrence 2007:100). The uneven distribution of artefacts within the stratigraphic sequence in 970/1000 pit (Table 6.2) also supports the sporadic use of FAO during this chronological period.

The surface disturbance during the middle Holocene by both clearing and burning are obvious evidence of human activities at the site. The density and distribution of obsidian artefacts give a good indication of how these activities were spatially organised and it is possible to reconstruct some aspects of the site's use from archaeological evidence. There are two areas of concentration of obsidian artefacts: 970/1000 pit which was interpreted as a dumping ground where "rubbish was swept downhill behind the houses" (Torrence 1993:5) and 1000/1010 pit with a thick layer of obsidian waste apparently representing a workshop (Symons 2001:56-82; Torrence 1993:5). These features within the site provide some information about an intra-site structure with spatially organised activity areas.

Archaeologically, it is assumed that because tasks were distributed differently in space, the tools employed in these activities would also have a patterned distribution (Rigaud and Simek 1991). However, many human and non-human factors (e.g. the length of occupation, intentional cleaning of waste to maintain activity areas, size sorting of artefacts across and within occupation floor, geological processes and topography) can influence spatial distribution of artefacts (Gosden 1991a; Keeley 1991; Kelly 1992; Kent 1991:34; Rigaud and Simek 1991; Stevenson 1991). All of these factors should be considered in the identification of spatial patterns when the site structure is examined using the distribution of artefacts (Carr 1991).

The most visible activity represented in the archaeological record is knapping and tool manufacturing. Flaking debris resulting from production activity is likely to have been deposited at or very near its locus of origin within the site (Ahler 1989). This should contrast with the distribution of tools which may have been influenced by the movement of tools and their discard in areas away from where they were used for the
performance of particular tasks. However, in the situation when formal tools are extremely rare (the Middle Holocene period) or absent altogether (the Late Holocene period), the consideration of tool distribution and activity patterning is almost impossible without use-wear/residue studies.

In contrast to artefacts, the distribution of functionally identified tools can provide more precise data about the use of space on the site, but this issue has to be incorporated into a much wider context of human behaviour (Keeley 1991). For instance, the cleaning of intensely used domestic areas can affect where and when a tool will be discarded in two ways. First, cleanup material will accumulate in the special disposal area: for example, the dumping ground at FAO. Such a disposal area will contain a wide and slightly confusing variety of tools in high densities and will include larger tools (Keeley 1991:258). Second, as a result of cleaning, the activity area is likely to be evidenced by a low-density of small tools and their fragments which escaped cleaning operations on the site (Keeley 1991:258; O'Connell et al. 1991:67).

It is also important to emphasise that regular cleanup behaviour is a characteristic of sites which are occupied for a greater length of time than of short-term camps. Cultural remains simply do not accumulate during relatively brief periods of occupation and groups who moved camp frequently may have rarely engaged in intensive refuse cleanup operations (Gregg, Kintigh and Whallon 1991:150; Stevenson 1991:270). The various stages of an occupation may also be associated with different patterns of refuse disposal and space use at the site because the common trend in re-occupation is to avoid camping on the debris of previous occupation or refuse cleaning (Keeley 1991:258-260; Stevenson 1991:275-276).

For a better understanding of how prehistoric people could organise their tasks spatially when they occupy a place, it is important to review some existing ethnoarchaeological and ethnographic knowledge obtained through the study of societies in comparable tropical and subtropical regions. According to these data, activity areas in the residential camp of tropical societies usually include household, communal, and special activity areas (O'Connell et al. 1991:65-68). Household areas are occupied by one group and include a hut marked by a circle of cleared ground 2 to 6 m in diameter and hearths inside and outside the hut. Around the hut is an activity area used for a wide range of domestic tasks, including preparation and consumption of food, the manufacture and maintenance of tools, clothing and other equipment. Activity areas are usually kept clean of refuse by sweeping. Much of the cleared material is deposited in secondary refuse areas along the edge of the activity area. Some proportion of smaller
items may be trampled into the ground rather than be swept into disposal areas and large ones are removed. Communal areas are used for the same range of activities but are used by all members of the group who gather around. This area is also periodically swept clear of refuse. The size of the area varies from 4 to 6 m across and usually does not contain any structures. (e.g. Bartram, Kroll and Bunn 1991: 96-97; Hogbin 1938:175; Kirch 1997:167; O'Connell et al. 1991:67-68; Parkinson 1999:27).

The early stage of the middle Holocene occupation of FAO is observed only in two pits: 1000/1000 and 970/1000 (Torrence and Webb 1993:6-7). According to the concentration of artefacts recovered by spit 4 (106 specimens) and 5 (56 specimens) in 1000/1000 pit, it would be reasonable to suggest that most activities were concentrated at the central part of the site (Table 6.2). In contrast, in 970/1000 pit, a small number of artefacts were excavated by spit 4 (27 specimens) and increased density was recovered by spit 3 (92 specimens) indicating that this area was not used as a dumping ground during the earliest stage of occupation (Chapter 6). Furthermore, use-wear/residue examination of all the artefacts recovered by the excavations of these two test pits revealed unexpected functional variability between 1000/1000 and 970/1000. The concentration of artefacts in the central part of the site is comprised mainly of the by-products of knapping activity (160 specimens). Only two flakes were tools used for working non-siliceous soft wood (Table 8.2). This fact clearly indicates that the area was probably briefly used for flaking activity. In contrast, a "dumping ground" area (970/1000 pit) includes numerous and diverse tools (30 tools of the total 119 artefacts) which were involving in woodworking activities (21 tools), processing tubers (5 tools), greens (3 tools) and working shell (1 tool) (Table 8.2). This distributional pattern of actual tools in both test pits suggests that the domestic activity area was apparently located close to the western edge of the hill during the initial occupation while the centre of the site was used differently: as a localised space for the manufacture of lithic implements.

Significant differences in the distributional pattern of activities at FAO are observed in the upper part of the deposit associated with the latest stage of occupation immediately before the WK-2 eruption. The central area (pits 1000/1000, 1001/1000 and 1000/999) is characterised by the concentration of flakes (212 specimens) and tools (21 specimens) representing probably a kind of "communal" area (Figure 8.1) where members of the group could perform their daily activities with periodic cleanup of accumulated refuse (Lentfer and Torrence 2006:100). Tools in this area were used for food processing (tubers and fish), working greens and skin, woodworking and knapping.
activities (Table 7.8). All of these activities were related to meeting daily needs, including knapping of flakes when they were required for the performance of tasks.

A dumping ground, or refuse area (970/1000 pit), which is obviously associated with the last stage of occupation prior to the W-K2 eruption, contains a high concentration of discarded material (166 artefacts). The area is located 30 metres away from the "communal area", on the western edge of the hill (Figure 8.1). Among 25 discarded tools of different sizes, woodworking implements are prevalent (16 specimens), although tools for processing food, greens, skin and shell are also presented (Tables 7.7 and 8.2).

Pits 980/1000 and 990/1000 are located between the "communal" and refuse areas some 10 metres from each of them and include a relatively low number of artefacts (63 and 72 specimens accordingly). Each pit contains 12 tools and these tools were used for working woody plants, tubers, fish, greens and skin (Table 8.2). Interestingly, that of the total of 11 small tools involved in processing skin, 7 were found within these pits and reflect the kinds of specific social activity performed around this area. A low number of unused flakes within these pits indicate that knapping activity probably occurred only occasionally. The set of tools and associated activities, as well as a relatively low density of artefacts within these pits suggests that the area around these pits was probably used as a living space or household area (O'Connell et al. 1991:66) which could potentially comprise some kind of shelter construction surrounded by an area for domestic activities (Figure 8.1).

The very dense deposit of obsidian waste recovered in 1010/1000 pit located some 10 metres to the north of the "communal" area (Figure 8.1) can be considered as an area associated with a specific workshop activity. A wide variety of flakes, some relatively small cores and a limited number of tools (Symons 2001:57) clearly indicate the intentional creation of a specific space outside the main habitation area of the site which was used either for flaking obsidian raw material or as dumping ground for debris resulted from knapping activity.

The proposed reconstruction of the intra-site structure at the final stage of the middle Holocene occupation includes a system of spatial organisation involving a "communal" activity area, dumping ground for cleanup material, living or some sort of household area and lithic workshop. These discrete areas suggest a prolonged period of occupation of FAO which was interrupted by the devastating WK-2 eruption. In comparison with this later period, the activities at the early stage of middle Holocene occupation were concentrated close to the western edge of the hill overlooking the sea.
It is difficult to examine in more detail the spatial organisation of activities of the earliest inhabitants because of the limited data available. However, it is obvious that habitation areas of the early and late stages of occupation do not overlap stratigraphically or spatially (Figure 8.1; Table 6.2) indicating a chronological gap between occupation periods. It is possible to suggest that the hill was sporadically used by people at the beginning of the middle Holocene in contrast to the more organised and prolonged occupation which occurred at the end of the middle Holocene. This suggestion as to changes in spatial patterns of activities over time is generally supported by past human disturbance of the surface observed in the distributional patterning of phytoliths within the sediments (Lentfer 2003:301-304; Lentfer and Torrence 2007, Parr et al. 2001).

The nature of FAO as a consumption site with its multiple activities is difficult to assess from the perspective of overall settlement patterns on Garua Island because of the limited amount of comparable information that is available for other types of sites distributed within the island's landscape (Torrence 1993; Torrence and Webb 1992). My use-wear/residue functional interpretation of stemmed tools found off-site and at 8 sites located on a variety of topographical settings allows the assumption that other sites with multiple activities and prolonged periods of occupations similar to FAO possibly existed on Garua Island during the middle Holocene period (Kononenko, Torrence and Doelman, in prep). This assumption together with the full range and spatial organisation of activities at FAO suggested above, the complex intra site structure along with evidence of regular cleanup of habitation areas does not support the hypothesised settlement patterns of short-term occupation of locations within the island's landscape by highly mobile groups (Torrence 2002a:773; Torrence et al. 2000:237).

8.6 FAO Site Structure and Settlement Patterns on Garua Island during the Late Holocene Period

The distributional pattern of discarded artefacts indicates a significant shift in human behaviour on Garua Island during the Late Holocene (Torrence 2002a:774; Torrence and Stevenson 2000:338). The material recovered by test pits shows a more clustered pattern of the distribution in the Late Holocene deposits than its homogeneous spread in the Middle Holocene period. The clustered patterning of artefacts on the coastal plain, ridges and hilltops and, rarely, in the high interior regions of the island, allowed the proposal that human activities during this chronological period were more
focused on a few particular places in the landscape and this is considered as evidence of long-term occupation of the sites associated with more intensive forms of land use and cultivation (Lentfer and Torrence 2007:100; Torrence 2002a:773-774; Torrence and Stevenson 2000:338-339; Torrence et al. 2000:241-242).

Following the WK-2 eruption, five phases of land use on Garua Island were determined (Torrence and Stevenson 2000:335-337). Phase 1 (ca. 3400 - 2800 BP) represents the first re-colonisation of the island after abandonment caused by the devastating W-K2 eruption. This phase is associated with coastal locations FYS and FAAN. Tephra erosion observed around FYS probably indicates clearance of this site as part of the initial re-colonisation (Boyd and Torrence 1996:269). The location at FAAN may represent rubbish dumps on the edge of sites with the majority occupation on the beach (Torrence and Stevenson 2000:335). Many fragments of Lapita pottery were collected in a redeposited coastal context at FQY that allow the suggestion that there were a number of other early Lapita sites on Garua Island. This evidence indicates that during Phase 1 people occupied only the coastal part of the island (Torrence and Stevenson 2000:335).

The coastal zone remained in use during Phase II (ca. 2800 – 2400 BP), although human activities were expanded into other parts of the island. Most of the locations (FAO, FQY, FSZ, FAAJ and E7) are situated on hilltops or slopes with steep sides and are orientated towards the coast with panoramic views of the sea. An exception is inland site FAQ where no pottery has been found but one of the test pits contained abundant obsidian artefacts and Canarium shell nuts dated about 2720 BP. Probably this location has been used for special activities, such as gardening or nut harvesting (Torrence and Stevenson 2000:336).

Phase III (ca. 2400 – 2000 BP) demonstrates a significant expansion of land use into a wide range of topographic settings including small hills, ridges, inland plain, and hollows. Most of the locations occurred within the vicinity of the previously occupied areas at FSZ, D7 and FAO. It is suggested, that the reason for this change might be related to a rise in population density, or a difference in the nature or intensity of activities, or a shift from a centralised to a dispersed settlement pattern. The general distribution of the locations shows that easy access to the coast continued to be an important factor (Torrence and Stevenson 2000:336-337).

During Phase IV (ca. 2000 – 1600 BP), the FAO site may have been used less intensely or even abandoned whilst a few other key locations (FSZ, E1, and G11) continued to be intensively used. Finally, Phase V (1600 – 1000 BP) is associated only
with the easily defended hilltops at FSZ and FAO. Probably by this time many people had left the island (Torrence 2002a:772-773; Torrence and Stevenson 2000:337).

The occupation of FAO after WK-2 eruption is associated with Phases II and III (Torrence and Stevenson 2000:336). The first inhabitants appeared at the site when grasses and pioneer regrowth forest were already established in the area. However, sediment sequences indicate severe forest degradation, deliberate vegetation clearance and burning episodes related to human activities at the site (Boyd et al. 2005; Lentfer and Torrence 2007). The centre of FAO was continually disturbed by activities of the late Holocene inhabitants while vegetation on the southeast part of the site experienced only minor disturbance (Parr et al. 2000:132). It is also stressed that the overall density of discarded obsidian artefacts essentially decreased during the late Holocene occupation and pottery appeared at the site in contrast to the middle Holocene period with its high density of artefacts and absence of pottery (Lentfer and Torrence 2007:100).

The late Holocene stratigraphical unit at the site is identified as Layer 8 (Lentfer and Torrence 2007). This layer comprises the lower, middle and upper parts which were excavated by spits 3, 2 and 1 respectively (Torrence 1993:5; Torrence and Webb 1992:6-7). Each of these parts is characterised by different densities of accumulated artefacts within each excavated unit (Table 6.2). The lower part of Layer 8 excavated by spit 3 indicates at least two structural components of the site: the refuse area (970/1000 pit) and probably a "communal" area which was located around 1000/1000 pit. The refuse area includes the high concentration of debitage (164 specimens) and tools (35 specimens). Discarded tools were mainly involved in woodworking activity (25 artefacts) though tools for processing food, including tubers (3 tools) and fish (3 tools), greens (3 tools) and skin (1 tool) were also present (Table 8.3). The "communal" area is characterised by a relatively low number of finds which include 58 unused flakes and nine flake tools used for processing siliceous soft wood, palm and bamboo (5 artefacts), soft non-siliceous wood (1 artefact) and tubers (3 artefacts). At this level of excavation there are two other pits with some significant density of artefacts: 989/1020 pit which is situated in the northern part of the site and 990/990 pit which is located in the south side of the site (Figure 6.2).

Some changes in the patterning of obsidian artefacts are observed within the middle part of Layer 8. Firstly, the density of artefacts essentially increases in the northern and southern parts of the sites in comparison with the centre (Table 6.2). Secondly, the number of artefacts in the refuse area dramatically dropped indicating that
there was some change to the cleanup strategy employed. Among 54 discarded artefacts in 970/1000 pit are eight tools which were used for processing wood, tubers, greens and skin (Table 8.3). Finally, the number of unused flakes and tools in the "communal" area slightly decreased: 58 flakes and five tools including four woodworking implements and one small tool for processing skin. A few tools and small number of unused flakes were found in 980/1000 and 990/1000 pits (Table 8.3) indicating the performance of some occasional tasks in places outside of the main activity area.

The distribution of artefacts in the upper part of Layer 8 shows the continuity of the previous observed trend: a gradual spatial reorganisation of activities from the central part to the southern and northern edges of the hill (Table 6.2). At this level of occupation the refuse area apparently stopped being used. It is notable that of the total of 32 artefacts found in 970/1000 pit at this level, 11 were used for processing wood (6 tools), tubers (3 tools) and greens (2 tools) signalling the use of this part of the site for domestic activities, possibly as a "communal" area, during the latest period of occupation (Figure 8.2). The central part of the site including the former "communal" area around 1000/1000 pit demonstrates occasional use of this space probably as a living area (Figure 8.2): in summary the number of artefacts recovered at the central part comprises 77 flakes of which eight were used for woodworking tasks and one small flake was involved in processing skin.

Gradual changes in the spatial organisation of activities at FAO observed in the archaeological record are definite evidence for the continuous use of this location through the late Holocene period. However, the comparison of the distributional patterns of artefacts between lower, middle and upper parts of Layer 8 shows that the density of artefacts within each part of the deposit is generally low and most likely resulted from non-intensive but repeated use of the site. The refuse area (970/1000 pit) mainly functioned during the earliest phase of occupation. Northern (989/1010 pit) and southern (990/990 pit) parts of the site were apparently used more intensively probably as "communal" areas in the latest period of occupation (Figure 8.2; Table 6.2) and this is evidence of the repeated re-use of FAO.

The spatial and temporal changes in the distributional pattern of activities from the central part of the site, at the beginning of occupation, to the southern and northern edges of the hill, in the later period, and the transformation of dumped ground into an area for domestic activities over time allow the assumption that the site was not a large village or small stable hamlet permanently occupied over a long period of time (Kirch 1997:167; Torrence 2003:298). FAO was a convenient place which was repeatedly
settled by small groups of people. Multiple activities and some structural features which are reflected in the set of tools and their distribution suggest a relatively prolonged period of time spent by inhabitants at the site during each stage of occupation. This pattern of the late Holocene occupation of FAO in association with the evidence of marine resource exploitation and gardening (Lentfer and Torrence 2007) is consistent with the model of mobile Lapita sites proposed by Gosden and Pavlides (1994) for the Arawe islands and Summerhayes's model of mobility for the early Lapita period in the Bismarck Archipelago (Summerhayes 2000:234).

8.7 FAO and Technological Aspects of the Middle Holocene Obsidian Assemblage

The middle Holocene lithic assemblage at FAO comprises a large number of flakes, some cores (Symons 2003) and eight retouched tools represented by small and medium-sized stemmed tools. The presence of stemmed tools is considered as an important technological and chronological marker for the early and middle Holocene periods that is closely linked to the system of technological organisation, mobility and settlement patterns of human populations in New Britain (e.g. Pavlides 1999, 2006; Torrence 1992, Torrence et al. 2000).

The concept of technological organisation considers such aspects of human activities as raw material procurement, production, use, maintenance, transportation and discard of stone artefacts, and this provides the foundation for the investigation of the relationship between subsistence, mobility and settlement patterns. There are two general types of technological organisation which are established in archaeological and ethnographic observations: organisation based on expedient technology and the system associated with curated technology (e.g. Bamforth 1986, 1991, Binford 1979, 1996; Jochim 1989, Nash 1996; Odell 1996a, 1996b, Schiffer 1975, 1979, Torrence 1989 a, 1989b, 2003).

Technological organisation based on expediency produces technologically simpler and formally less patterned lithic assemblages, comprised of tools that are manufactured, used and discarded according to the needs of the moment (e.g. Bamforth 1986; Binford 1979; Nash 1996; Odell 1996). This type of technological organisation is common in prehistory and until relatively recent times was representative of societies inhabiting the Pacific region (e.g. Allen 2003; Gosden 2005; Gosden and Robertson 1991; Marshall and Allen 1991; Pavlides 2006; Sillitoe and Hardy 2003; Spriggs
An exception is that of assemblages from the early and middle Holocene periods in New Britain in areas with abundant lithic raw material sources. These assemblages indicate relatively complicated technological behaviour associated with a curated technology (Pavlides 1999, 2006; Symons 2003; Torrence 1992, 2002a, b; Torrence et al. 2000).

Technological organisation based on curation is characterised by technologically sophisticated and formally distinct lithic assemblages comprising tools that are manufactured in anticipation of use, effective for a variety of tasks (multiple uses), maintained through a number of uses, transported from locality to locality and recycled to other tasks when no longer useful for their primary purposes (e.g. Bamforth 1986; Binford 1979:269; Hayden, Franco and Spafford 1996; Nash 1996; Odell 1996b; Torrence 1989a, 1989b). Data obtained through functional analysis have offered the possibility of extending the interpretation of the main components of both expedient and curated technologies which are usually reconstructed by scholars on the basis of morphological and technological studies (Odell 1996b).

Obsidian stemmed artefacts are the only distinctive category of formal tools within the early and middle Holocene lithic assemblages in the Willaumez Peninsula and on Garua Island. These tools were mostly found on the surface near the obsidian sources on Garua Island, Talasea and Mopir regions of West New Britain. However, a number of stemmed tools were recovered from stratigraphic contexts at Bitokara Mission and Garua Island (Fullagar 1992; Specht et al. 1988; Specht et al. 1991; Torrence 1992; Torrence et al. 1990) and these finds formed the basis for Torrence's model (1992:120-123) of the early and middle Holocene curated technology associated with a highly mobile settlement pattern of the human populations in West New Britain.

According to this model, stemmed artefacts were manufactured at the obsidian sources in anticipation of use as portable implements that were employed as multi-purpose tools for a variety of tasks, carried around, maintained and re-used as cores (Torrence 1992, 2004a, Torrence et al. 2000). Torrence's model was supported by Fullagar (1992, 1993a, 1993b) on the basis of his use-wear/residue examination of 13 stemmed tools excavated at the FRL site, Bitokara Mission. The analysis revealed multi-functional use of five tools which were involved in the processing of both plants and animals, while eight stemmed artefacts were associated with the working of plants (Fullagar 1992:140, 1993b:2-3; Kealhofer et al. 1999:534).

In contrast to the excavated samples, stemmed tools from the surface collection are large in size and are usually formed on deliberately prepared blades (Type 1) or
Kombewa flakes (Type 2) (Araho et al. 2002:63-66; Torrence 2004a:165). Technological and morphological characteristics of both these types have been taken to indicate that their production was costly, both in terms of time and effort, and that the manufacturing process incorporated a multi-staged reduction sequence involving skill and knowledge (Araho et al. 2002; Rath and Torrence 2003; Torrence 2004a).

Three main interpretations are proposed by scholars for the function of stemmed tools found in West New Britain. The first interpretation, that stemmed artefacts were associated with utilitarian functions, formed the basis of the proposal for a curated technology (Fullagar 1992, 1993a, 1993b; Kealhofer et al. 1999; Torrence 1992, 2004a; Torrence et al. 2000). The second suggested function of stemmed tools is associated with Araho's proposition that stemmed tools were produced and circulated within a ceremonial system of exchange (Araho et al. 2002). The third notion proposed that stemmed obsidian artefacts had multiple roles within the society including utilitarian use, ceremonial and utilitarian exchange and as symbolic valuables that played an important role in creating and maintaining prehistoric social relations (Araho et al. 2002; Rath and Torrence 2003; Specht 2005; Torrence 2002b, 2003, 2004a; Torrence and Summerhayes 1997; Torrence et al. 2000). The finds of isolated obsidian stemmed tools in different areas of New Britain (Specht 2005), on mainland New Guinea, New Ireland and Manus suggests that these types of artefacts circulated widely as valuables and were curated and maintained by the users (Araho et al. 2002:75, Torrence 2004a:169). Because of the great effort and time invested in the preparation and manufacture of large stemmed tools of both Type 1 and Type 2, they could simultaneously hold both utilitarian and symbolic functions in the context of the particular social situation. Once distant from the stemmed tool quarries and with a short supply of stone raw material, this category of tools might have been resharpened and heavily used until reduced to the point of exhaustion. Two stemmed artefacts from Baku Hill (Torrence 2004a:165-167) clearly support this strategy of rational use of valuables.

The vast majority of by-products related to the core preparation and stemmed tool manufacture are found at the exposed obsidian sources and close-by sites: e.g. FRL at Bitokkara Mission and FAP in the Malaiol Stream on Garua Island (Fullagar 1993a; Rath and Torrence 2003; Torrence 1992; Torrence et al. 1992). This indicates that both FRL and FAP represent quarry sites where the manufacture of large stemmed tools was undertaken (Araho et al. 2002, Rath and Torrence 2003; Torrence 1992). In addition, a large collection of bladed forms of stemmed tools was found at the FAR site located on
the eastern coast of the island (Torrence and Boyd 1996b:8) and these finds probably also indicate a workshop site.

In contrast to quarry and workshop sites, excavated sites on Garua Island do not contain evidence of the complicated, staged production of large stemmed tools, with, probably, the exception of FAO and FAQ (Rath and Torrence 2003; Torrence 2004a). The location of these finds is significant in seeking to address questions of the functional and technological relationship between large stemmed tools found in surface contexts at quarry sites and the much smaller versions in stratigraphical context recovered from excavated sites including FAO.

Of the total 103 stemmed artefacts found by Torrence's excavations on Garua Island (Torrence 1993; 1995; Torrence and Boyd 1996; 1997; Torrence and Webb 1992), 36 tools were the subject of my use-wear study (Kononenko, Torrence and Doelman, in prep.). The examined collection comprises stemmed tools found directly at FAO (8 specimens) and off-site (6 specimens from pits E4, E5, E9 and E10) (Torrence and Boyd 1997: Table 1) and also includes 22 finds from other 8 middle Holocene sites distributed throughout various topographical settings on the island: FQY, FAAI, FAAQ, FAQ, FSZ, FAAK, FAAN and FAP (Kononenko et al., in prep.; Torrence, Swadling, Ambrose, Kononenko, Rath and Glascock, in press). The technological and functional comparison of these stemmed tools revealed some common trends in their manufacture and use.

Stemmed tools from FAO are small to medium in size and were made of flakes with the exceptions of one formed on a Kombewa flake and one made on a blade-like flake. Use-wear/residue analysis of six artefacts revealed their moderate use for whittling/scraping and drilling of hard siliceous wood and soft wood, scraping/slicing tubers, cutting/piercing and cutting skin (Chapter 7). There are no indications of their multiple uses, maintenance through resharpening or recycling of used stemmed artefacts for other tasks.

Off-site stemmed tools, also made of flakes, were discarded after short or moderate periods of use for similar functions as those from FAO: scraping tubers, whittling/sawing and drilling soft wood. The tools are small and medium in size and do not indicate multiple uses or resharpening (Kononenko et al., in prep.). Similar technological feature are observed on stemmed tools from other sites on Garua Island. The result of their microscopic examination indicates either short-term or moderate duration of use for scraping/slicing tubers, sawing, whittling, scraping and drilling soft wood and piercing and cutting skin. All the analysed stemmed tools were single purpose.
implements which were discarded after the performance of tasks. The number of finds of skin processing tools (10 of 22 analysed stemmed artefacts) can be explained by their frequent loss because of their small and very small size. I believe that the manufacture of skin processing implements, as a category of utilitarian stemmed tools, was a specialised task by people using obsidian raw material and the tools had specific functions related to body adornment and medical treatment.

My preliminary observation of stemmed artefacts found by excavation, rather than those found on the surface, on Garua Island, followed by my microscopic examination of the sampled tools indicate that they were mainly made of simple flakes by casual percussion or pressure retouch using hammer stones. Tools made of deliberately prepared Kombewa flakes or blades are rare. The morphology, size and wear patterns of these tools demonstrate a set of common features which make it reasonable to combine and classify them under the generalised Type 3. This type is obviously separated by its utilitarian function from large stemmed tools of Type 1 and 2 considered as valuables (Araho et al. 2002; Rath and Torrence 2003; Specht 2005; Torrence 2003, 2004a; Torrence et al. 2000).

The fact that large samples of Type 1 and 2 are extremely rare at the excavated sites on Garua Island and also that they are represented only by broken stems allows the assumption that those group of tools regarded as valuables were not circulated between the middle Holocene inhabitants of the island on a regular basis. However, the finds of small stemmed tools of Type 3 clearly indicate that inhabitants were definitely familiar with the technological aspects of the manufacture of this category of artefacts. This knowledge and probably tradition, as well as the abundance of obsidian raw material on the island (Torrence et al. 1992) encouraged people to produce small utilitarian stemmed tools for the performance of daily tasks using widely available flakes and they avoided the costly search for large blocks of obsidian, special preparation of cores, knapping of blades and Kombewa flakes and final manufacture of large stemmed tools (Araho et al. 2002; Rath and Torrence 2003; Torrence 1992, 2004a).

My experiments with knapping and manufacture of small stemmed tools showed that forming the stem on an appropriate flake using any stone as a hammer, including chunky pieces of obsidian, does not require much time, energy and skill as has been suggested for the manufacture of Type 1 and 2 (Araho et al. 2002; Torrence 2004a). Moreover, the stem of the tool itself was not always intended to be used for attaching a handle which needs to be inserted and tied or glued into a wooden devise to create the composite tool. The useful role of the stem is more able to be appreciated in the hand-
hafted mode of tool use. The retouched stem, separated from the working body of the tool especially when it is wrapped, protects the hands from occasional cutting and provides a comfortable and confident hold during the performance of tasks. Some of the examined stemmed tools from sites preserved residues and wear indicating their wrapping in plant materials and this practice is further supported by phytoliths analysis (Kealhofer et al. 1999).

Use-wear results of excavated stemmed tools on Garua Island (Kononenko et al., in prep.; Torrence et al. in press) indicate common trends: (1) medium or light intensity of use, (2) moderate or short term duration of use, (3) processing of a variety of plant and non-plant materials and (4) diverse modes of use. This pattern of use of formal tools on Garua Island generally, and at FAO particularly, is consistent with an expedient strategy of the use of flakes detected at FAO (Chapter 7). The manufacture of small utilitarian stemmed tools was apparently performed at the site as a casual activity when such type of tools was needed. The efficiency of this strategy in tool manufacture and use is closely related to the availability of obsidian raw material around the habitation area which definitely affected the way that implements were produced and utilised (Bamforth 1986; Odell 1996b).

The abundance and accessibility of secondary and, to a lesser extent, primary obsidian sources on Garua Island (Torrence et al. 1992) apparently influenced all aspects of technological organisation of those social groups which inhabited the island. From the behavioural perspective, easy surface access to immediately available obsidian cobbles, blocks and small tabular pieces did not require the organisation and performance of highly energy and time consuming activities associated with the manufacture of tools in anticipation of use, their maintenance, recycling and transportation (Bamforth 1986, 1991; Binford 1979; Torrence 1989a, 1989b). Useful obsidian on Garua Island was easily accessible on the surface of some hilltops, beaches, and streams including the bed of Malaiol Stream with a series of exposed secondary sources (Specht et al. 1988; Torrence et al. 1992; Torrence et al. 1996). As Bamforth (1986) pointed out, in an area rich in lithic resources it would be more efficient to pick up more flakes and to use them as new tools than to resharpen or recycle worn out or broken old implements. Also, there is no need to "transport tools from place to place if raw material could be obtained everywhere" (Bamforth 1986:40). Furthermore, the tropical rainforest and marine resources could provide a wide range of alternative raw materials (e.g. wood, bamboo, shell) which would be useful for the manufacture of effective perishable implements for day-to-day activities, such as spears, knives,
scrapers, digging sticks and weapons (Parkinson 1999; Sillitoe 1988; Torrence 2004b). These kinds of raw materials "were more widely available at low cost and could provide sharp edges that were generally stronger and more durable than any retouched obsidian artefact" (Torrence 2004b: 121). From this point of view, there is some doubt that the middle Holocene inhabitants on Garua Island had complicated technological organisation based on curated technology (Torrence 1992, 2004a, 2004b).

As emphasised above, available archaeological data obtained on Garua Island (e.g. Torrence 1992, 1993, 1995, 2002a, 2004a, 2004b; Torrence and Boyd 1996, 1997; Torrence and Stevenson 2000; Torrence and Summerhayes 1997; Torrence and Webb 1992; Torrence et al. 2000) and detailed use-wear/residue analysis of the middle Holocene obsidian assemblage at FAO does not produce evidence of technologically sophisticated and formally distinct lithic assemblages. A similar trend in lithic assemblages is observed in the Isthmus region of the Willaumez Peninsula (Torrence et al. 2000). Stemmed tools, as the only category of formal tools, functionally represent two major classes as proposed by Araho et al. (2002): non-utilitarian large stemmed tools consisting mainly of Types 1 and 2 and utilitarian small stemmed tools comprising mostly of Type 3 and occasionally Type 1 and 2. Utilitarian tools were mainly made of flakes in a casual manner when they were needed to perform the task and do not indicate any features of their manufacture in anticipation of future use.

Multifunctional use of Type 3 stemmed tools for two or more tasks was not identified within the examined collection on Garua Island. Also resharpening or recycling of used stemmed artefacts for other tasks was not detected in the collection. The potential use of stemmed tools as cores is possible only for the early stage of life of stemmed tools and only if they were large enough in size to permit further reduction. The utilitarian stemmed tools are small. The largest one is less than 5 cm in length, 4 cm wide with maximum thickness of the stem about 1.5 cm and so are too small to produce useful flakes and would themselves be ruined by attempts to do so on fragile obsidian. All of these data do not support the hypothesis of curated technology and associated highly mobile settlement pattern proposed by scholars (Fullagar 1992, 1993a; Torrence 1992, 2004a; Torrence et al. 2000). The middle Holocene pattern of tool use on the island with abundant obsidian resources is evident in the expedient technological strategy. However, this does not preclude the co-function of ordinary sites at which a diverse set of activities were carried out and special quarry sites set aside for the manufacture of non-utilitarian stemmed tools within the cultural landscape of Garua Island.
Large stemmed tools of both Type 1 and Type 2 on Garua Island were mostly manufactured as valuable items at FAP quarry site and then distributed within the region through exchange and other social actions (Rath and Torrence 2003). Use-wear/residue analysis of three stemmed tools of the total of 28 samples recorded at FAP (Kononenko et al., in prep.) provides new insight into the interpretation of this quarry site. Firstly, despite large amounts of by-product associated with the manufacture of stemmed tools, there are some complete samples including tools with utilitarian functions. Two medium-size stemmed tools made of flakes (M150 and M 539) show wear patterns associated with the processing of tubers. This fact indicates that prehistoric inhabitants not just visited the quarry to obtain raw material and produce valuables, but stayed for periods of time performing some other daily activities. Moreover, used stemmed tools support the pattern observed within lithic assemblages from the excavated sites: ordinary stemmed tools for utilitarian tasks were manufactured using simple flakes.

Secondly, one large and complete stemmed tool (M267) recovered from the stratigraphic deposit at FAP site is characterised by distinctive wear patterns (Torrence et al., in press). The working edge of the tools is slightly rounded in plan view and is characterised by continuous feathered micro scars, parallel or slightly diagonal, narrow and deep striations and light merging polish. These wear features indicate that the tool was used for cutting soft elastic material such as meat with occasional contacts with a harder substance such as bone that resulted in a more intensive scarring on some parts of the edge. Interestingly, similar wear patterns are identified on two large Kombewa flakes with very sharp, strong edges and hafting areas which were partly and deliberately formed by percussion retouch.

Use-wear peculiarities resulted from the contact with bone and meat and morphological features of these three artefacts allow the suggestion that they were kinds of weapons. Interestingly, stemmed tools similar to these large types were used as spearheads in warfare to lacerate an enemy in close combat on Easter Island between about A.D. 1500 to 1722 (Kirch 2000:273-274). If my suggestion is correct, then the presence of both Type 2 and large Kombewa tools with utilitarian functions as weapons at the quarry site may be considered as evidence of possible social conflicts between the group of people who probably owned and controlled the quarry (Rath and Torrence 2003:126) and newcomers seeking the ability to procure valuable obsidian material and to establish social links (Torrence 2004b:121-122). The maintenance of prehistoric social relations between the inhabitants of Garua Island and the mainland population...
during the middle Holocene is well shown by the presence at the FAP quarry site of some imported obsidian from the Kutau/Bao sources transported by watercraft to the island (Araho et al. 2002:72-75; Rath and Torrence 2003; Torrence 2004a:170; Torrence and Summerhayes 1997:81-82; Torrence et al. 1996:217). The presence of weapons on the quarry site indicates that social relations were not necessarily always peaceful within the middle Holocene cultural landscape on Garua Island.

8.8 FAO and Technological Aspects of the Late Holocene Obsidian Assemblage

The Late Holocene obsidian assemblages in West New Britain including Garua Island demonstrate changes in technological organisation associated with the disappearance of stemmed tools and introduction of the expedient production and use of unmodified flakes. Formal tools during this period are extremely rare and include four small stemmed tools which were found at the FEA Lapita pottery site on Boduna Island located in Garua Harbour, at FRI at Walindi and at FEL on Garua Island (Ambrose and Gosden 1991; Gosden et al. 1989; Specht 2005; Specht et al. 1991; Torrence 2002b). The finds of these tools raises the issue as to whether their manufacture continued from a former chronological period or had they been scavenged from the older stratigraphical context (Specht and Summerhayes 2007; Torrence 2002b:186).

No formal tools were found in the late Holocene deposit at FAO where the lithic assemblage is represented by flakes and very rarely by small amorphous cores and chunky pieces of obsidian. Some flakes preserved unsystematic edge damage which resulted mainly from the use. Use-wear/residue examination of obsidian artefacts from FAO indicates that flakes were used for a variety of activities (Chapter 7). The choice of flakes for the performance of particular tasks apparently was determined by the shape and sharpness of the working edge and the material being processed and, to a lesser degree, by the overall shape and size of the implement. Thin and relatively sharp, straight or irregular edges were employed for cutting greens, cutting/slicing tubers, piercing and cutting soft elastic material and carving soft wood while much stronger and thicker profile edges were required for woodworking activities.

Of the total number of used tools at the site, 33 percent preserved cortex on dorsal surfaces (Table 7.16). This indicates that, firstly, no particular technological strategy was involved in the manufacture of flakes and, secondly, the selection of flakes for any activity was based on those morphological features which were the most appropriate for
the performance of particular tasks. These technological and morphological peculiarities of the late Holocene implements and their mostly short-term use for a diverse set of activities at FAO are consistent with the nature of the expedient technology proposed for this chronological period (Torrence 1992:120-121). The concept of expedient technological organisation as a practical solution to the problem of having the tools available when they are needed (e.g. Bamforth 1986; Binford 1979; Nash 1996; Odell 1996a, 1996b) allows comparison with ethnographic and historical data obtained in West New Britain and other areas of the New Guinea.

The ethnographic data show that remarkably expedient tool manufacture, use, and discard practices existed among relatively recent users of stone tools. Any flake having a suitable edge might be used for a task, and often shape played a minor role in decisions about tool use (White and Thomas 1972). In relation to obsidian raw materials in New Britain, Specht (1981:346) noted that suitable pieces of obsidian were collected from the ground or by digging at the sources. The selection of samples was based on the appropriateness of shape and size as being necessary for knapping. Further reduction of the selected pieces often took place at villages. Blocks or large flakes of obsidian were transported to the village to be used as a core from which flakes with sharp edges were knapped. Core preparation was limited to the removal of weathered surfaces. There were no attempt to prepare striking platforms and flake size and shape were less controlled during knapping because the main task was to obtain flakes with sharp edges. The modification of flakes by retouch was not practised (Specht 1981:346). Similar approaches to the collecting and knapping of stone raw materials where the main task was to obtain flakes with sharp edges which could be used without further modifications, are recorded in the New Guinea Highlands (e.g. Sillitoe and Hardy 2003; White 1967, 1968; White and Thomas 1972). Many of these features of tool use strategies are similar to those that have been observed in the late Holocene obsidian assemblage from FAO.

The change in the late Holocene lithic technology at FAO is comparable with common trends observed in the archaeological record in New Britain (Pavlides 1999, 2006; Torrence 1992, 2000a; Torrence et al. 2000) and corresponds well with the expedient technology widely recognised at Lapita sites in the Bismarck Archipelago (e.g. Allen 2003; Allen and Bell 1988; Gosden 1991b; Green and Anson 1991; Halsey 1995; Hanslip 2001; Kirch et al. 1991; Sheppard 1992; Summerhayes 2003, 2004; Swete-Kelly 2001; White and Harris 1997).
The reasons for mobility among prehistoric populations are complex and there are various forms of mobility. The colonisation of Pacific islands using watercraft technology is one of the forms which occurred in the Late Pleistocene and continued throughout prehistory (e.g. Allen 2003; Anderson 2000; Gosden and Pavlides 1994; Kirch 2000:9; Lape, O'Connor and Burningham 2007; O'Connor and Chappell 2003; O'Connor and Veth 2000; Spriggs 1997:27-31; Torrence et al. 1996). The occupation of Garua Island in the Middle and Late Holocene occurred because of the ability to cross the water barrier that surrounded the island. The development of watercraft was also required for the maintenance of exchange systems and of social relationships and for access to and use of marine resources as important components of the subsistence strategies of the island's inhabitants (Torrence and Summerhayes 1977, Summerhayes 2004, 2007; Torrence et al. 1996, 2000).

From the behavioural perspective, the relationship between environmental resources and subsistence is a crucial factor that affects the nature of mobility (Binford 1996; Kelly 1992; Kent 1991). The changes in the resource availability caused either by environmental conditions (e.g. climatic phenomenon such as droughts) or human behaviour (e.g. population increase or territorial constraints) encourage the development of new adaptive strategies involving technological innovations, re-organisation of settlement patterns and social relations (Kelly 1992:46).

Although environmental conditions and resources recovered after each Holocene volcanic event were generally unchanged on Garua Island (Boyd et al. 2005; Lentfer and Torrence 2007), the archaeological record indicates two different behavioural patterns of inhabitants who occupied the island before and after the catastrophic eruption. As noted earlier in this chapter, on the basis of earlier technological and partly functional studies of obsidian artefacts and their distribution within the landscape some researchers suggested that during the middle Holocene Garua Island was occupied by highly mobile groups with short-term occupation of sites, curated technology and gradual intensification in land-use (Fullagar 1992, 1993a, b; Torrence 1992, 2000a, 2000b, 2004a, 2004b; Torrence and Stevenson 2002; Torrence et al. 2000).

However, recent results obtained through paleoenvironmental studies by Boyd, Lentfer and Parr (Boyd et al. 2005; Lentfer 1995; 2003; Lentfer and Torrence 2007; Parr 2003; Parr et al. 2001) provided new data which, to some extent, contradict the
proposed explanation of the middle Holocene history of the island. According to these data, a shift towards long-term site occupation occurred before the WK-2 eruption and this is documented by evidence for *Canarium* nut harvesting, a shift in technology which is associated with the use of bamboo as a raw material and the development of subsistence linked to early cultivation of useful plants close to occupation sites (Boyd *et al.* 2005:388).

The result of my study of the obsidian assemblage at FAO is more consistent with paleoenvironmental data than with the proposed model of highly mobile pattern of human behaviour during the middle Holocene. Use-wear/residue examination and morphological observation of artefacts in conjunction with the distribution of tools and unused flakes clearly show an expedient production and use of flakes and a few stemmed tools of Type 3 for a diverse set of activities which were spatially organised and maintained at FAO. The full range of daily activities related to the procurement and processing of stable marine resources and collecting, production and processing land resources including gardening products, such as tubers, indicate a low level of mobility which was probably associated with the nature of "swidden" gardening or "shifting cultivation" (Kirch 1997:203).

The Late Holocene behavioural pattern on Garua Island demonstrates some significant changes: stemmed tools disappeared, the character of artefact assemblages changed; Lapita pottery arrived; a different form of subsistence pattern established itself and was perhaps linked to the introduction of new plants and animals; a gradual shift toward reduced mobility became more pronounced and a new system of social interaction involving intra-regional exchange of obsidian and pottery was introduced. All of these changes indicate that a different social system appeared on the island after the WK-2 catastrophic volcanic eruption and this system allowed small groups to practice a subsistence pattern that depended more highly on cultivation (Boyd *et al.* 2005; Lentfer and Torrence 2007; Specht *et al.* 1988; Therin *et al.* 1999; Torrence 1992, 2002a, 2002b, 2003, 2004b; Torrence and Stevenson 2002; Torrence and Summerhayes 1997; Torrence *et al.* 1996, 2000).

Despite the diverse evidence for change, the tool use pattern and set of activities identified for the late Holocene assemblage have many common features with the previous chronological period. There are also some similarities in the spatial organisation of activities performed at FAO suggesting that a low level of mobility was a main characteristic for both middle and late Holocene periods at this site particularly, and Garua Island and the Isthmus region of the Willaumez Peninsula generally.
The difference between the middle Holocene and late Holocene occupations of FAO becomes apparent in the pattern of the spatial re-arrangement of activities over time which is unfortunately well documented only in the Late Holocene deposits. The relocation of activities is a significant indicator of repeated use of the site with some time gap between occupation episodes. In conjunction with the evidence of gardening around the site (Boyd et al. 2005:388-389), the pattern of re-occupation of the same location over time is consistent with the model of shifting cultivation reconstructed for the Lapita economy in the Bismarck Archipelago (e.g. Kirch 1997:203). This model suggests discontinuous occupation of one precise spot for some years caused by relocation of the settlement close to the gardens (e.g. Hogbin 1938:143; Parkinson 1999:68, 341). If the repeated nature of occupation of FAO and its relationship with gardening practices is a plausible explanation of the low late Holocene mobility of inhabitants, then it may be comparable with the mobile Lapita subsistence and settlement patterns proposed for the Arawe Islands (Gosden 1994; Gosden and Pavlides 1994). However, to test this suggestion further, use-wear study of obsidian artefacts recovered at FAO, as well as from other contemporary sites on the island is required.

As a conclusion, the middle and late Holocene environmental conditions on Garua Island, with an abundance of obsidian raw material, stable and rich marine resources, diverse and accessible terrestrial resources provided favourable conditions for a style of life with relatively low mobility in both chronological periods of occupation. More advanced gardening practices, an expedient technological organisation and pottery are the post WK-2 features which were introduced by the incoming population with a different social system. Use-wear/residue studies of obsidian artefacts in association with distributional approaches, paleoenvironmental data and ethnographic analogies provide new insight into the complex prehistory of the island particularly and the Middle and Late Holocene history of the Bismarck Archipelago in general.
Chapter 9

Conclusions

9.1 Introduction

The aim of my thesis was to answer fundamental questions about the function of obsidian tools and their relationship with settlement organisation and mobility patterns in the middle and late Holocene periods on Garua Island, West New Britain, Papua New Guinea. Scholars have generated a range of hypotheses concerning human behaviour during these crucial periods of prehistory in the Bismarck Archipelago. In some regions in West New Britain, these hypotheses are based on artefact morphology, technology and their distribution within the landscapes (Pavlides 1999; Torrence 1992, 2002a; Torrence and Stevenson 2000). Fullagar (1992, 1993a; Fullagar et al. 1998; Kealhofer et al. 1999) introduced integrated use-wear and residue analysis which provides more objective and more precise assessment of the function of stone tools and their significance for past cultural processes. My study represents a large scale, on-site use-wear/residue analysis of obsidian artefacts recovered from FAO. This analysis was specifically designed to identify used tools and reconstruct tool function to assess the validity of existing hypotheses about middle and late Holocene subsistence and settlement patterns. In this chapter, I summarise the major conclusions of my use-wear study of obsidian tools and discuss their implications for Pacific archaeology.

9.2 Research Background

My research had two important components: (1) the development of use-wear methodology based on a multi-facetted comparative method utilising low and high power microscopic examination and (2) a broader archaeological investigation of the obsidian lithic assemblage from the FAO site. In order to understand use-wear formation and taphonomic factors, I developed a comparative approach that involved extensive replication experiments and studies of archaeological assemblages of obsidian artefacts from Vanuatu, Korea and Russia. Through experimental data and specific use-wear literature I was able to develop a practical approach to my task of documenting and assessing the use-wear on 190 tools of a total of 1,395 artefacts examined from FAO. I was fortunate to collaborate with Richard Fullagar in some of this work.
As a consequence of my use-wear/residue analysis, I am able to conclude that, in spite of the sampling limitations of test pit excavation in comparison with large open area excavation, the excavation at FAO produced a quantity of tools which provided significant data on the lifeways of people in both the middle and late Holocene. The acidic ground conditions have eliminated most of the organic material from the past and it is only through an examination of the stone tools, limited ceramic finds, phytoliths and other preserved residues that insight into past human behaviour can be gained. A large open area excavation of FAO could have provided a greater understanding of the function and spatial organisation of the site itself, but, given that the site is about one hectare in area, it would have been difficult to excavate the whole of the site to a depth of over two metres.

The number of tools studied was sufficient to provide evidence of a wide spectrum of human activity in the middle and late Holocene at FAO and by inference on Garua Island and, perhaps, the wider Bismarck Archipelago. The interaction of people in the middle and late Holocene with their environment became evident through the application of the ecological approach and from ethnographic analogies.

9.3 Limitations of the Study

Before considering the implications of my research findings, it is important to acknowledge that there are some limitations on my conclusions due to the time constraints inherent in a PhD and because of taphonomic factors.

It is important to examine all artefacts recovered by excavation in order to reconstruct the full range of activities at a site. However, use-wear/residue analysis is a highly time consuming method and this makes it difficult to study entire stone assemblages from sites. An appropriate sampling strategy was required to achieve the aims of this research project because of the nature of the assemblage and the time demands of use-wear/residue analysis.

My identification of the function of tools was not based entirely on observable use-wear patterns but was also supported by the presence of starch and other residues. However, the preservation of starch residues on obsidian is somewhat problematic and depends on many factors, including post-depositional processes and post-excavation cleaning of artefacts (Fullagar 2006b:191). Most of the examined artefacts from FAO had been cleaned in the field and this reduced the opportunity of finding residues which might have been preserved on the tools prior to their cleaning.
Fragile obsidian raw material is easily influenced by both physical and chemical processes. Some artefacts do not preserve identifiable use-wear features and residues because of surface alteration. This limitation reduces the opportunity to involve use-wear analysis in the study of archaeological collections. In the case of FAO, obsidian artefacts from the middle Holocene deposit have more altered surfaces which have been changed by chemical damage than do those of the late Holocene artefacts. This indicates that, in some particular environmental conditions, use-wear/residue analysis of obsidian artefacts may not be productive.

The data from the study is summarised in Table 8.1. The results are expressed as percentages and have thereby been normalised. The distribution of tools over the full range of functional categories produces group totals that are too small for statistical significance testing. However, when data on subsistence and on craft activities are compared it becomes quite clear that they are generally similar in both periods. It can be readily seen from the data that the differences in tool use are not so great as to suggest a major change in subsistence and craft activities between the middle and late Holocene.

Despite the limitations, the results of my study provide reliable information on the nature of tool use at FAO during the middle and late Holocene. These results represent a significant foundation for the reconstruction of prehistoric lifeways in this region and for making hypotheses about subsistence and settlement patterns in other areas in the Bismarck Archipelago. In future studies, increased sample size along with detailed residue identification would significantly overcome these limitations.

9.4 Evaluation of Predictions and Hypotheses

The use-wear/residue study shows that obsidian tools from FAO were used to process a wide range of materials in both the middle and late Holocene periods. Plant and non-plant materials, including siliceous and non-siliceous wood, palms, bamboo, hard wood, non-woody plants (such as tubers and grasses), fish, skin, shell and clay, were worked by various modes of use: scraping, sawing, whittling, carving, drilling, cutting, slicing, peeling and piercing. With rare exceptions, in both chronological periods flakes were generally used for a short period of time as single purpose tools, to perform a particular task. This expedient pattern of use also characterises the function of small stemmed tools from the middle Holocene deposit at FAO. My functional and technological examination of a series of small stemmed tools recovered from stratigraphic contexts on Garua Island does not support the suggestion that they were
manufactured and used as multipurpose tools (Torrence 1992:121). Consequently, I found no evidence to support the presence of a curated technology associated with high mobility during the middle Holocene habitation of Garua Island (contra Torrence 1992, 2002a, Torrence et al. 2000). Furthermore, there is no concentration of tools with intensive wear patterns in the middle Holocene deposit and the use of flakes from the late Holocene deposit was of a medium intensity which generated identifiable use-wear that is not consistent with my initial prediction. The strategy of expedient tool use is a feature of stone assemblages from both chronological periods.

In both the middle and late Holocene periods most tools are associated with craft activities. Subsistence related implements were involved in the processing of tubers and fish, but no tools used for direct procurement of food were identified in the stone assemblages. In addition, a small number of artefacts in both the middle and late Holocene tool assemblages were probably associated with tattooing and scarification of the human body. These represent evidence of social aspects of human behaviour in the past. Generally, the functional composition of the middle Holocene tools and their use in subsistence, craft and social activities is similar to that for the late Holocene set of tools and associated activities. These data contradict Fullagar's (1992) previous suggestion, that during the middle Holocene only a few tool-using activities, with a limited range of tasks, took place at individual sites and that this reflected a high level of mobility of the inhabitants. Similarities in the pattern of tool use and the structure of associated activities were observed in both periods and are more consistent with a relatively sedentary way of life probably created by the population's involvement in gardening practices.

It is apparent from my interpretation of the use-wear/residue data that the pattern of tool use is not closely associated with changes in technology: i.e. away from the manufacture of stemmed tools during the middle Holocene period and into expedient flake production of the late Holocene period (Torrence 1992, 2002a). The small stemmed tools in the middle Holocene assemblage do not have a specific function: they were utilitarian tools used in a similar way as flake tools. This fact clearly indicates that use-wear analysis on its own does not provide essential information regarding concepts of cultural continuity and gradual changes (Torrence 1992; 2002a) between the middle and late Holocene periods.

However, there is some variation in the proportions of tools involved in different activities that together with the spatial organisation can be potentially considered as an indirect indicator of chronological and cultural discontinuity. First, the percentage of
tools involved in subsistence is higher in the middle Holocene assemblage and there is
some change in the proportion of tools used in particular craft activities over time. For
example, during the late Holocene siliceous soft wood, palms and bamboo were more
widely used for the manufacture and maintenance of domestic items than in the middle
Holocene.

Second, there are some slight differences in the spatial organisation of activities
indicating both repeated re-occupation of the site and slightly different approaches to
the use of space in the late Holocene. For example, domestic activities at FAO during
the early phase of the middle Holocene occupation were concentrated at the western
edge of the relatively flat hill top, while the centre of this hill was used as a localised
space for knapping and the manufacture of flaked implements. The intra-site structure
of the later phase of occupation immediately before the W-K2 eruption is characterised
by a more complicated spatial organisation. The later occupation involved a
"communal" activity area and a "living", or household, area which were both located in
the central part of the site. The dumping ground for material was located on the western
dge of the hill and the lithic workshop was located some 10 metres to the north of the
"communal" area. The earliest and latest habitation areas do not overlap each other
stratigraphically and this indicates a certain time gap between occupational episodes and
establishes the repeated re-use of this location as a consumption site during the middle
Holocene period. This interpretation of the middle Holocene occupation of the site,
therefore, does not support my initial prediction of short-term, intermittent use of this
location for particular tasks and also it does not support the concept of highly mobile
populations on Garua Island during this period (Fullagar 1992; Torrence 1992, 2000a;
Torrence et al. 2000). Moreover, the presence of a full range of daily activities related to
the procurement and processing of marine resources and the collecting, production and
processing of land resources (including gardening products, such as tubers), when
considered in conjunction with evidence for the spatial organisation of activities,
indicates a low level of mobility of the middle Holocene inhabitants.

During the late Holocene, the first people to appear at the site after the W-K2
eruption and the lengthy period of abandonment (Petrie and Torrence, in press;
Torrence et al. 2000) used not only the centre of the hill for their domestic activities, but
also the northern and southern parts of the site. In the occupation stages that followed,
activities were mainly concentrated on the northern and southern edges of the hill. The
space which was initially used as a dumping ground for material was re-used in the later
stages of occupation as an area for domestic activities. These changes in the spatial re-
organisation of activities over time, observed in the stratigraphic profile, are definite evidence of the repeated re-use of the site throughout the late Holocene period. The evidence for multiple activities and some structural features, reflected in the set of tools and their spatial concentration, suggest a relatively prolonged period of stay by the site's inhabitants during each stage of occupation.

In the late Holocene, intra-site structure with defined organised activity areas, repeated occupations over time, evidence of gardening (Lentfer and Torrence 2007) and for the exploitation of marine and terrestrial resources are all features which are generally similar to those identified in the latest stage of the middle Holocene occupation of the site. These similarities support my prediction that a low level of mobility, or semi-sedentary way of life, was the main characteristic of both the middle and late Holocene societies who occupied Garua Island. This conclusion, based on my use-wear/residue study of obsidian tools and their stratigraphic and spatial distribution, indicates continuity in the pattern of tool use, subsistence and settlement strategies. The continuity observed in the archaeological record supports my hypothesis that the combination of such factors as the physical needs of human beings, the physical properties of stone raw material used for the manufacture of tools and similarities in ecological conditions and available resources will inevitably result in similar tool use patterns and similar structures of associated activities over time. Obsidian tools provide evidence of the type of materials processed and establish that similar resources were exploited during the middle and late Holocene as supported by paleoenvironmental data (Boyd et al. 2005; Jago and Boyd 2005; Lentfer and Torrence 2007; Parr 2003:209-213). The data show that despite the catastrophic W-K2 eruption, recovery processes gradually regenerated similar environmental resources to those which existed prior to the eruption.

It is apparent that the continuity in subsistence practices, settlement strategies and tool use patterns on Garua Island between the middle and late Holocene does not directly correlate with the changes in technology as documented in the archaeological record (Torrence et al. 2000). The favourable geographic setting and attractive environmental conditions allowed a society with a new social system, new stone technology, pottery and advanced subsistence practices (Torrence et al. 2000), to arrive and to establish itself on the island after the W-K2 eruption. This community quickly adjusted to the island's landscape and developed economic systems with settlement patterns involving a low level of mobility similar to those of Lapita sites proposed by Gosden and Pavlides (1994) for the Arawe Islands.
9.5 Implications from Research Results

This research has made significant contribution to both (1) use-wear methodology in the study of lithic assemblages and (2) new interpretations for subsistence, settlement patterns and mobility of the middle and late Holocene populations on Garua Island, with implications for the Bismarck Archipelago generally.

In order to understand how and under what conditions use-wear is formed on obsidian tools, a comparative approach, which included extensive replication experiments and microscopic examination of prehistoric artefacts from four regions (West New Britain, Vanuatu, Korea and Russia), was developed. Task-oriented experiments involving 292 replicated obsidian tools were conducted using a wide range of local tropical plants and non-plant materials some of which were not previously incorporated into obsidian use-wear experiments. This extensive range of experiments both replicates some previous studies by Hurcombe (1992), Fullagar (1986) and Kamminga (1982) and also provides a new reliable database for understanding the general process of use-wear formation on obsidian tools and, more specifically, interpreting the function of tools from FAO. The extensive and detailed photographic documentation of wear patterns observed on artefacts and experimental tools has generated an important resource for future comparative studies of obsidian assemblages both in the Pacific region and elsewhere.

My integrated use-wear/residue study of 190 obsidian tools from site FAO on Garua Island has significantly extended the documented range of functions of obsidian tools used for subsistence, craft and social activities, some of which had not been previously recognised as occurring in the middle and late Holocene periods in Papua New Guinea. Most of the tools had been used in craft activities, notwithstanding their chronological origin. Plant materials, including soft wood, hard wood, palms, bamboo, non-woody plants (tubers, leaves and grasses), as well as non-plant materials such as shell and clay, were worked by various modes of use: scraping, sawing, whittling, carving, drilling, cutting, slicing and peeling.

The working of skin, particularly piercing, is probably related to tattooing and scarification of the human body in both Papua New Guinea and Korea, and suggests a social function of stone tools not previously recognised.

The wider implication of my research is associated with testing current hypotheses on the likely functions of obsidian artefacts and their involvement in site activities. First, with rare exceptions, flakes were used for short periods of time as single purpose
tools in both chronological periods. This expedient pattern of use also characterises the function of small stemmed tools from the middle Holocene deposit at FAO confirming an expedient tool use strategy as a common technological feature in the Bismarck Archipelago throughout the Holocene.

Second, no previous attempt had been made to study the structure and organisation of activities at the site through a systematic analysis of used tools and the pattern of their discard. The interpretation of spatial patterning in activities has often depended on analyses of faunal remains and, rarely, on inferences as to stone tool use, based on morphology and ethnographic analogy. For most of the middle and late Holocene assemblages in the Bismarck Archipelago, no previous attempt had been made to establish site activities through an analysis of the function of used tools. The set of used tools recovered from the site does not necessarily mean that only activities associated with these identified tools were carried out by the inhabitants of this site. Some crucial activities could have been performed outside the site by the same people, for example: building canoes and such activities are not yet reflected in the archaeological record. Data available from my study provides important insights and a starting point for further investigation of the intra-site structure and organisation of activities in the middle and late Holocene history on Garua Island and in the Bismarck Archipelago generally.

My systematic study of obsidian tool use has revealed continuity in subsistence practices, settlement strategies and tool use patterns on Garua Island, during both the middle and late Holocene. This significant result suggests that the human populations had a low level of mobility and that gardening practices were developed in West New Britain before the Lapita pottery tradition was introduced into region following the W-K2 catastrophic eruption. This conclusion is consistent with hypotheses of other scholars (Allen 2000; Kirch 2000:85-88; Lentfer and Torrence 2007; Torrence et al. 2000).

Moreover, the absence of obvious changes in the strategy of tool use, settlement organisation and subsistence activities coinciding with the appearance of new social groups with Lapita pottery, new lithic technology, advanced agricultural practices and domesticated animals, raises a number of important issues. These issues are associated with further investigations into the relationship between the function of tools, available environmental resources and cultural and social traditions of middle and late Holocene populations in the Bismarck Archipelago. These new issues emerge from use-wear/residue studies of stone tools and are critical for understanding the processes
involved in the development and spread of the Lapita Cultural Complex in the Pacific region.

9.6 Prospects for Future research

This thesis demonstrates that appropriate methodologies involving a proper series of procedures and techniques are necessary to ensure reliable results in the study of obsidian assemblages. The creation and presentation of useful records of the analyses in the form of images of highly magnified use-wear and residues is an important component of functional studies. Further research into these methodological aspects of use-wear analysis would be considerably useful.

My experimental program was designed to examine wear formation on obsidian tools by using mostly local resources from the area under investigation. However, many particular tasks involving a wide variety of worked material and different modes of use remain to be studied in the future. For example: my experiments prove that there are some peculiarities in scarring, striations, rounding and polish that indicate diagnostic characteristics which are useful in the identification of tools involved in processing different materials. The comparison of sets of wear produced by different plants showed that the precise definition of the worked species, on the basis of use-wear alone, can only be made on a broad level. This is, in part, related to the fact that some groups of soft and hard species of wood, palms and tall grasses have high silica content, whereas other soft and hard wood and non-woody plants which consist of green leaves and tubers are non-siliceous. Further experimental investigation into the relative differences between the wear variables produced by each of these groups of plants would make a significant contribution to the functional interpretation of stone tools and associated human activities in the Pacific archaeology.

The study of microscopic organic residues on experimental tools is another area requiring further investigation. The detailed analysis of these residues is of particular importance and would allow comprehensive comparison with residues on artefacts and make possible the identification of the material worked. At this stage of my study, the suggested classification of use-materials is mainly developed on the basis of wear characteristics observed on artefacts and a more precise identification of the use-material processed by obsidian tools requires more detailed residue analysis than was able to be undertaken in this study.
Although this thesis represents a use-wear/residue analysis of stone tools on a large scale compared to previous research projects, not all artefacts excavated from FAO have been studied and future analysis could be useful in further understanding how the site was used. Moreover, the project has concerned obsidian tool use at one specific site on Garua Island. However, for a more coherent understanding and explanation of tool use strategies, settlement patterns and subsistence in the middle and late Holocene, further examination of larger obsidian assemblages from other sites from the middle and late Holocene on the island and throughout the Bismarck Archipelago in general would be particularly illuminating.

My study identified a variety of tasks associated with the use of middle Holocene stemmed tools. Further use-wear/residue research into the function of obsidian stemmed tools based on excavated samples from other sites on Garua Island would allow further review of existing concepts of curated middle Holocene stone technology and address related questions about the emergence of the earliest valuables in the Pacific region. This study has produced a significant volume of new data about stone tool usage, human subsistence and settlement patterns and has generated new insights into the prehistory of the Bismarck Archipelago.
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