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Experimental and Archaeological Studies of Use-wear and Residues on Obsidian Artefacts from Papua New Guinea

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ABSTRACT. The importance of microscopic examination and experimental replication techniques are being increasingly recognised in the field of functional analysis. The integrated use-wear/residue analytical techniques presented here focus particularly on understanding the processes of wear formation and the extent to which wear patterns on both ancient obsidian artefacts and experimental tools can be identified by microscopic techniques. The careful application of a wider range of techniques and a more precise methodology than had been employed in previous studies of obsidian implements increases the reliability of functional interpretations of prehistoric artefacts. A specific case study is presented to demonstrate the validity of the methodology developed. Methods of functional analysis were used to study obsidian assemblages dating to the middle and Late Holocene recovered from excavations at the FAO site on Garua Island, West New Britain, Papua New Guinea. The results of the research allow reconstructions of human behaviour over time to be substantiated or challenged.

The comprehensive set of colour microphotographs of identified wear patterns derived from an extensive experimental program are presented alongside images of archaeological tools which had been replicated by the experimental tools. The images represent a valuable resource providing researchers with useful tools for the analysis of obsidian artefacts derived from archaeological contexts in many other parts of the world. This research is intended as a reference tool for students and specialists, particularly those analysing artefacts made from obsidian.

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Part 1 Introduction

A wide range of methodological approaches has been developed to study stone tool assemblages. Use-wear and residue analysis are among the most powerful techniques for reconstructing the ancient function of artefacts made from various materials including stone. This monograph contributes to that field of functional analysis which is based primarily on the observation of macroscopic and microscopic traces of wear and, to a lesser extent, of residual materials. It outlines the overall methodology adopted, including the replication experiments made, and describes the equipment and techniques utilised in the functional studies. The research is intended as a reference tool for students and specialists, particularly those analysing artefacts made from obsidian. Obsidian artefacts require special approaches since, as previous scholars have shown, their physical properties are somewhat different from flint artefacts and that methods devised for the study of flint tools are not necessarily relevant to obsidian assemblages (e.g., Aoyama, 1995; Hurcombe, 1992:24; Semenov, 1964:15). This research builds on previous studies, and particularly Hurcombe's (1992) seminal monograph, but it also introduces new approaches and presents an extensive range of reference materials thus enabling more precise results to be obtained. The study presents data on the wear patterns resulting from artefact use on a wider range of materials than has been previously published and with a particular focus on tools used in working with tropical plants.

The monograph has three main goals. The first is the further development of integrated use-wear/residue analytical techniques and replication experiments on obsidian tools with a particular focus on understanding the processes of wear formation and the extent to which wear patterns on ancient obsidian artefacts can be identified by microscopic techniques in spite of taphonomic factors. The research was undertaken with the expectation that the careful application of a wider range of techniques and a more precise methodology than had been employed in previous studies of obsidian implements (e.g., Aoyama, 1995; Fullagar, 1986, 1992, 1993b; Hurcombe, 1992; Kamminga, 1982; Lewenstein, 1981; Semenov, 1964) will increase the reliability of functional interpretations of prehistoric artefacts. To demonstrate the validity of the methodology developed, a specific case study is presented in which functional analysis is applied to obsidian assemblages dating to the middle and Late Holocene, recovered from excavations at the FAO site on Garua Island, West New Britain, Papua New Guinea (Fig. 1).

The second aim is to present a comprehensive set of colour microphotographs showing identified wear patterns derived from an extensive experimental program alongside photos of archaeological tools interpreted as being used for the same functions. The images available here comprise a considerable resource that will provide researchers with a tool for the analysis of obsidian artefacts derived from archaeological contexts in other geographical areas. Tool functions, wear formation processes which affect the tools during use and post-depositional taphonomic factors are all likely to be very similar throughout the world. Thus, even though many of the experiments were performed on tropical materials similar to those found around the site under investigation, researchers will find notable similarities with their own material.

The third aim of the study is to look at the investigation in a broader context. The Late Holocene, starting from about 3300 years ago, saw large-scale changes throughout the Western Pacific. On Garua Island itself, large stemmed tools were no longer made while Lapita pottery appeared in many sites (Torrence, 2002a). Elsewhere, domestic animals such as pig and chicken made an initial appearance, and there are widespread claims of extensive changes in language, biology and social structure. These changes have frequently been interpreted as marking the arrival of new settlers in the region (e.g., Green, 2003; Kirch, 1997:45–52; Spriggs, 1997:67–106). It might be expected that such sweeping changes would be accompanied by changes in the tool use strategy of people and the question of whether or not this was the case is discussed.

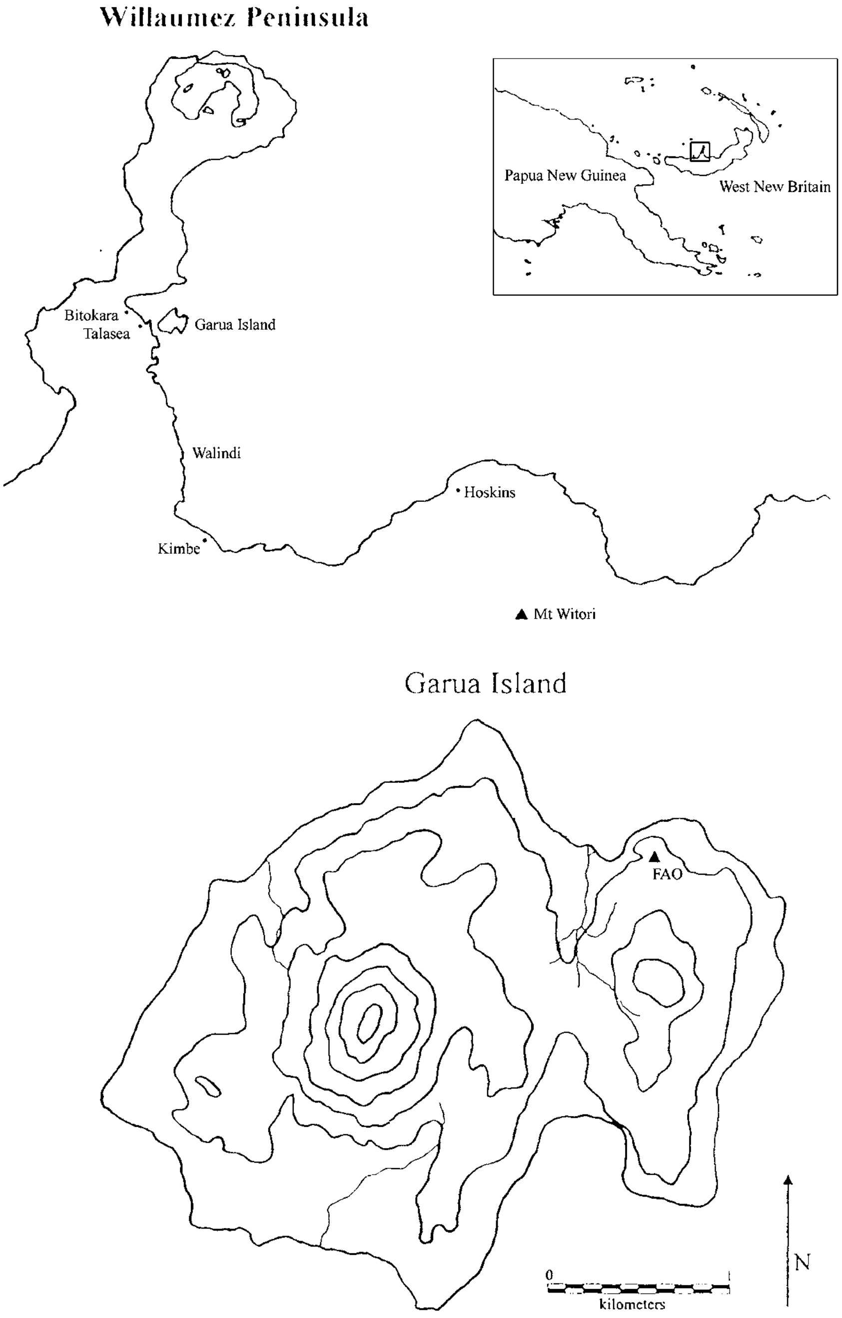

Figure 1. Map showing the area under study and the location of FAO site on Garua Island.

Functional analysis

The general purpose of functional studies of artefact assemblages is to reconstruct, as completely as possible, the primary economic and technological activities of prehistoric populations. Functional analysis of stone tools is based on several sets of evidence: (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 analogy (Fullagar, 2006a:208–209). Two main types of information are provided by functional studies of prehistoric artefacts: (1) the way in which the tool was manipulated (use-action) and (2) the material on which it was used (use-material). Undertaking a functional analysis means making an assessment of the major forms of macroscopic and microscopic use-wear and the residues observed on a tool's surfaces, particularly near the edges, to determine how and on what it was used. Use-wear usually refers to surface modification that occurred during all stages of use, including hafting, handling, and sometimes storage (e.g., Anderson-Gerfaud, 1990; Fullagar, 2006a; Hayden & Kamminga, 1979:2–5; Keeley, 1980:1–2; Lewenstein, 1987:5–10; Vaughan, 1985:4). Residues are the materials that are attached to, or absorbed within, a tool surface (e.g., Anderson, 1980; Anderson-Gerfaud, 1990; Fullagar, 2006a; Kealhofer *et al.*, 1999; Vaughan, 1985:44).

Following S. A. Semenov's (1964) pioneering research in the 1930s to 1960s, new approaches adopted for functional analysis of stone tools have been developed by a number of scholars. The most significant area of investigation is employing both low and high magnification to study distinctive polishes and other use-wear features observed on tools (e.g., Aldenderfer *et al*., 1989; Anderson-Gerfaud, 1990; Aoyama, 1995; Fullagar, 1986, 1991; Hurcombe, 1992; Ibánez & González, 2003; Juel Jensen, 1994; Kamminga, 1982; Keeley, 1980; Odell, 2004; Rots & Williamson, 2004; Vaughan, 1985).

A second important area of research involves the microscopic investigation of a range of plant (e.g., phytoliths, starch), animal (e.g., blood) and inorganic (e.g., ochre) residues preserved on tool surfaces (e.g., Anderson, 1980; Briuer, 1976; Fullagar, 2006b; Hardy *et al*., 2009; Haslam, 2006; Jahren *et al*., 1997; Kealhofer *et al*., 1998; Lombard & Wadley, 2007, 2009; Loy, 1983, 1994, 2006; Petraglia *et al*., 1996; Robertson, 2005; Shafer & Holloway, 1979; Shanks *et al*., 2005; Wadley *et al*., 2004). Scholars have realised that the reliability of identification of prehistoric tool use strategies is markedly increased when use-wear examination and residue analysis are integrated into a single study (e.g., Fullagar, 1998; Haslam & Liston, 2008; Högberg *et al*., 2009; Kealhofer *et al*., 1999; Robertson *et al*., 2009; Rots & Williamson, 2004; van Gijn, 1998).

There is little published work which uses the functional approach in the analysis of obsidian tools. The first use-wear study was initiated by Semenov (1964:13–15) who emphasized that wear on obsidian will be quicker to appear than on flint and that the forms of wear will be slightly different. Further research has shown that the general principles of use-wear and residue analysis are applicable to all classes of stone material but specific methods and interpretative rules need to be developed for particular raw materials such as obsidian (e.g., Aoyama, 1995; Fullagar, 1986; Hay, 1977; Hurcombe, 1992; Lewenstein, 1981). This is primarily because of significant differences in the ways in which obsidian responds to use when compared to other siliceous raw materials. Obsidian is brittle and edges easily wear away when used to work resistant materials. These characteristics combine to make the functional analysis of obsidian artefacts particularly complicated. In addition, obsidian is especially prone to surface alteration by chemical, and to a lesser extent, mechanical transformation (Hurcombe, 1992:34)

Functional studies of all raw materials, and not only of obsidian, have certain limitations. First, post-depositional effects can cause a high degree of surface alteration that may obscure or mask any wear traces. Second, use-wear patterning itself depends upon a range of inter-related factors. The wear formation process varies with time and is dependent on the types of materials worked and the mode of tool use. For instance, if an obsidian artefact has been used for only a very short time, use-wear will not be observed (Aoyama, 1995; Hurcombe, 1992:61; Lewenstein, 1981). A tool used for processing hard wood will usually be exhausted much faster than a knife used for butchering animals. In addition, some tools might have two or even three sets of use-wear features (Fullagar, 1993a; Lewenstein, 1981:186). In most cases, a single task involves more than one action. For example, processing soft wood may require three actions: whittling, sawing and cutting/slitting. In this case, it may be difficult to determine the dominant kind of wear. However, in some situations the combination of wear features can be distinguished by their different distribution on the working edge (Aoyama, 1995; Tringham *et al*., 1974). If the tool has 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 can sometimes be resolved by comparison with available experimental data and ethnographic material.

In the Pacific region, the study of stone tool function using microscopic examination of wear patterns, residues and experimental replication was initiated by Kamminga (1982), Fullagar (1986) and Loy (Loy *et al*., 1992). Fullagar (1986) introduced the integrated approach to the study of tool function combining replication experiments with low and high powered microscopic analysis of wear and residues. This approach provided more reliable data for the reconstruction of human behaviour than simpler, traditional techniques (Fullagar, 1994, 1998, 2006a; Fullagar *et al*., 2006; Kealhofer *et al*., 1999). Following previous studies, further significant contributions have been made by integrated studies of use-wear and residues on stone tools from sites in the Pacific region (e.g., Barton & Fullagar, 2006; Barton & Matthews, 2006; Barton & White, 1993; Barton *et al*., 1998; Fullagar, 1992, 1993a,b; Fullagar *et al*., 1998; Haslam & Liston, 2008; Kealhofer *et al*., 1999; Loy, 1993; Loy *et al*., 1992; Fullagar *et al*., 2006). However, current interpretations of lithic assemblages, subsistence and settlement history still leave many questions under-resolved and more complete functional information about prehistoric tool use strategies is required. This is an especially important subject for the Pacific region because much of the archaeological record consists of simple flakes with few recognisable types of retouched tools and only microscopic examination allows the determination of their function.

Another problem is that it is difficult to build on previous results of functional analysis of obsidian assemblages, particularly those from the Pacific, because of inadequate documentation. Despite attempts by Aoyama (1995, 1999), Hay (1977), Hurcombe (1992), Lewenstein (1981, 1987), and to a lesser extent Fullagar (1986) and Kamminga (1982), much of the early use-wear data from studies of artefacts and experimental tools is difficult to use for comparative analysis because wear patterns are not documented in enough detail to be replicable. This research is designed to overcome these limitations, in particular by providing a comprehensive range of illustrations of use-wear/residue patterns.

Synopsis

The first part of this report (Parts 2–4) summarises a methodology which is appropriate for the functional analysis of obsidian tools. In Part 2, the fundamental analytical methods and approaches employed in functional analysis of artefacts, particularly those made of obsidian, are described and discussed. Part 2 emphasises the importance of conducting specially designed replication experiments as one component of the functional study of stone tools. Parts 3 and 4 present the methodology and results of the replication experiments developed for the project. The program was designed with the intention that information obtained from a framework of experiments could be applied to the functional analysis of obsidian assemblages from archaeological sites. The material worked, the activities engaged in, the wear variables observed and recorded, together with the technological features of the experimental tools, are described in Part 3.

Part 4 analyses and describes the results of experiments conducted in a natural setting near the site of the case study on Garua Island, Papua New Guinea (Fig. 1). Wear patterns on experimental tools produced by the processing of materials which were likely to have been available to prehistoric inhabitants are directly compared to wear traces found on prehistoric artefacts. The value of experimental data used in the interpretation of the function of obsidian artefacts was greatly enhanced by this approach.

The experimental study addresses two interrelated themes that were examined through 292 task-oriented and controlled experiments involving the replication and use of obsidian tools similar to those found in Papua New Guinea. The first theme outlines the experimental study of the formation of wear features, including scarring, striations, edge rounding, polish and residues. This study, in association 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 the 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 plants and non-plant materials used by indigenous people in West New Britain. Similar plants and non-plant materials were likely to have been used by prehistoric populations.

The second part of the monograph (Parts 5–7) comprises a case study which applies the methodology established in Parts 2–4 to the functional analysis of the obsidian assemblages from the FAO site. Both the ecological setting and archaeological context of the site under investigation need to be considered in the functional study of lithic assemblages, for framing the experiments and also for interpreting the results (Keeley, 1974). It is for this reason that experiments must be carried out under conditions which approximate those of prehistoric times and with materials obtained from the local area. Part 5 briefly describes the environmental background and geographical setting of the site and the stratigraphic and chronological sequence of deposits containing the lithic assemblages. The project involved a total sample of 1395 obsidian artefacts found within seven test pits at FAO. Of these, 832 artefacts are from the Middle Holocene levels and 563 artefacts are from the Late Holocene levels. The results of the use-wear/residue analysis of all these obsidian artefacts revealed 190 tools, including 102 tools from the Middle Holocene assemblage and 88 tools from the Late Holocene assemblage. Similarities and differences in the functional and morphological characteristics of tools and their relationship with particular activities in each chronological period are discussed in Part 6.

Part 7 assesses the functional information derived from use-wear/residue examination and experimental replication, together with available archaeological information from neighbouring regions, ecological evidence and ethnographic analogies, and proposes reconstructions of various categories of daily activities, site structure and settlement patterns. Part 7 also emphasizes that methodologies involving an appropriate 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 patterns and residues, are important components of functional studies (Bamforth, 1988; Högberg *et al*., 2009; Hurcombe, 1988; Lombard & Wadley, 2007). The extensive documentation of wear patterns on prehistoric and experimental tools presented in this research has produced a significant volume of new data about stone tool usage and has generated new opportunities for further functional interpretation of stone tools and associated human activities. It is anticipated that the large quantity and range of images presented here will for the first time allow researchers to directly compare their own material with an external sample. This should allow the accurate testing of predictions concerning tool and site usage and the reconstruction of technological and cultural changes over time in many parts of the world.

Part 2 Functional analysis: variables and recording methods

The formation of use-wear and residues on stone tools is a complicated and dynamic process which results in the modification of the tools' working edges and surfaces. Edge scarring (microchipping), edge rounding, striations, micropolishes, and embedded residues are the most common variables for assessing tool use (e.g., Anderson, 1980; Briuer, 1976; Fullagar, 2006b; Hurcombe, 1992; Keeley, 1980; Lewenstein, 1981; Lombard & Wadley, 2007; Odell, 2004; Semenov, 1964; Vaughan, 1985). Assigning a particular function to a tool requires detailed observation of a sufficient number of variables. More importantly, a combination of experimental replication and techniques of macroscopic and microscopic analysis are critical for obtaining good correlation between observed variables and tool use. Careful recording of these variables enables inferences to be made about details of tool function such as the action in which a tool was involved, the kind of material processed and, to some extent, an estimate of approximate duration of use of a particular tool.

The analyst should be aware, however, that there are some analytical problems associated with the interpretation of observed wear patterns and residues (e.g., Barton *et al.*, 1998; Fullagar, 2006a,b; Högberg *et al.*, 2009; Lombard & Wadley, 2007; Robertson, 2005:30–31; Wadley *et al.*, 2004). For instance, use-wear traces occur directly on working edges as the result of the tool's contact with the worked material and, as a consequence, the combination of wear variables provides reliable information regarding the mode of use of the tool and, to a lesser extent, the material worked. The presence of residues allows more precise identification of the material being processed. However, since residues are mostly deposited not directly on the working edge but at a little distance away from it, and, because non-use related residues often occur on the tool's surface, the recognition of the exact location of the used edges on tools can be complicated. Disadvantages inherent in both use-wear analysis and residue analysis can be overcome by, firstly, conducting replication experiments and, secondly, by combining these two different sources of data (Fullagar, 1994; Hardy & Garufi, 1998; Haslam & Liston, 2008; Högberg *et al.*, 2009; Kononenko, 2007, 2008a; Lombard & Wadley, 2007; Petraglia *et al.*, 1996; Robertson *et al.*, 2009; Rots & Williamson, 2004).

Part 2 outlines the methodology used for obtaining functional data from stone artefacts, particularly from obsidian tools. First, a variety of use-wear attributes and residues are discussed. Second, laboratory equipment and systems for recording the key attributes are described.

Use-wear variables

Wear traces are direct evidence of tool use. They are formed by the wearing down and removal of small stone particles from the working edge due to friction, pressure and resistance of worked materials making contact with the tool. There are five main variables that are important for describing the kinds of use-wear found on stone artefacts: scarring, striations, edge rounding, polish and residues. The manifestation and patterning of these variables is affected by many factors including: the raw material from which the tool was made, tool design and edge morphology, use-action (e.g., scraping or sawing), use-duration (e.g., short- or long-term tool use), and the physical properties of the material worked (e.g., wood, bone, stone, skin, meat or shell) (e.g., Ahler, 1979; Anderson-Gerfoud, 1990; Fullagar, 2006a,b; Hayden, 1979; Högberg *et al.*, 2009; Hurcombe, 1992; Kamminga, 1982; Keeley, 1980; Odell, 2004; Semenov, 1964; Tringham *et al.*, 1974; Vaughan, 1985). The key variables are described at length below.

Scarring. Edge damage in the form of scars, or chips, is common on used tools, especially on obsidian. The mechanical processes by which edge damage is created by use are similar in principle to the flaking technique of knapping (Tringham *et al.*, 1974). The occurrence and nature of use scars are linked 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 of the tool edge which can be observed in plan-view and the edge angle seen in cross-section. The initial edge morphology may affect the extent of scarring and also the size and shape of scars. The distribution, orientation, size and shape of use scars are considered as reliable indicators of the kind of tool use, although there is some debate about distinguishing deliberate retouch or accidental damage from those scars which resulted from use (e.g., Hayden & Kamminga, 1979; Hiscock, 2007; Kamminga, 1982; Odell, 1980; Tringham *et al.*, 1974; Vaughan, 1985:11–12).

In this study, scars on used edges of the tools are classified as bending, feather, step and hinge, following Cotterell & Kamminga (1979). Most of the used obsidian artefacts have scars of a small (<2 mm) to medium (2–3 mm) size which are visible to the naked eye, but micro-scars, which can only be observed under magnification, are also often present. The different types of scars on artefacts and their distribution on the working edge were recorded and compared with experimental data in order to verify their relationship with the use-material, use-action and use-duration.

Striations. Striations on the working edge represent the most important indicator of the direction of tool use or "kinematics" (Semenov, 1964:88). Striations are linear deformations of the surface caused by abrasive particles. Abrasive particles can come from different sources, for example: 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; Semenov, 1964:15). 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). In contrast to flint and other lithic raw materials, the smooth fresh fracture surface, as well as the brittle and fragile nature of obsidian means striations are formed easily in both use and non-use contexts.

The type of striations identified in this study follow Hurcombe (1992:37): (1) sleeks or plastic modification of the surface by straight-sided fine striations with a smooth cross-section, (2) rough-bottomed striations with slightly irregular or straight sides but an irregular bottom, (3) intermittent striations that are related to a series of small, rounded and distinct points of damage arranged in a line on the surface, and (4) flaked striations that are associated with a line of fracture damage on the edge. In addition, some linear features, or alignments, in the form of shallow, wide, discontinuous and poorly defined striations (Fullagar, 1986:80; Kamminga, 1982:14) were also recorded. The different types of striations and their orientations (e.g., parallel, transverse, diagonal and two-crossed diagonal) in relation to the edge axis indicate the mode of use (Hurcombe, 1992:57).

Edge rounding. Edge rounding is an attritional process, associated with abrasive smoothing and dulling of the edge through use. 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 its extent (e.g., Ahler, 1979:308; Fullagar, 2006a:225–226; Hurcombe, 1992:25; Kamminga, 1982:17; Vaughan, 1985:12–13). Obsidian is particularly likely to become abraded. This process affects the prominent points of the working edges, creates some variation in the profile of used edges and is clearly visible as a rough and darker surface area. Following Fullagar (1986:80), the degree of edge rounding on obsidian tools in this study was determined as being (1) very slight, (2) slight, (3) medium and (4) intensive.

Polish. Surface alteration from abrasive roughening through smoothing to a highly reflective gloss is an important variable in many tool-use patterns. This modification of the natural flaked surface on the working edges of stone tools has been referred to by scholars as “polish” (e.g., Fullagar, 1991; Hurcombe, 1992:12; Kamminga, 1979; Keeley, 1980:22; Mansur-Franchomme, 1983; Semenov, 1964:4; Vaughan, 1985:27). Keeley (1980:23) was the first researcher to stress that polishes can be distributed differently over the surface topography, can vary in extent and brightness and correlate closely with the character of the worked material. In functional studies of stone artefacts, including obsidian tools, the appearance, distribution and orientation of polish are all used as the main criteria for identifying worked material and, to a lesser extent, the mode of use (e.g., Aldenderfer *et al.*1989; Aoyama, 1995; Fullagar, 1986; Hurcombe, 1992; Juel Jensen, 1994; Keeley, 1980; Kononenko, 2008a; Vaughan, 1985).

There is still no agreement between specialists about how polish is formed on stone tools nor is there consensus on the timing and sequence of polish development (see references in Fullagar, 1991). All surface alterations, caused by the material being worked, go through different stages of development. As Vaughan (1985:29–30) pointed out, all polish types begin as a generic weak polish resulting from limited contact with worked material. This polish is dull, more or less flat and looks smoother than an unpolished surface. Generic weak polish is often difficult to distinguish from natural bright spots on the surface of a tool made of medium-fine grained flint (Vaughan, 1985:30). Over time, as the material continues to be worked, characteristic developed polish and well-developed polish are formed. However, not every type of polish progresses through the same stages, nor at the same rate. For example, polish resulting from cutting meat rarely progresses beyond the generic weak type (Vaughan, 1985:38). The highly variable nature of polish formation on different materials therefore imposes some limitations on the identification and interpretation of polishes on stone tools.

Fullagar (1991) has pointed out that many different uses of tools made from a highly siliceous raw material like obsidian can result in intensively polished surfaces, independently of the amount of silica within the worked material. He defined four stages of polish formation that apply to obsidian tools. The first stage is similar to Vaughan’s (1985:29–30) generic weak polish and involves abrasive smoothing and loss of features on the freshly fractured surface. On obsidian tools, it is also 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 and this, in conjunction with other use-wear/residue features (e.g., scarring and striations), 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 seen as patches of smoothed polish located within abraded surfaces. At this stage, the physical removal of material, levelling of peaks, deepening of subsurface cracks and impaction of granular material into surface depressions is visible along with some flaking from the surface and polishing on levelled peaks. Polishes sustained at this stage still do not clearly indicate the material worked (Fullagar, 1991:6; Kealhofer *et al.*, 1999:530).

At the third stage, developed polishes are formed and allow the determination of the worked material (wood, plant, bone or skin). During this stage, predominant mechanisms are the extension of subsurface cracks and flaking out of the surface, gradual removal of surface defects and the formation of an extensive stable polished surface. 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 by scholars 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) (Aoyama, 1995; Lewenstein, 1981; Hurcombe, 1992:36). All of these terms are related to an obvious surface levelling. The unused surface of obsidian is not perfectly smooth and contains some characteristic features. Any modification of these features can be easily identified as a rougher area in comparison with the surrounding surface. In this research, Fullagar’s (1991) concept of stages in polish formation has been adopted, although slightly different terms have been used 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 Fullagar’s stage 3, and (4) well-developed polish which is similar to Fullagar’s stage 4. Although polish on obsidian tools is generally seen in association with edge rounding, a number of other attributes, such as the location of polish in relation to the edge and its extension along the edge, are also useful attributes in the identification of the type of polish on obsidian tools.

Hafting wear traces

The presence of scarring, rounding, striations and polish, or a combination of these, can occur on the surfaces of artefacts located opposite the working edge. Usually these features are associated with the method of prehension or hafting (e.g., wrapped and hand-held or hafted in wooden hafts). The identification of hafting is important. It may affect the rate of polish formation because hafted tools can be used with a more forceful and rapid motion than hand-held tools (Kamminga, 1982:21; Keeley, 1982:799; Odell, 2004:152–153; Rots, 2003; Rots & Williamson, 2004). As Rots (2003:806) stresses, hafting use-wear on tools made from flint and some other raw materials has two distinguishable features: (1) scarring and (2) isolated spots of polish on the surface. For obsidian tools, the pattern of hafting wear is slightly different because it also includes abrasion and striations. One of the important indicators of hafting is the presence of residues such as resin and leaf phytoliths (Kealhofer *et al.*, 1999) since organic materials were often used in the construction of a handle or grip for hand protection (Fullagar, 1986:171–172, 2006a:218, Hurcombe, 1992:74; Parr, 2006:186–187). The analysis of hafting wear and residues was not a major concern of this study, but any modifications of the surface or residues related to the hafted, or held, part of the tool were recorded.

Residues

Residues on stone tools are an important source of information for interpreting past functions (e.g., Anderson, 1980; Briuer, 1976; Fullagar, 1998, 2006a,b; Haslam & Liston, 2008; Hayden & Kamminga, 1979; Hurcombe, 1992:26; Keeley, 1999; Lombard & Wadley, 2009; Loy, 1994; Robertson *et al.*, 2009; Shafer & Holloway, 1979:385). However, there are three potential problems with residue analysis. The first is the level of confidence in the connection of the residue to the actual used edge. The second is the difficulty in distinguishing plant and animal residues. Finally, 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; Haslam, 2006; Högberg *et al.*, 2009; Lombard & Wadley, 2007; Robertson, 2005:30–31; Rots & Williamson, 2004; Torrence, 2006; van Gijn, 1998).

The difference between use-related and other residues can be confidently determined on the basis of the context of the residues and their position on the edge or surface together with distinctive properties of sediments at the site. Non-use related or incidental residues usually appear as isolated occurrences on a tool. 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. Sometimes residues smeared on the edge, and in association with striations, clearly indicate direction of tool use (Hurcombe, 1992:26; Fullagar, 2006b:189; Rots & Williamson, 2004:1293).

Residue studies in the Pacific region have contributed significant data to the methodology of functional analysis of prehistoric tool assemblages. The distinctive structure and shape of residues on obsidian artefacts from archaeological sites have been identified as cellular tissue, starch grains, phytoliths, calcium oxalate crystals (raphides), resins and yellow-red plaques (cf. blood) (Barton *et al.*, 1998; Brass, 1988; Crowther, 2009; Fullagar, 2006a,b; Kealhofer *et al.*, 1999; Lentfer, 2003, 2009; Lentfer & Green, 2004; Parr, 2006; Parr *et al.*, 2001).

Some plant residues on obsidian tools have distinct cell structures and sometimes are observed as rough folds of tissue with bright birefringence under polarized light. 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 use (Fullagar, 2006a:216–217; Wadley *et al.*, 2004:1500). Starch and raphides can be seen on the surface of tools and, after extraction, on prepared microscope slides. 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, have a distinct dark extinction cross, visible under cross polarized light (Barton & Fullagar, 2006:50; Gott *et al.*, 2006:43; Fullagar, 2006a:217; Haslam, 2009; Lentfer, 2009). 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, 2009; Loy, 2006; Wadley *et al.*, 2004:1500).

Animal residues, including blood cells, have been identified on some obsidian artefacts (Fullagar, 1992). Prehistoric blood deposits in the form of proteinaceous film and red blood cells or erythrocytes can be observed at high magnifications in cracks and recesses on tool surfaces. 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 (e.g., Fullagar, 2006a:219; Fullagar *et al.*, 1996; Loy, 1983, 1993; Robertson *et al.*, 2009; Wadley *et al.*, 2004). A range of approaches and techniques has been applied to the identification of blood residues (see references in Garling, 1998 and Högberg *et al.*, 2009). In this study, blood residue identification was conducted at a basic level including microscopic observation and the presumptive test, *Hemastix*$^{\mathrm{TM}}$.

Distinctive white residues were observed on some obsidian tools but these residues have not yet been identified. There is a suggestion that some white residues may represent the result of cooking or heating plant material rich in starch (Wadley *at al.*, 2004). White residues observed on obsidian tools in this study have a bumpy texture with no clear form and shape. There are no similar residues in the project database and thus further studies are required including the determination of their chemical composition. However, the patterned distribution of these residues, seen near used edges and associated with surface microtopography, implies that they were linked to the use of tools.

Surface preservation on obsidian artefacts

Use-wear/residue studies are particularly concerned with distinguishing wear patterns, produced by use, from those alterations resulting from natural chemical and mechanical processes. There are many contexts, other than use, that may cause non-use modification of the edges and surface of stone tools (e.g., Burroni *et al.*, 2002; Keeley, 1980:4–5; Levi Sala, 1996; Moss, 1983; Plisson & Mauger, 1988; Tringham *et al.*, 1974; Vaughan, 1985:23–25, 41–44). Surface alteration on obsidian can destroy or mask use-wear patterns and greatly reduce the opportunity for an accurate functional definition of used tools (Hurcombe, 1992:34–5). Consequently, it is important to understand these factors before studying use-wear patterns.

The physical structure of obsidian is a fine amorphous matrix with scattered small crystals of silica (Hurcombe, 1992:24). This structure means obsidian produces a good conchoidal fracture and therefore has excellent flaking properties. A freshly flaked obsidian surface is very smooth and bright. Other distinct features of a freshly flaked surface are irregularities, stress fissures and ripple marks (Hurcombe, 1992:24) which are all visible under a microscope. These features are present on each obsidian flake and are easily distinguished from other features by their characteristic shape and orientation.

There are two main factors which influence the surface of obsidian artefacts: physical damage and chemical alteration (Hurcombe, 1992:71–72). Obsidian, as a very brittle raw material with a reactive surface, is susceptible to non-human physical processes. Contact with gravel and soil particles causes edge damage, surface abrasion and striations. 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 visible on archaeological obsidian flakes is the sporadic nature of the distribution of scars, along with 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. Obviously, most fresh scars have been formed recently, perhaps due to recovery, transportation, bagging or storage.

Abrasion and striations which appear on obsidian as a consequence of natural or post-depositional factors are easy to recognise because they are not normally distributed in a regular fashion and are not aligned with the flake edge. 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, post-depositional abrasion, if located close to the edge, may occasionally mask the use-wear pattern.

Chemical damage of obsidian surfaces, in the form of a number of roughly hemi-spherical pits unequally distributed on the surface, has been observed on some of the prehistoric artefacts analysed. This surface alteration indicates that some natural combination of chemicals has etched the original flaked surface over time. As a result of chemical damage, use-wear features on the working edge can be destroyed or greatly altered (Hurcombe, 1992:81). In order to distinguish the degree of chemical damage on prehistoric artefacts, a scoring system following Fullagar's categories (Kealhofer *et al*., 1999:530) was adopted for this study: slightly pitted, medium pitted, and heavily pitted.

In addition to physical and chemical damage, other weathering processes (e.g., wave action) can contribute to surface alteration. The combination of these factors may affect use-wear features to different degrees. Sometimes the surface may be so greatly altered that any use-wear definition is impossible. Fortunately, the number of obsidian artefacts with completely altered surfaces in the study sample is relatively small.

Experimental study

Replication experiments play a significant role in the development of the methodology employed in the functional analysis of artefacts. Experimental replication forms the basis for reconstructing wear formation sequences on which inferences about tool use strategies and associated activities are made. There are two basic requirements for replication experiments. First, tools of similar raw material, size, and shape as prehistoric artefacts should be used and, second, experimental tools and worked materials used in experiments should approximate those used by the prehistoric population under study (e.g., Fullagar, 1986; Hurcombe, 1992; Kamminga, 1982; Keeley, 1974, 1980; Lewenstein, 1981; Odell, 2004; Semenov, 1964; Vaughan, 1985; Yerkes & Kardulias, 1993) If replications are faithful to past conditions, then wear patterns observed on experimental tools can be compared, verified and assessed with those identified on artefacts and tool functions can be confidently assigned.

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 & 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). His experimental program was designed to create a considerable comparative collection of used tools and to stimulate interest in microscopic studies of chipped and ground stone tools under low magnification (Kazarjan, 1990; Korobkova & Filippov, 1987; Odell, 1995; Semenov, 1964). Following the publication of Tringham *et al*. (1974) and Keeley's (1980) seminal studies, a comprehensive range of systematic use-wear experiments has been performed by a number of scholars (e.g., Aldenderfer *et al*., 1989; Anderson, 1980; Anderson-Gerfaud, 1990; Aoyama, 1995; Boot, 1987; Davenport, 2003; Dennell, 2009; Fullagar, 1986; Hurcombe, 1992; Juel Jensen, 1994; Kajiwara & Akoshima, 1981; Kamminga, 1982; Kononenko, 1986, 2008a; Korobkova & Filippov, 1987; Lewenstein, 1987; McBrearty *et al*., 1998; Odell, 2004; Rots, 2005; Vaughan, 1985). These experiments have delineated a number of relevant factors which distinguish the key wear patterns on stone tools and demonstrate the formation of all major forms of use-wear. 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 the combination of replication experiments and use-wear and residue studies (e.g., Fullagar, 1986:197, 1994, 1998; Högberg *et al*., 2009; Lombard & Wadley, 2007; van Gijn, 1998).

Systematic tool-use experiments were therefore undertaken with the aims of producing an empirical basis for verifying use-wear patterns previously observed on obsidian artefacts, investigating the factors which caused the formation of wear traces and, finally, the creation of a reference collection of wear and residues that are essential for the identification and interpretation of prehistoric obsidian tools. These results are reported in Parts 3 and 4.

Preparation procedures

The sequence of procedures for preparing experimental tools and excavated artefacts for use-wear/residue study was basically similar, but with additional procedures for artefacts largely determined by the way they had been handled in the field. Experimental tools 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. Each sample was then washed in an ultrasonic bath, air dried and cleaned with alcohol before microscopic examination for use-wear. Solutions with residue were stored in centrifuge tubes for further analysis.

Most of artefacts were washed in the field but some were carefully collected for organic residue studies during excavation and were not washed (cf. Barton *et al.*, 1998). The washed and unwashed artefacts required different treatments. Before microscopic examination, surfaces of washed artefacts were lightly swabbed with alcohol 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 obvious wear traces, were noted on a standard recording sheet (Fig. 2). The tool was then set aside for further analysis under higher magnification using a metallographic microscope using vertical incident lighting, brightfield/darkfield and polarizing filters. Those artefacts not exhibiting signs of use-wear were also recorded and

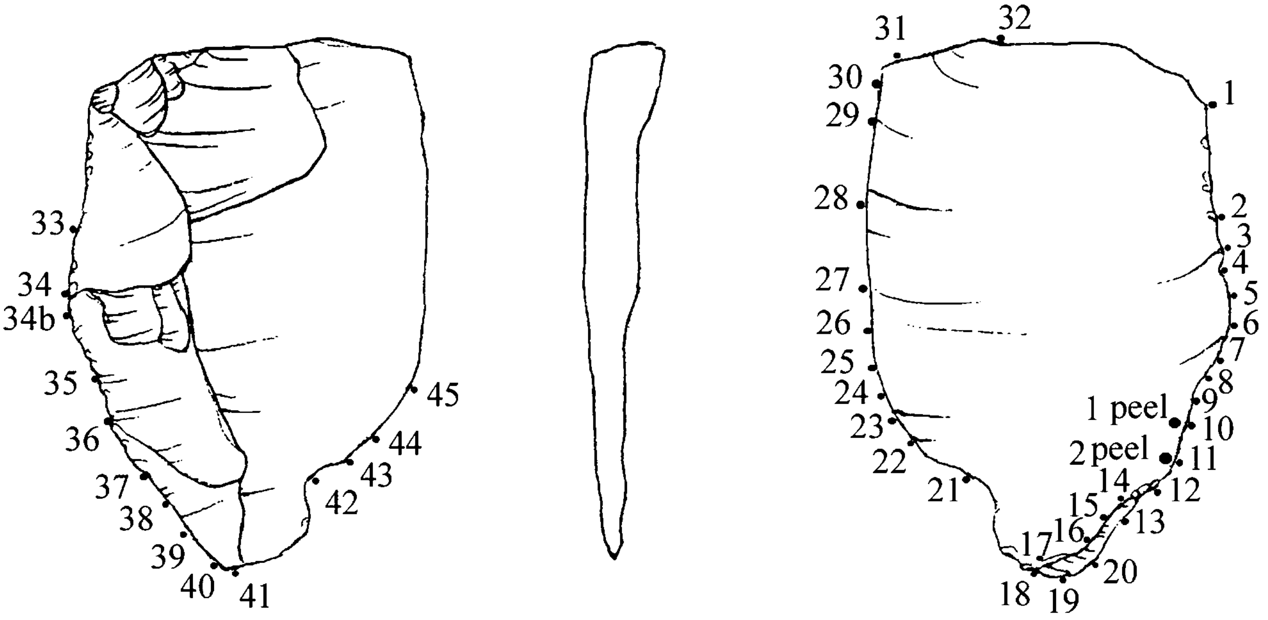

Figure 2. Recording form for data obtained from artefacts.

FAO M336, test pit 970/1000, level 4, spit 3. Medium pitted surface. Irregular microscars are visible on both sides of the edge. Peels and images were taken on 1 and 2 December 2004. Peel 1 was taken before the artefact was cleaned and peel 2 was taken after the artefact was cleaned.

1	Points 1 and 2	Microscars, diagonal striations, slightly rounded edge, light polish.
2	Points 3 to 5	Some scars, diagonal striations, light polish, some starch grains.
3	Points 6 to 9	Mostly parallel and some diagonal striations, developed polish, some scars.
4	Point 13	The edge is formed by burin-like spall, white residues.
5	Points 14 to 18	Diagonal striations, light to developed polish, plant tissue and “white” residues.
6	Point 19	Slightly rounded edge, light polish, diagonal and parallel striations. It seems that this part of the edge has been used after the burin spall appeared.
7	Points 20 to 23	Dense diagonal and parallel striations, medium rounded edge and developed polish.
8	Points 24 to 32	Some white residues.
9	Points 33 to 37	Diagonal and rarely parallel striations on the dorsal surface, continuous microscars, patchy distributed light and developed polish.
10	Point 36	Starch residues concentration.
11	Points 38 to 45	Some black organic residues (resins?)

Function: very intensive use for whittling and sawing soft and probably siliceous wood or palm. There are some starch grains and resin-like residues.

were scanned under the high power microscope for residues. If residues were located, a photographic record was made, and sometimes samples were extracted and mounted on microscope slides for further investigation.

More complicated preparation procedures were required for unwashed artefacts. For a residue study, it is important to preserve the diagnostic structure of residues on the tool surface prior to any cleaning procedure (Fullagar, 2006a:213). All unwashed artefacts were processed using a technique developed by Fullagar (2006b; Loy & Fullagar, 2006). Unwashed specimens were slightly cleaned with 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. Each artefact was then drawn and the surface was scanned by 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.

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 to sample residues. 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) (Coltène AG, Altstätten/Switzerland). A small amount of PVS was applied to the surface or edge of the artefact. After five to seven 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 unwashed artefact where any concentration of residues was noted during preliminary microscopic observation. These locations were recorded on drawings (Fig. 2). The peels with residues were then stored for further examination by specialists.

Because the identification of starch and phytolith 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. Then the residues were agitated with the nylon tip and the liquid was drawn back into it. The solution was transferred to a microscope glass slide. When the water evaporated from the glass slide, the dried sample was sealed with a glass cover slip, and purified water added for transmitted light microscopy.

After initial observation and pipette extraction, further residue and sediment removal from selected artefacts was undertaken. Each artefact was placed into a separate clean plastic container, and purified water was added to just cover particular surfaces or, sometimes, the entire artefact. Depending on the amount of sediment adhering to the surface, the container was then suspended for between 30 and 60 seconds in an ultrasonic bath. The artefact was then 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 five minutes. Finally the tool edges were cleaned with alcohol prior to scanning for use-wear.

Recording

The recording of use-wear and residues involved two stages and followed the same procedures for both the experimental tools and the prehistoric artefacts. First, a standard form was used for each tool. It included a drawing of the artefact (Fig. 2) showing the locations of residues and use-wear and the position where images were taken, noted as "point 1", "point 2", etc. Each experimental tool was also recorded on an additional form where the position of the working edge was noted along with information on (1) the name of person who conducted the experiment, (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) and (6) description of the visible features which appeared on the tool during its use (e.g., irregular scars on the edge after five 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 and the degree of polish development was recorded. The type of residues was also recorded on the form and in an Excel database (Table 1). Each experimental tool was scanned on both faces under microscopes with magnifications from 50× to 1000×. Areas with wear and residues were then photographed before and after cleaning.

For the archaeological sample, features of use-wear and residues observed at each point were also described on the recording form (e.g., "point 1—micro-scars with parallel striations, light polish and starch residues") (Fig. 2). These data were supplemented by digital images. On the basis of detailed observations, an inference was recorded about the mode of use of the tool (e.g., scraping), the worked material (e.g., starchy soft wood), approximate time duration, the possible pattern of hafting and the type of residue (e.g., tissue, starch).

Next, a summary of use-wear and residue data was made in a separate Excel database that includes four main types of information about each examined artefact (Table 6). The first set of information is the identification number of the artefact and the archaeological context in which it was found (e.g., site, unit, level). Second, some technological and morphological features were noted (e.g., size of flakes, the presence of cortex, scars, and retouch). The third category of information relates 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, and 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.

The images are essential for standardising the interpretive criteria which were used in the examination of artefacts. 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. These full colour images form an important part of the comparative collections and permit readers to fully assess the criteria by which identifications of wear patterns and residues were made in this research.

Microscope and camera equipment

Microscopic studies of use-wear traces and residues can be conducted under low-power (up to 100 ×) or high-power magnification (from 100× to 1000×). Both these approaches have their advantages and disadvantages (Odell, 2004:139). In this study, obsidian artefacts were examined using both a low-power stereomicroscope (Orient SM 1) with an external light source and a high-power microscope Olympus BX60M fitted with both vertical incident and transmitted light sources, bright and dark field illuminations and cross polarizing filters.

The first step in the study of use-wear/residue was observation of the entire artefact under the stereomicroscope with magnifications ranging from 6× to 50×. These low magnifications with an external reflected light provide a three-dimensional view of the used surfaces and permit the examination of edge scarring, surface alteration (e.g., abrasion, smoothing), striations and some residues. The artefacts were either hand-held or set on a stage to enable them to be viewed in such a way that the angle of external light reflected on the surface and could be adjusted allowing the observation of tools of different sizes.

In the second step, the metallurgical microscope Olympus BX60M was used as the main instrument for the identification, analysis, and interpretation of the working edges on the tool, the mode of use, and worked material. 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 100× to 1000×. 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. Transmitted light was used to examine residue extractions mounted on glass microscope slides. The disadvantage of high magnification, however, is that it is impossible to observe the entire field of vision with the same depth of focus because of the uneven micro-topography of the used area of the tool. This limits the size of the area for which wear patterns can be documented using photographs (Högberg *et al.*, 2009; Hurcombe, 1988; Lombard & Wadley, 2007)

During use-wear/residue analysis of obsidian tools, different microphotography systems were used. In the early stage of the study, colour slides were taken with an Olympus PM-10AK camera attachment. The colour reversal film (Kodak Ektachrome 160) used by this camera provides high quality records of the distribution of scars, striations and residues on the surface of black obsidian artefacts. In the later stages, 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 was increasingly difficult to obtain both a good focus and contrast in the image. The software with the camera also had some problems with labelling and scaling of images and the database was difficult to use.

These disadvantages disappeared with the use of a ColorView II camera and Soft Imaging System GmbH attached to the metallographic microscope. This digital camera system produces images of improved quality (e.g., Plate 1) and makes it easy to record and store information in the computer database.

Assigning function

The structure of this use-wear/residue study of both experimental tools and prehistoric artefacts has been determined by methodological approaches developed for functional studies of stone tools, particularly obsidian tools. All obsidian experimental tools and archaeological artefacts were 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. Third, further microscopic analysis made a 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, a functional interpretation of tools was made on the basis of comparing characteristics of use-wear/residues observed on artefacts with available experimental samples and where relevant ethnographic analogies were employed.

Having developed and set out the analytical approaches for the study of stone tools, Part 3 describes the experimental program with the aim of determining how and what specific tasks and functions create characteristic wear features and residues on obsidian tools.

Part 3 Experimental methods

Experimental replication provides a basic understanding of the processes contributing to wear formation and yields new data that aid in the recognition, interpretation and verification of wear patterns on prehistoric artefacts. Experimental research is, however, limited in several respects. First, even if general or approximate "contemporary" conditions can be simulated through the performance of experiments using local resources within the natural environment surrounding the site, it is still not possible to completely replicate past human behaviour and environments (Hayden & Kamminga, 1979:5; Keeley, 1974, 1980:6; Yerkes & Kardulias, 1993). Second, no experimental program can realistically replicate all the possible variations in function which may have occurred in prehistory (Hurcombe, 1992:29; Vaughan, 1985:9). Finally, since wear patterns on experimental tools made from freshly flaked obsidian do not exactly match those observed on archaeological specimens that have undergone taphonomic changes, they cannot provide precise analogies for prehistoric tasks (Fullagar, 1986:82; Hurcombe, 1992:29; Keeley, 1980:6). Despite these problems, it is possible to construct a reasonably comprehensive and realistic framework for use-wear experiments that provide a means of observing general trends that can be applied to the reconstruction of function of obsidian artefacts derived from archaeological contexts.

Ethnographic data about the manufacture and use of stone tools from the region under investigation are important for the functional interpretation of lithic assemblages (e.g., Flenniken, 1984; Ibáñez & González, 2003; Keeley, 1974; Rots & Williamson, 2004). Although ethnographic and ethnobotanic data should not be used as direct analogies, consideration of the forms of resource exploitation and tool-use behaviour of a local population in particular environments can provide a valuable comparative source of knowledge to structure the experiments and to support functional interpretations of tools (e.g., Davenport, 2003; Fullagar, 1994; Kamminga, 1982; Robertson, 2005). Consequently, a review of available data on tool-use among indigenous groups in the tropical Pacific region (e.g., Allen *et al.*, 1997; Chowning, 1978; Conte, 2006; Floyd, 1954; Fullagar *et al.*, 1992; Haddon & Hornell, 1937; Hogbin, 1938; Kamminga, 1982; Parkinson, 1999; Sillitoe, 1988; Specht, 1981; White, 1967, 1968; White & Thomas, 1972) was used to assist the choice of relevant plant and animal species and appropriate inorganic materials for the experiments.

There are some factors which necessitate experimental research to further the functional interpretation of prehistoric tools found on Garua Island. Firstly, these obsidian tools exhibited some peculiarities in wear patterns which had to be examined in the light of experiments prior to the functional definition of artefacts from the site being made. Although earlier experimental studies of obsidian tools covered all the main aspects of wear formation (cf. Hurcombe, 1992:126, Table 3), the level of investigation of particular variables lacked a consistent approach. Researchers of the uses of obsidian have not always published detailed and well-documented experimental data and it is difficult to use their results for further comparative analysis. Hurcombe's study (1992) presents an excellent summary of the functional analysis of obsidian tools based on a series of well-documented experiments. However, since Hurcombe's use-wear characteristics did not always fully correspond with wear patterns observed on the obsidian artefacts from Garua Island, further verification of some aspects of use-wear formation was sought through replication experiments based on local ethnographic information and using local resources.

The second factor concerns the nature of worked material. The silica contents and densities found in many of the plants growing in the tropical environment of Garua Island 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). The experimental program was designed to use local materials in a wide range of experiments, many of which had never been previously conducted. New findings from these experiments are highly relevant to the investigation of wear formation. Finally, the material used in these replication experiments provides useful comparative data for the reconstruction of resources which could have been exploited by middle and Late Holocene populations in the Pacific region and tropical environments in other parts of the world.

Some general principles and approaches to experimental studies of lithic assemblages and particularly of obsidian tools are introduced in Part 3. The aims and the methodological strategies which were used in this experimental program are outlined. Wear variables examined during experimental work are set out and the features of tools that were made and used in replication experiments are described. The factors associated with wear formation on obsidian tools are explored with particular attention to variation in the stages of surface alteration and the stages of development of distinctive use-wear patterns for specific types of use. Finally, experiments were conducted to clarify the potential influence of taphonomic factors on the surface alteration of the tools.

Aims and design of the experimental program

The general approaches developed by many scholars, (e.g., Hayden, 1979; Hurcombe, 1992; Juel Jensen, 1994; Keeley, 1980; Semenov, 1964; Odell, 2004; Tringham *et al.*, 1974; Vaughan, 1985) were used to develop the research framework, but the purpose and structure of the replication experiments also differed in important respects from previous experimental studies of Pacific stone assemblages by Akerman (1998; Akerman *et al.*, 2002), Davenport (2003), Fullagar (1986) and Kamminga (1982). 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, first, to study the efficiency of stone material in the performance of tasks associated with the processing of organic materials widely used by Australian Aborigines. Second, 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 his experimental data, Kamminga (1982:19) used microscopes with magnifications mostly between 50× to 100× which allowed the analysis of use-scarring, striations, rounding, abrasion and polish in its developed stage. However, initial stages of wear formation and some specific polish characteristics, which can usually only be viewed under higher magnification, were rarely recorded. This project employed both low and high magnifications to ensure optimum recognition of wear patterns.

The main objective of experimental research by Fullagar (1986) was the study of polish formation and residues as major indicators of worked material (Fullagar, 1991, 2006a,b). Using a range of tropical and subtropical plants, animals, fish and shell, Fullagar concentrated on determining 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.

The experimental study of obsidian tools 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) examined use-material and its state, use-actions, duration of use, and wear features which occurred on the surface of obsidian independent of human activity. However, her comprehensive description of wear did not include a detailed analysis of scarring patterns that resulted from use. Also, when characterising the plant materials involved in the experiments, Hurcombe (1992:39–43) did not specify their silica content and density, which can 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 the study of lithic assemblages from the Pacific were not included, in particular tropical plants, shell and clay.

In contrast to previous experimental programs, this study includes wear patterns generated in the earlier stages of wear development on obsidian tools, considers the relationships between the rate of wear formation, tool efficiency and use duration, and focuses on tools involved in the processing of local tropical plants and non-plant materials. The specific aims of replication experiments were (1) to examine when, and under what conditions, major forms of wear such as scarring, striations, rounding, polish and residues are formed on obsidian tools, (2) to assess to what extent obsidian flake tools are efficient in the performance of specific tasks at different times in their 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 aims, it was also important to conduct a series of experiments using obsidian raw material which was identical to that of the prehistoric artefacts from the site under investigation.

The development of the experimental program began by assessing the use-wear/residue characteristics identified on the middle and Late Holocene obsidian artefacts from the site. The functional, archaeological and ecological context of assemblages from the study region on Garua Island determined the design of experiments and selection of materials. The program explored the stages of formation of the main forms of wear in simulated prehistoric conditions. For this reason, each experimental tool was used to perform a specific activity for a predetermined period of time in as realistic a situation as it was possible to achieve. At the same time, the results were observed and recorded in a scientifically controlled manner. These task-oriented experiments involved a realistic mode of tool movement in the performance of tasks and were of higher comparative value than those using tools that were restricted to simpler, timed repetitive actions (Yerkes & Kardulias, 1993:103). Moreover, task-oriented tools reflect a more complicated combination of wear variables than more controlled and limited experiments. Some of the experiments were performed by local people from Kimbe which is located on the mainland of West New Britain close to Garua Island. They were asked to make a spear, handle, comb and knife from local plant materials and they often used only one or two obsidian flakes for the whole process. In other experiments, the completion of the whole of a particular process was not attempted using one flake, although a more limited version of a particular task used the same materials and motions as would be the case if it were being performed in a prehistoric situation. For the most part, the experiments were conducted in the field whilst 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.

The experimental study involved 292 separate experiments each using a different tool. Use-wear and residues on a sample of 154 tools were systematically recorded. The remaining tools form a reference collection for future residue studies. Residues were recorded on the basis of their obvious and distinctive form (e.g., starch grains, blood cells, fibre, and films). In addition to the experimental program, 15 other experiments were included that 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 1. To maintain consistency, the actions or mode of use involved in processing these materials and the duration of use are separately described. In the conclusion of Part 3, the key wear variables that form on obsidian are briefly summarised.

Manufacture of experimental tools

The tools made for this project are mostly unretouched flakes, similar to those in the archaeological assemblages, although a few retouched stemmed tools were also produced (Fig. 3.3–4). Obsidian cobbles and nodules for knapping were collected at both the Baki source on Garua Island and the Kutau source at Bitokara Mission (Torrence *et al*., 1992). Most cobbles had an angular shape with potential flaking platforms and good flaking properties. However, many larger pieces contained internal air bubbles and very thin, fracture 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. Some Kombewa cores and Kombewa flakes following description of Owen (1938:205) and Inizan, Roche and Tixier (1992) were made for this project, but their size was limited by the small size of the blocks of obsidian obtained 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

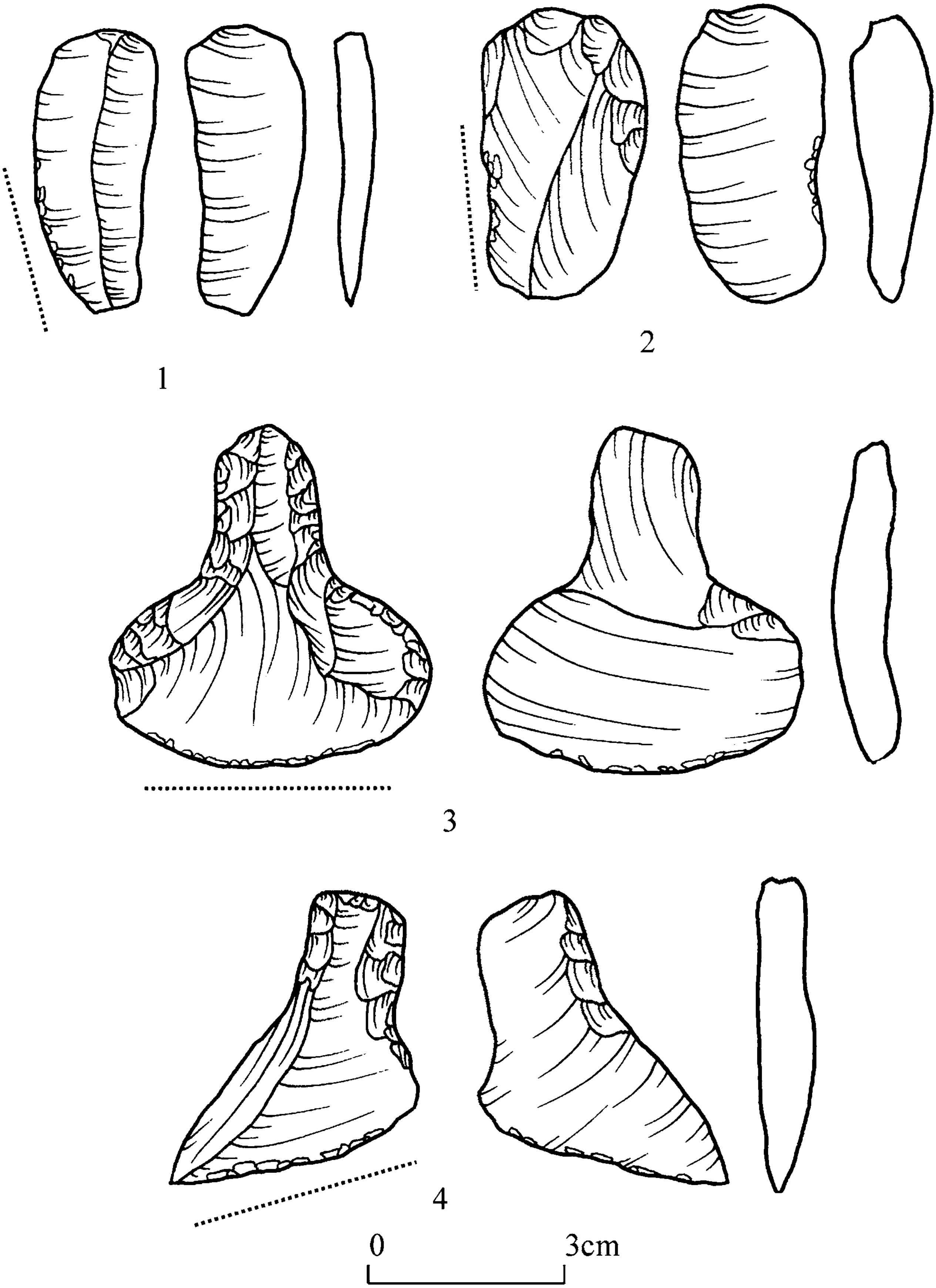

Figure 3. Experimental tools used for working palms and coconut shell.

performance of particular tasks, several specific attributes thought to be significant in use-wear formation were carefully considered. These included (Table 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°; and
4 mode of hafting (hand-held, wrapped, hafted in wood).

With the exception of stemmed tools with retouched stems, none of the tool edges were sharpened before use because the unretouched obsidian cutting edge is already thin and sharp. The tools were used as naturally as possible and were generally treated casually, as perhaps prehistoric tools were, although they were not dropped, stepped on, or used with gritty hands. Exceptions were those experiments performed by indigenous people who were more casual in their use of tools. This sometimes involved dropping the tool on the sandy ground, or placing it on a stone platform or wooden bench, holding it in the mouth between teeth during a break or after performing the work. In some cases, this tool use behaviour was reflected on the edge and surface of experimental tools (non-patterned edge damage and abrasion) and was recorded.

Key factors in wear formation

The main factors which cause wear formation on obsidian include the type of material worked, 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).

Use-material variety. The materials used in replication experiments were determined by prior examination of use-wear patterns observed on obsidian artefacts, ethnographic data about native plant species used by indigenous people and by current local environmental conditions. All materials used in the field experiments were available locally. Materials used in experiments 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 (Table 2). 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 included trees, shrubs, grasses and tubers. The distinction between trees and shrubs, as well as between tall grasses (e.g., bamboo) and shrubs is not precise (Floyd, 1954) so the plants were divided into four groups, according to the mechanical properties associated with the density of the material (Kamminga, 1982:57) and their silica content (Fullagar, 1991:4–7). It is known from previous research that both the density and the silica content are closely related to the formation of wear and residue patterns 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 2).

The soft elastic materials (category 2) are represented by three species of fish, including parrotfish (*Scaridae*), wrasses (*Labridae*) and salmon (*Oncorhynchus gorbuscha*) as well as chicken (*Gallus gallus)*. Additional use-material such as human skin (shaving) was also included in the experimental program because ethnographic observations 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). Experiments with thin chicken skin were conducted in order to replicate piercing and cutting human skin, since human skin has similar relevant characteristics to the skin of raw chicken breasts (David *et al*., 2006).

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

Use-material state. The condition of the worked material may cause variations in scarring, striations, rounding and polish on obsidian tools. Therefore, the state of worked samples was assessed in all experiments, with particular attention paid to moisture content (fresh and green or dry species) as one of the significant factors that softens worked material, reduces friction, and slightly increases the density value for plants (Fullagar, 1986:99; Hurcombe, 1992:31; Keeley, 1980:44; Vaughan, 1985:9).

Most of the 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, one species of soft wood and coconut shell which were all used in a half-dry or dry condition. Tubers 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 fresh chicken. In contrast shell and clay were used half-dried.

Mode of use. Use-action is responsible for certain aspects of wear attributes including the location and distribution of scars, direction of striations, features of rounding, polish and abrasion (Semenov, 1964:15–18; Hurcombe, 1992:33). The actions employed in replication experiments consisted of the basic modes of tool use that are not directly influenced by cultural or environmental factors because there is a limited range of tasks that can be undertaken using particular materials (Kamminga, 1982:29; Vaughan, 1985:16).

Two general categories of use-actions were recognised: uni or bi-directional transverse and uni or bi-directional longitudinal (Grace, 1989:110; Semenov, 1964:3–4; Tringham *et al*., 1974:188). A transverse motion is one at right angles to the working edge. If uni-directional, it can be away from or toward the user (e.g., scraping). Differences in contact angle and edge angle generate several variations (Tringham *et al*., 1974; Vaughan, 1985:16). Transverse actions in these experiments are represented by scraping, whittling, planing and chopping.

Longitudinal actions refer to the motion which is parallel to the working edge. 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; Tringham *et al*., 1974:188; Vaughan, 1985:24–25). Replication experiments in this project included cutting as a more general action which could involve both uni- and bi-directional movement, such as sawing and slicing, which are generally performed by a slightly angled action, and carving, which involves a more complex cutting action with a combination of whittling and scraping motions performed by a small area of edge or the tip of a pointed tool.

Some experiments were conducted using a rotational action (drilling wood, piercing skin and green leaves). This action combines transverse and rotary movements and produces wear traces oriented in two directions: perpendicular to the tip and rotational around the side edges (Semenov, 1964:18; Vaughan, 1985:16).

Many experiments were designed to perform only a single task and the mode of use was relatively simple and repetitive. However, most of the experimental tools were used without hafting, and hand-held implements were not able to precisely repeat the same action each time. This means that any simple action potentially involved occasional movement in more than one direction. This resulted in some variation in the orientation of the striation on the working edge. For example, some tools used for sawing palm and wood developed mostly parallel striations although a few isolated diagonal striations were also observed.

During some experiments, a combination of two and, rarely, three motions were used as a more effective way to process the material. For instance, whittling wood required occasional cutting or sawing actions. Processing tubers was more effective if both scraping and slicing actions were used. However, multiple uses of obsidian tools were infrequent because the form 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 prehistoric assemblages that were studied had a small number of tools involved in two or more actions.

Use-duration. Use-duration is important because it determines the stage of wear formation. 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 (Hurcombe, 1988). Use-duration, the material worked, mode of use, and the angle of working edge are interrelated factors on which the extended use of a tool is dependent (e.g., Fullagar, 1986:88; Hurcombe, 1992:34–35; Schiffer, 1979:18–19; Vaughan, 1985:15).

There are various ways of measuring use-duration in experimental research. Some scholars count the number and length of strokes as the basic unit of measurement (e.g., Aoyama, 1995; Kajiwara & Akoshima, 1981; Lewenstein, 1981; 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 these replication experiments, Hurcombe's (1992:34) measure of time in elapsed minutes ("use-time") was adopted.

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 five, 15 and 30 minutes. According to Keeley (1980:82–83), most wear on the tools is formed within 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 after a given period of use. 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 these 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.

Use-wear variables and residues

The main variables selected to describe use-wear on experimental tools are derived from previous studies (e.g., Fullagar, 1986; Hurcombe, 1992; Kamminga, 1982; Keeley, 1980; Lewenstain, 1981; Lombard & Wadley, 2007; Semenov, 1964; Tringham *et al*., 1974; Vaughan, 1985). These include edge damage or scarring, striations, edge rounding, polish and residues. These forms of wear have common mechanics of formation, but the physical properties of brittle obsidian contribute to some peculiarities in the rate and appearance of wear patterns (e.g., Fullagar, 1991; Hurcombe, 1992:24–27; Kamminga, 1982:4–5). This study therefore concentrated on variables which have been shown to be particularly relevant to use-wear patterns observed on obsidian.

Scarring. Scarring is formed on obsidian far more frequently than on other lithic raw materials used for the same task. The relationship between types of scars, material worked, direction of action and the shape and angle of the working edge was recorded during experiments. The most common types of scars observed on the obsidian experimental tools are bending, feather and step scars (Table 1). Often a combination of two or, in rare cases, all types are present. Flake scars with a hinge termination are extremely rare and were usually recorded in association with step or feather scars. In addition to use-related scars, scars formed as a result of accidental or post-depositional factors were observed.

Striations. Striations were noted on most experimental tools, and their orientation, morphology and size recorded. The number of striations was not counted but their relative density or isolation from each other was noted. Striations were recorded as parallel (or longitudinal), perpendicular (or transverse), diagonal and/or crossed in their orientation in relation to the axis of the edge (Table 1). As reported in Part 2, the following types of striations were also recorded: sleek, rough-bottomed, intermittent, and flaked striations.

Edge rounding. Edge rounding was commonly observed on most experimental tool edges and was often associated with polish. On experimental tools edge rounding was characterised as: (1) very slight, (2) slight, (3) medium and (4) intensive (Table 1).

Polish. The stages of polish development on experimental tools were determined following Fullagar's (1991) categories: (1) very light, (2) light, (3) developed and (4) well-developed. Brightness (intense, bright, dull), texture (very smooth, smooth, and slightly smooth), and the location and distribution of polish along the edge were also recorded (Table 1).

Residues. The experimental program was designed to investigate the relationships between different kinds of use-wear and residues as well as their distribution on the working edge of tools. Taxonomic identification and detailed characteristics of residues were not part of this study, only the general properties of the residues were described (Table 1). Residues recorded on experimental tools comprise oily film, plant tissue, animal tissue, including rainbow-coloured residues, human skin residues, fish scales, starch granules, resin, needle-like residues some of which may be raphides (Loy, 2006:136), blood-like residues and unidentified white coloured residue. Since not all the residues were extracted from the experimental implements, the remainders are available to assist future studies.

Hafting wear and residues

Most of the experimental tools were hand-held. Tools were either used in the bare hand with no protective materials or were wrapped in plant leaves or vines. Wooden handles were used for some stemmed tools and adzes. The formation of hafting wear and residue was not the main subject of the study. However, any modifications to the surface that related to the hafted part of the tool, and any associated residues, were recorded and used for comparative analysis with the patterns of hafting wear observed on prehistoric artefacts.

Taphonomic wear attributes

In order to examine the processes and nature of surface damage not related to tool use, 24 obsidian flakes were buried in Sydney within a loam on a slope for 22 months. Although the time scale was short, the results of this experiment established that certain natural and accidental factors can produce physical and chemical damage to obsidian surfaces. These results 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.

The foregoing discussion and examples demonstrate the importance of replication and methodology. These principles need to take into account a range of ecological and archaeological issues and also recognise a number of constraints before the experimental program is finalised. This study generated a series of experiments designed to further investigate the complex process of use-wear formation. The results of these task-oriented replication experiments involving obsidian tools are presented in Part 4.

Part 4 Experimental use-wear patterns and residues

The results of the replication experiments are presented using the three categories of use-materials described in Part 3. These categories include (1) plants (palms, soft and hard wood, herbs, grasses and tubers), (2) soft elastic materials (fish, chicken and human skin) and (3) hard, dense materials (shells and clay). Within each category, the types of use actions and the duration of use are linked to detailed characteristics of the main forms of wear variables. These variables show how use-material, use-action and the duration of use affect the kind, degree and rate of wear formation on experimental tools. These relationships can then be used to identify the function of prehistoric artefacts. Further, since the particular kind of use-wear may be consistent with the residues resulting from contact with processing materials (Fullagar, 2006b:201), it is also important to describe these residues and their distribution on experimental tools. Data derived from hafting wear patterns and taphonomic experiments are presented as additional essential information which may assist in the analysis of artefacts. The concluding section Part 4 describes how these results can be employed in the interpretation of the function of prehistoric tools.

The experimental results are presented in Tables 1 and 2. Most of these experiments are accompanied by images (Plates 1–115). These images present trends and variations in use-wear patterns in an understandable and unambiguous way.

Palms

Palms contain large quantities of starch and are thus an economically significant species in the Pacific region (Kealhofer *et al*., 1999:543; Powell, 1976:182). Seven species of palms (Table 2) were processed by several modes of use. Most of the palm woods are of light to medium density and have high silica content. The exception is 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 are of similar density and hardness to soft wood, they produce similar scarring patterns on obsidian tools. Experiments lasting five, 15, 30 and more minutes of use were conducted to determine how the main forms of wear are built up.

Sawing. *Scars*. The sawing of palm (Figs. 3.3–4, 4.1–3) resulted in small and medium scars with feathered and bending fracture terminations commonly occurring on the working edge (Plates 1A–B, 5). Many scars are formed within the first few minutes, 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, 7, 9). Scars are irregular in shape and are continuously distributed (Plates 2A–B, 9) on either the ventral or dorsal surface depending on which has had the more contact with the worked material. Occasional scars are distributed in a discontinuous manner along the opposite surface and are oriented towards the edge in a perpendicular or slightly diagonal direction. Similar scar patterns appear on edges used for cutting actions (Plate 9).

Striations. 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 1A–C, 2A–B, 5, 6). When a working edge shows intensively sustained bending fractures, striations running parallel to the edge can be seen between these fractures (Plate 7). The sleek, straight-sided and rough-bottomed types of striations are most common, but intermittent striations (Plates 6, 7, 10A, 11A–B) can also be present. In well-developed polish areas, the striations are mainly of the shallow and short sleek type (Plates 1B, 9). Sometimes both parallel and diagonal patterns of striations appear as a result of an occasional whittling action (Plate 7). Striations are formed during the first five minutes of sawing (Plates 1A–C, 5, 10A–B) and their density dramatically increases in the following 10–15 (Plates 2A–B, 6) and 30 minutes (Plates 7, 11A–B).

Edge rounding. 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, 5, 10A), often develops into intensive rounding that can be observed on the preserved edge areas (Plate 6). With further use of the tool for 30 or more minutes, all prominences on the working edge and the flake scar intersections are rounded to varying degrees (Plates 9, 11B).

Polish. All experimental tools involved in sawing palms demonstrate developed and well-developed stages of polish formation during the first five to 15 minutes (Plates 1C, 5–7, 10A–B). Along the surface prominences which have experienced the most forceful contact with the worked material, very smooth polish appears to be more even and the polished area occurs most extensively. This polish does not extend fully from the highest peaks into the surface depressions (Plates 1C, 6, 10, 11), even after more than one hour of sawing (Plate 9), and it is usually more widespread on one side of the edge than on the other.

Summary. Sawing experiments indicate that highly siliceous palms with light and medium densities produce identifiable wear features within short time periods. A combination of visible scars, longitudinal striations, slight to medium rounding and developed polishes is formed on the working edge after only five minutes of use. But the association of rounding and polish is more reliable in the identification of worked material after 15 minutes. Moreover, experiments show that sawing palms by unretouched flakes with edge angles of between 15° and 55° is most effective during 10 to 15 minutes and, to a lesser extent, up to 30 minutes of use. Experiments demonstrate that the straight edge of the tool is more convenient for a sawing action. Although, edges with convex and concave profiles are equally effective in the performance of sawing actions.

These results indicate that prehistoric artefacts with similar morphological features and wear characteristics can be regarded as tools with only a short-term use history and which were probably discarded after some 15 to 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 100× magnifications, observation of edge rounding and especially types of polishes require magnification from 200× up to 1000×.

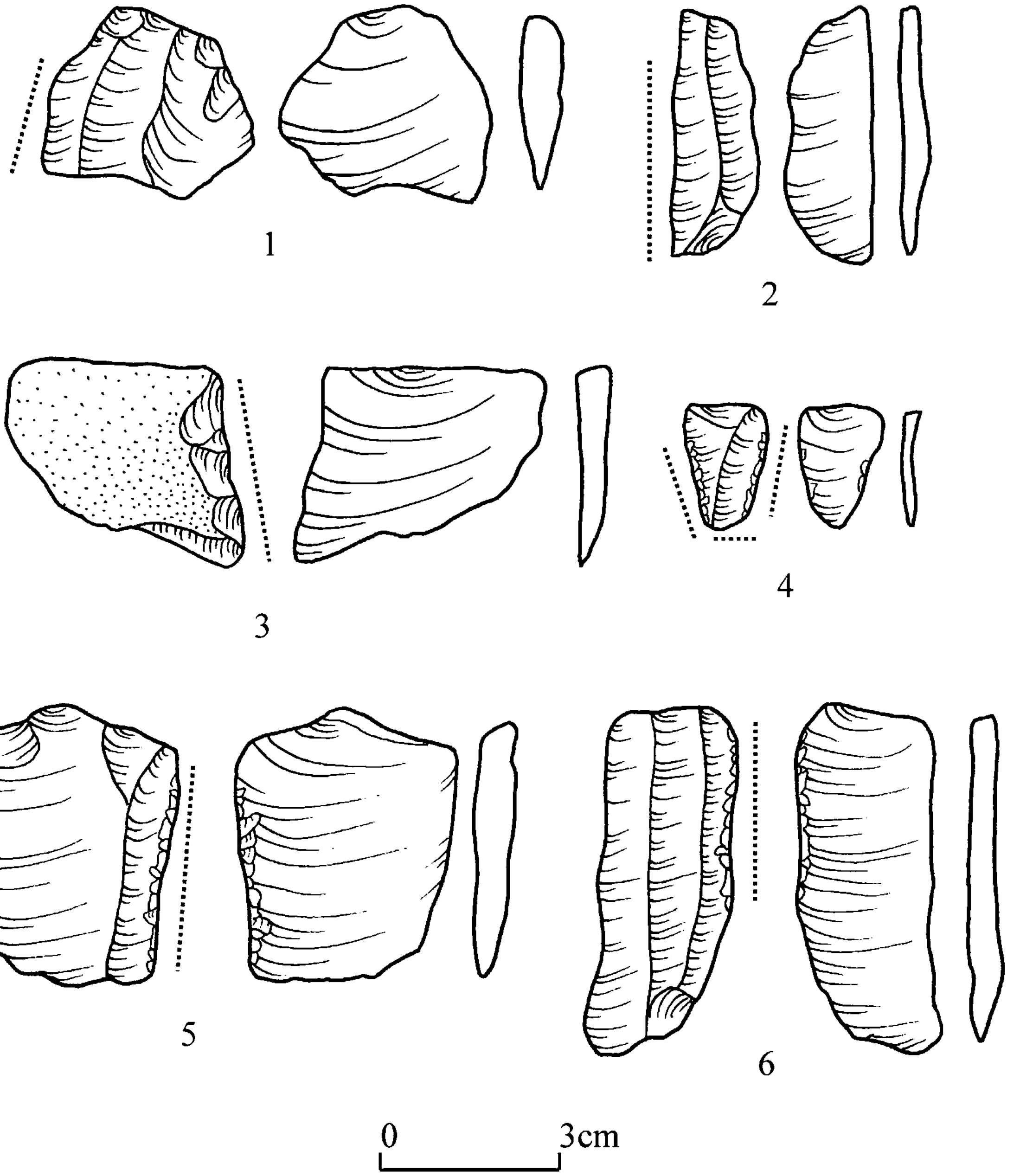

Figure 4. Experimental tools used for processing rattan and bamboo.

Whittling. *Scars*. Scarring patterns on the tools used for whittling palms (Fig. 3.1) are generally restricted to one side of the edge. Most scars have bending and feather terminations, although shallow feather terminated scars prevail on the contact edge. They are oriented at a slight diagonal to the edge (Plates 3A–C), while 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. They form a continuous distribution on those parts of the edge which have the most contact with the worked materials.

Striations. Striations have similar features to those seen after sawing and include shallow, short sleeks, rough-bottomed and intermittent types, but they are oriented mainly diagonally (Plate 3C). Sometimes both diagonal and parallel striations which cross each other are formed as a result of the cutting action (Plate 3B).

Edge rounding. 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).

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

Summary. 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.

Scraping. *Scars*. During the first few minutes, scraping palms and coconut shell (Plate 4A) results in intensive use damage of the edge in the form of all types of scar terminations. Scars have a continuous distribution along the edge but are usually restricted to one side of the tool (Plate 8A). Scraping at an acute angle of less than 15° mostly generates bending scars on the upper surface. Tools with an edge angle of between 15° and 55° produce predominantly step and feather scars and, to a lesser extent, bending scars (Plate 4B). 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 their size varies from very small to medium.

Striations. Striations from the scraping action occur on the underside of the tool as a dense net of shallow short sleeks and both rough-bottomed and intermittent types. They are oriented perpendicularly or are slightly angled to the working edge (Plates 4B, 8A).

Edge rounding and polish. Scraping palms produces intensive edge rounding and well-developed polishes within a few minutes. This leads to the rounding and smoothing of all prominences on the surface and on flake scar intersections (Plates 4B, 8A). As a result, the working edge becomes progressively blunt and loses efficiency after 10 to 15 minutes of use. Because of use-scarring, the distribution of polishes can have a patchy character on the edge.

Carving. Carving involves a combination of cutting, scraping and whittling motions which are performed using a small area of the tool's edge. Accordingly, relatively complicated scarring patterns and striation distribution appear 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.

Summary. In general terms, wear variables on obsidian tools used for processing the relatively hard parts of palms (frond, stem, spathe, and midrib) have distinctive attributes due to the high silica content (cf. 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.

The set of wear variables formed on obsidian tools used for palm processing has not been described in previous experimental studies by Fullagar (1986), Kamminga (1982) and Hurcombe (1992), although Fullagar (1991:17) stressed that the high silica content of palms always produces a developed polish on tools used for a short time. The wear patterns obtained in the replication experiments establish significant diagnostic criteria that can be used to identify the functions of prehistoric artefacts with similar wear attributes. Moreover, the experimental data indicate that identifiable wear occurs on most tools during the first five to 10 minutes of use and, after 15 minutes, tool effectiveness dramatically decreases. This short use-life of obsidian flakes involved in working palms leads to a high rate of discard and must be taken into account in assessing prehistoric artefact assemblages.

Soft wood

In these 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 2, Fig. 5).

Sawing. *Scars*. Sawing soft wood using flakes with an edge angle of less than 15° results in very intensive scarring and mixed types of terminations. Scars appear during the first two to three minutes of use. Small bending, feather and step scars are generally distributed in a continuous manner on either the ventral or dorsal surface depending on which has had the most contact with the worked wood (Plates 14, 16). Occasional scars may occur on the opposite surface. Tools with an edge angle of between 15° and 55° sustain less initial use damage, but with continued use the number of small and medium scars with bending and feathered terminations increases.

Striations. Long, deep, sleek and rough-bottomed types of striations (Plates 17, 18A–B) are predominant, although intermittent striations can be present as well. Striations are oriented parallel to or at a slight angle to the working edge. They sometimes cross each other (Plate 17), but are individually well-defined despite their relative profusion. These data contradict Fullagar's (1986:180) finding for woodworking tools made of flint on which sleeks or rough-bottomed striations are rare or absent, but the results 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. It is important to emphasise that species of soft wood with high silica content, such as malas and *Calophyllum* sp., produce dense and closely packed short, deep and shallow striations similar to those observed on tools used for sawing palms (e.g., Plates 1A–B, 2A–B and 19, 20A). Similar wear patterns were observed by Hurcombe (1992, plates 3–4) on tools used for processing softwood.

Edge rounding. Edge rounding forms within a relatively short time on obsidian tools used for sawing soft wood (Plate 14). 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 15).

Polish. Patches of smoothed, developed and well-developed polish may appear during the first five minutes of tool use (Plate 14). 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 soft wood produces a continuous line of well-developed polish that extends further from the edge after 15–30 minutes of use (Plates 19, 20A, 21A).

Summary. The difference between wear patterns on the tools involved in sawing palms and less siliceous softwood is particularly obvious in terms of the appearance and

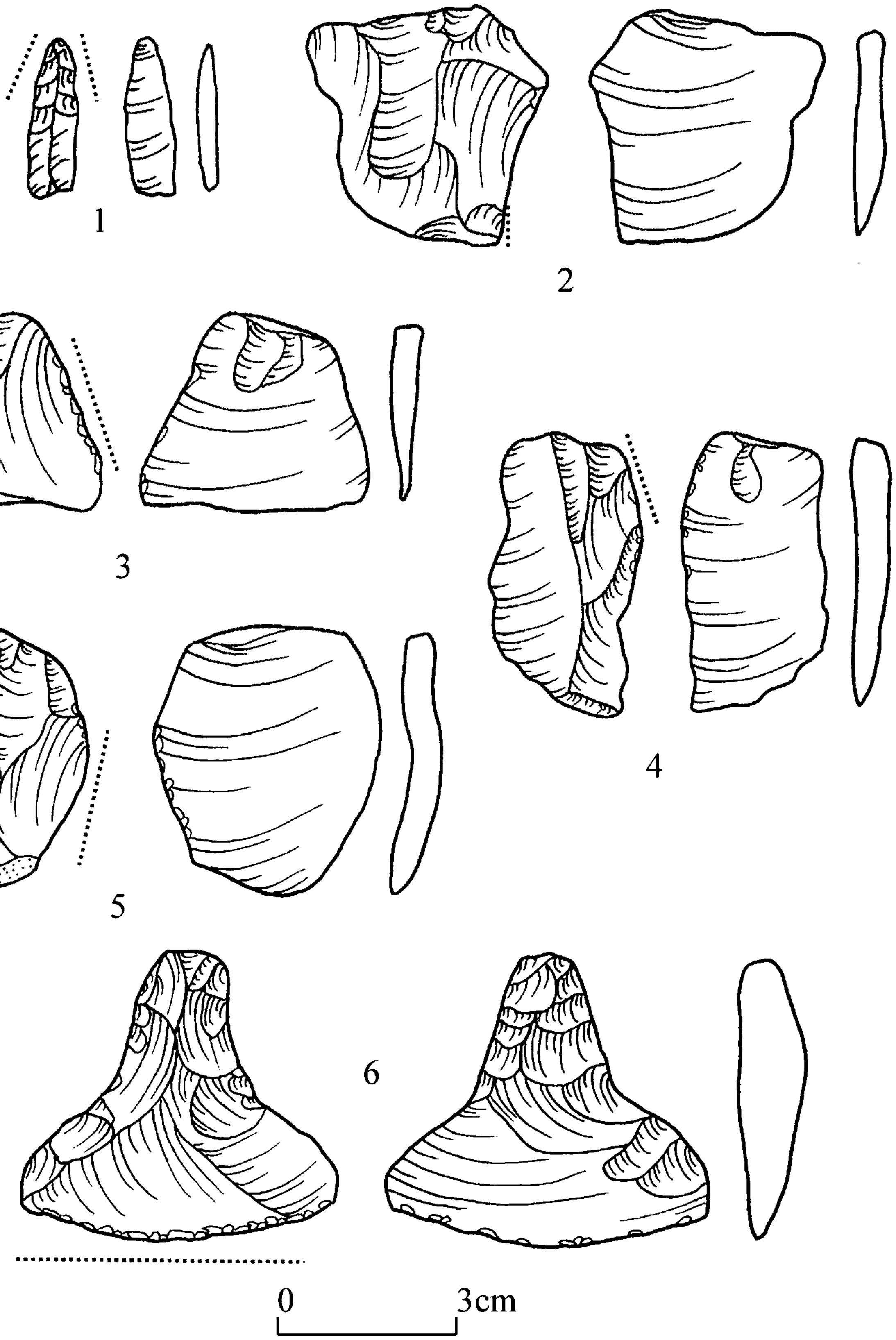

Figure 5. Experimental tools used for working soft wood.

distribution of striations (e.g., Plates 1A–B, 2A–B and 14–15, 17). These traits may be used as significant indicators in the functional identification of artefacts, especially in conjunction with other wear variables and residues. However, if species of soft wood have a high silica content, differentiation from palms on the basis of use-wear data alone probably cannot be made.

Whittling. *Scars*. Since the whittling mode of use requires more pressure than sawing, it creates intensive 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 (Plates 22A–B, 23A–B, 24A). Most scars are characterised by bending or feather terminations which are oriented at a slight diagonal to the edge and which are mainly distributed on one side of the edge with a few isolated small scars appearing on the opposite side.

Striations. 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 destroyed during use. It is possible to detect a few isolated, diagonal striations after five minutes of whittling (Plate 22A), but a patterned appearance forms after only 20 to 30 minutes. The patterns are represented by long shallow and deep sleeks and rough-bottomed striations (Plate 24A).

Edge rounding and polish. 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 24A). Species of wood with higher silica content (e.g., *Hibiscus tiliaceus*), produce slightly more intensive rounding and polish (Plate 23B) than does less siliceous erima (*Octomeles sumatrana*) (Plate 24A). On the basis of these experiments, it is obvious that if the whittling mode of use was applied to non-siliceous soft wood for less than 30 minutes, the resulting use-wear traces on artefacts would be difficult to confidently identify. Intensive rounding, with well-developed polish and patches of relatively dense striations, can appear on tools involved in the processing of non-siliceous softwood, if they have been used for a longer period.

Scraping. *Scars*. Scraping erima for one hour results in mixed scar patterns with stepped, bending and feathered terminations on one side of the edge. Continuous distribution of all types of scars resulting in the blunting of the edge is common for wood scrapers (Kamminga, 1982:67).

Striations. Slightly diagonal and perpendicular striations are long and deep. They also include shallow sleeks, rough-bottomed and, rarely, intermittent types, all of which are situated predominantly on one side of the edge (Plate 18A). Some patches of striations are visible at the intersection of scars and sometimes on the surface within the scar depressions.

Edge rounding and polish. Smoothed rounding and well-developed polishes are observed on some points of the edge (Plate 18A).

Occasionally, in addition to scraping, a sawing action was performed with different parts of the same edge. This activity is reflected in parallel and slightly diagonally oriented striations, randomly distributed feathered scars together with very light rounding (Plate 18B).

Carving and engraving. *Scars*. Experimental tools used for carving and engraving soft wood are characterised by mixed scarring with prevalent bending and feather terminations (Plates 28A–B).

Striations. Because these actions mainly involve cutting motions, distinctive long and deep striations are oriented in parallel or slightly diagonal directions (Plates 25A–B, 26A–B, 27A–B). 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.

Edge rounding and polish. 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. In contrast, carving siliceous malas for the same period results in intensive rounding and well-developed polish (Plate 26A). On the other hand, the actions on hibiscus and red cedar species, which have medium silica content, form intensive rounding and well-developed polishes on tools used for more than 25 to 30 minutes (Plates 25A, 27B). This means that it will be difficult to distinguish between wear patterns found on artefacts used for short-term carving of soft siliceous wood and long-term carving of soft wood with low or medium silica content.

Gouging. Gouging, sawing and carving soft wood (erima) using a small obsidian core with a flat percussion platform produces different sets of wear patterns on particular parts of the used edge. The gouging action is indicated by intensive abrasion, rounding with patches of well-developed polishes in association with closely packed intermittent and rough-bottomed striations. In contrast, sawing and carving are characterised by discontinuous bending and feather scars, long and deep sleeks and rough-bottomed striations and medium to intensive rounding with patches of developed polishes. The tool was effective in the performance of the task for the first five to 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. *Scars*. Drilling soft wood by pointed non-retouched flakes (Fig. 5.1) produces intensive scars with prevalent step and bending terminations on both sides of the edges in 1 to 2 minutes. With increased use-time, the edges are stabilised and blunted by scars.

Striations. Short, deep and shallow, sleek and rough-bottomed striations orient rotationally around the side edges (Plates 29A–B).

Edge rounding and polish. All prominences on the surface along the edges and scar intersections become intensively rounded after 15 minutes of use (Plates 29A–B). Patches of smoothed, well-developed polishes (Plate 29B) can be observed on the highest points of the obsidian surface on the working edges. Polish and rounding results 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.

Smoothing/polishing. The smoothing/polishing action on siliceous wood, which was initially worked by scrapers, produces well-developed wear on the side of the flake which comes in contact with the worked material. In the illustrated case it is the dorsal side (Plates 30A–D). After 15 minutes of smoothing, microfractures which occurred on ridges of the flake were thoroughly rounded. A dense net of deep and mostly long sleek and rough-bottomed striations were formed on prominent parts of the surface (Plates 30A–B). Bright, smooth and well-developed polish intensively flattened the working ridges, but this polish does not deeply penetrate into microdepressions (Plate 30C). Such smoothing implements are uncommon in archaeological assemblages, but use-wear characteristics resulting from intensive continuous contact of tools with soft and siliceous wood represents a particular area of interest for experimental studies of wear formation.

Summary. The wear on woodworking tools used for processing non-siliceous soft wood differs from wear produced by working palms. First, striations on these tools are generally longer, deeper and tend to be more separated from each other (e.g., Plates 6, 7 and 17, 25A). Second, there are some differences in the rounding and polish characteristics which form during the same duration of use on palms and woodworking tools. If one compares the wear patterns, then it becomes apparent that polished areas on tools used for working palms for five, 15 and 30 minutes are usually very smooth and more intensively flattened than on comparable polish on woodworking implements which processed highly siliceous malas for the same time interval (e.g., Plates 2B, 5, 7 and 19, 20A). 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 substantiate these differences, further experimental studies are required. At this stage of the analysis, functional differentiation of prehistoric artefacts can be made between two groups: (1) tools used for working siliceous softwood and palms (which produce similar wear patterns) and (2) tools that used for processing non-siliceous softwood.

Hard wood and hard palms

The replication experiments utilised eight species of hard wood (Fig. 6) and black palm (*Caryota* sp.) (Fig. 7) which were processed by sawing, whittling and scraping (Table 1). The most common wear feature on the tools used for working hard wood and hard palms is the intensive scarring that often removes other evidence of use-wear, such as striations, rounding and polish, from the working edge.

Whittling. *Scars*. Intensive scarring is very typical of tools used for whittling (Plates 31–33). Bending and feather scars appear on the edge in the first few minutes of use. Scars that are irregular in shape and medium to large in size generally occur on one side of the edge in this mode of use (Plate 32A). As the number of scars increases with continued use, overlapping fractured edges which are irregular in plan view are formed (Plates 33A–B).

Striations. A few isolated, diagonal striations appear on some parts of the edge. Sometimes long, deep rough-bottomed and sleek types occur (Plate 31B), but more commonly intermittent striations, which appear as patches of densely packed short scratches (Plate 32B), or long isolated lines are present (Plate 33B).

Edge rounding and polish. In most cases, very light or light rounding is observed on rarely preserved small areas of scar intersections. Sometimes these same areas contain patches of light to developed polish (Plate 33B). The areas located close to the edge are often characterised by light attrition that contrasts with the natural surface of obsidian (Plate 33B). Attrition occurs most often on tools used to work hard wood (Hurcombe, 1992:41).

Scraping. *Scars*. Scraping hard wood for 30 minutes produces intensive edge damage by continuous step, feather and bending scars (Plates 34A, 35A).

Striations. Isolated perpendicular or slightly diagonal striations are present on one side of the working edges (Plates 34A, 35A).

Edge rounding and polish. Pronounced edge rounding, developed and well-developed polish are formed after 30 minutes of scraping (Plates 34A, 35A).

Some unusual features in scarring patterns are observable on tools used for scraping hard and highly siliceous black palm. The edge immediately sustains multi-layered scars that severely modify the shape and profile of the edge because of the high density and hardness of these materials. The edge becomes irregular in plan view after only five minutes of use (Plate 41B), and with continued use the tool is further modified by subsequent scars. An intensive blunting by scars, rounding and polish makes the working edge inefficient after five to 10 minutes of use. When work ceased after 30 minutes, the upper side of the edge was covered with complex overlapping step and feather scars accompanied by dense deep and shallow striations, intensive rounding, and polish (Plate 42).

Sawing. *Scars*. Sawing hard wood results in very intensive scarring with mixed types of terminations. Scars appear during the first one to two minutes of use. Small bending, feather and step scars are distributed in a continuous manner on one side of the edge which has had the most contact with the worked wood (Plates 36A–B). Occasional scars may occur on the opposite surface.

Striations. Long and deep sleeks, rough-bottomed and intermittent types of striations are oriented parallel to the working edge (Plates 36A–B). Sometimes flaked striations are also formed on the edge (Plate 36B).

Edge rounding and polish. Patches of slight edge rounding and light to developed polish occur on the scar intersections and on the highest points of the surface microtopography after 30 minutes of use of the tool (Plate 36B).

Sawing highly siliceous hard wood [e.g., *Mangifera indica* (mango)] and siliceous hard palm [e.g., *Caryota* sp. (black palm)] for five and 15 minutes produces very intensive and continuous edge scarring (Plates 38–40). As a consequence of scarring, particles of obsidian which break from the working edge become embedded in the worked material and accelerate the formation of shallow and short, densely packed, sleek, rough-bottomed and intermittent striations (Plates 38, 39, 40B). Patches of intensive edge rounding and well-developed, flattened and smooth polish are formed during the first five to 15 minutes (Plate 38, 40B, 43A).

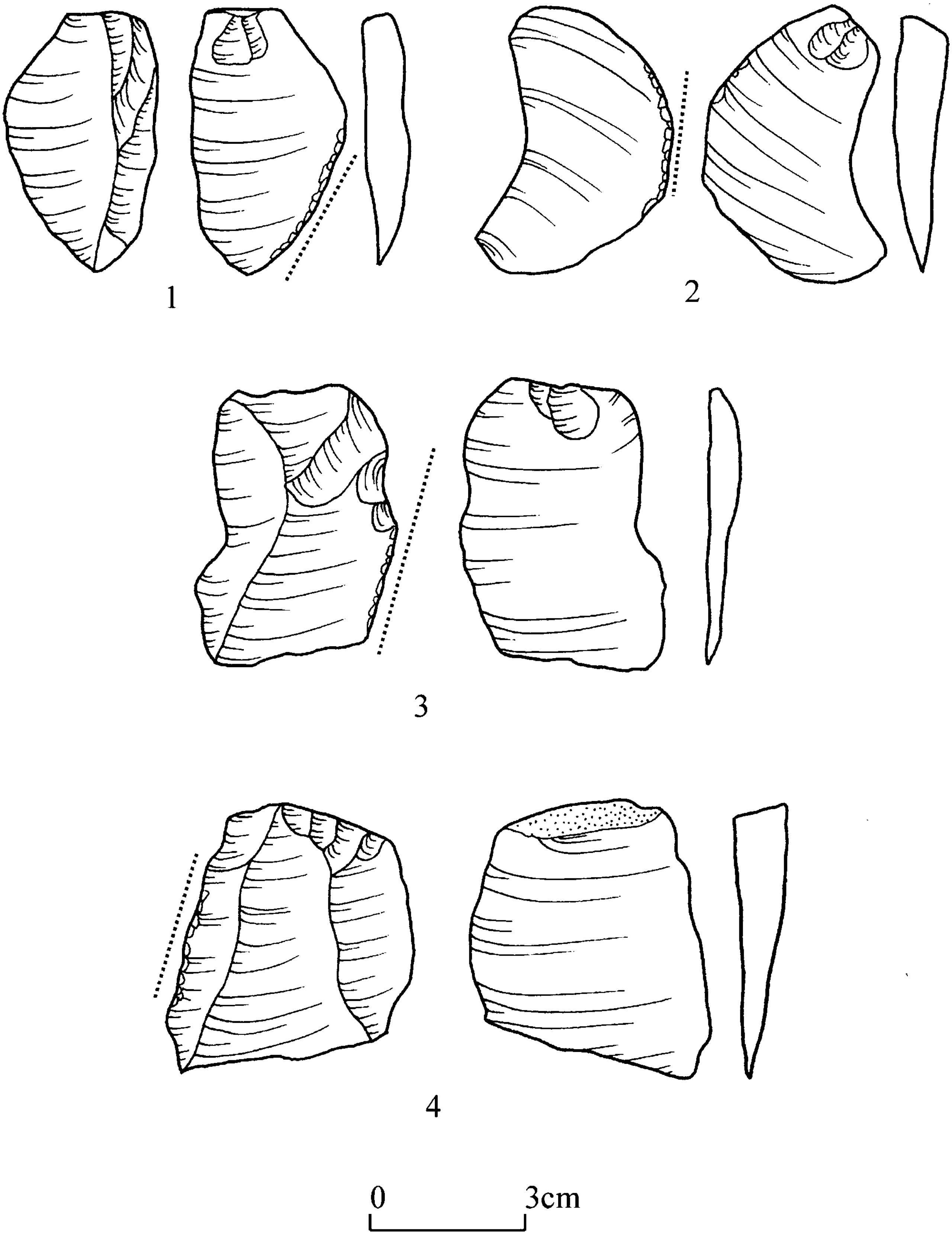

Figure 6. Experimental tools used for working hard wood.

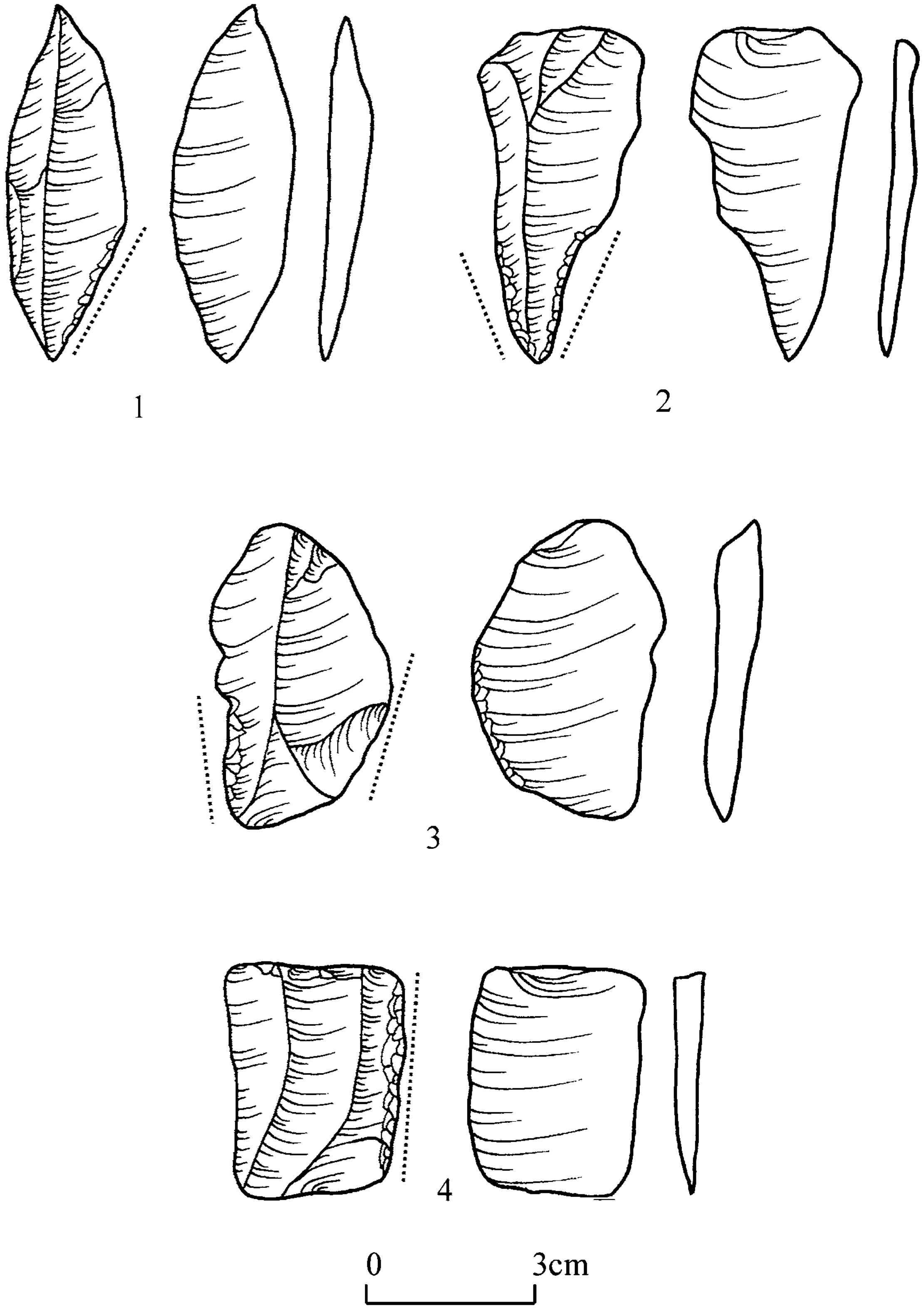

Figure 7. Experimental tools used for working black palm.

Summary. The highly fractured working edge resulting from use generates very distinctive scarring patterns that influence the location and distribution of other wear variables. As a consequence, intensive scarring, patchy distribution of striations, rounding and polish are common wear attributes observed on tools used to process hard wood and hard palms. However, there are some differences in size and type of striations and polish characteristics on the tools used to process non-siliceous hard wood, and siliceous hard wood and palms. Working non-siliceous hard wood produces mainly long, deep and well isolated rough-bottomed and sleek striations and smooth, developed and well-developed polish (Plates 31B, 33B, 34A, 35A, 36A–B). In contrast, processing siliceous species of hard wood and palms produces shallow and short, densely packed, sleek, rough-bottomed and intermittent striations and well-developed, flattened polish (Plates 38, 39, 40B, 41B, 42, 43A). These variations in the appearance of striations and polish potentially allow functional differentiation of artefacts as (1) tools used for working non-siliceous hard wood and (2) tools used for processing siliceous hard wood and palms. At this stage of analysis, artefacts which were used on some highly siliceous and hard species of wood cannot be distinguished from those involved in processing siliceous and hard palms on the basis of wear data, although separation may be achieved through the analysis of residues.

Non-woody plants

Experiments with non-woody plants involved 45 tools (Table 1, Figs. 4.4–6, 4.8–9) which were used to process 10 species of plants (Table 2).

Bamboo and cane. Plants with hard stems, such as green bamboo (*Bambusa* spp.) and cane (*Saccharum* spp.), are highly siliceous and have densities similar to palms (Fullagar, 1986:148–150, 1991:16–17) and siliceous soft wood. It is therefore not surprising that wear patterns on tools used for processing palms, siliceous soft wood, bamboo and cane are quite similar. For example, sawing (Plates 44–45), carving (Plate 46) and scraping (Plate 47) bamboo (Fig. 4.4–6) and cutting cane (Plates 48–49, Fig. 8.1) for five and 15 minutes leads to almost the same type and amount of wear formation as observed on tools used for processing palms and siliceous soft wood (e.g., Plates 1–2, 5–7, 10, 19–20, 26).

Some variations in wear pattern are seen in the dominance of certain types of striations on tools used for cutting/whittling cane (Plates 48–50). Intermittent striations are more common on these tools. This is probably associated with sand and soil that is attached to them (Plate 48A). Among these tools, those with thin, acute edges are more susceptible to bending scars during the first five minutes of use than tools with edge angles of between 15° and 55° (Plate 48B).

Based on these experiments with bamboo and cane, it is difficult to distinguish with confidence the differences between wear patterns on prehistoric artefacts resulting from working palms, siliceous soft wood, bamboo and cane, unless residues are diagnostic. As a consequence, in this project, artefacts with wear patterns similar to those on experimental tools used for processing palms, siliceous soft wood and bamboo were interpreted as implements for processing the generalised category of material "siliceous soft wood, palms and bamboo".

Greens and softer parts of woody plants (leaves and stems)

Cutting banana leaves. *Scars*. Cutting siliceous banana leaves (*Musa* spp) (Fig. 8.4, Plates 51–55) produces very small and small bending and feathered scars which are distributed in a discontinuous manner (Plates 52, 54).

Striations. A few shallow, isolated and parallel to the edge, sleek and rarely intermittent types of striations occurred at the start of the use action and their number and density increased with continued use (Plates 52, 53B, 54).

Edge rounding and polish. Slight edge rounding and light surface alteration are observed after five minutes of use (Plates 51–52). The surface alteration gradually transforms into light (Plate 53B) and developed (Plate 54) stages of polish with increasing time (up to the 30 minutes of the experiments). The tools were still perfectly useful when the experiments were completed.

Scraping banana stems. *Scars*. Scraping action produces irregular, small bending and step scars after 15 to 20 minutes of use (Plate 57A).

Striations. Very shallow, short, perpendicular sleeks and rare intermittent striations can be observed under high magnification (Plate 56B).

Edge rounding and polish. Scraping banana stems produces very intensive rounding and well-developed polish after 10 to 15 minutes of use. Smoothed polish extends deeply into surface depressions and scars (Plates 56–57).

Whittling ferns. *Scars*. Processing ferns (*Asplenium nidus*), by whittling for five and 10 minutes produces discontinuous scars with bending or feather terminations.

Striations. Some long, isolated, sleek and rough-bottomed striations oriented slightly diagonal to the edge can be observed (Plate 59).

Edge rounding and polish. Very light or light edge rounding and very light polish (Plate 59) are formed after 10 minutes of use of the tool. Fullagar (1986:182) noted that slicing bracken fern with flint tools for a much longer period of time (from 45 to 60 minutes) produces a relatively extensive polish.

Cutting aibika. Discontinuous small scars and microscars, parallel or slightly diagonal sleek and rough-bottomed striations, light edge rounding and very light polish (Plate 60A) are formed on the tool after 15 minutes of cutting of aibika (*Hibiscus manihot*).

Cutting taro leaves. In contrast to ferns and aibika, cutting taro leaves and stems (*Colocasia esculenta*) for 15 minutes (Plates 61A–B) results in small to medium scars with bending and feather terminations continuously distributed on the edge. Parallel and slightly diagonal striations are isolated, long sleek, rough-bottomed and intermittent types are present. Light edge rounding and light polish are more pronounced (Plate 61B).

Cutting croton. Tools used for cutting croton (*Codiaeum variegatum*) for five, 15 and 30 minutes demonstrate how wear variables develop over time. After five minutes of use there are few bending and feather scars, very light rounding as well as some isolated parallel and slightly diagonal

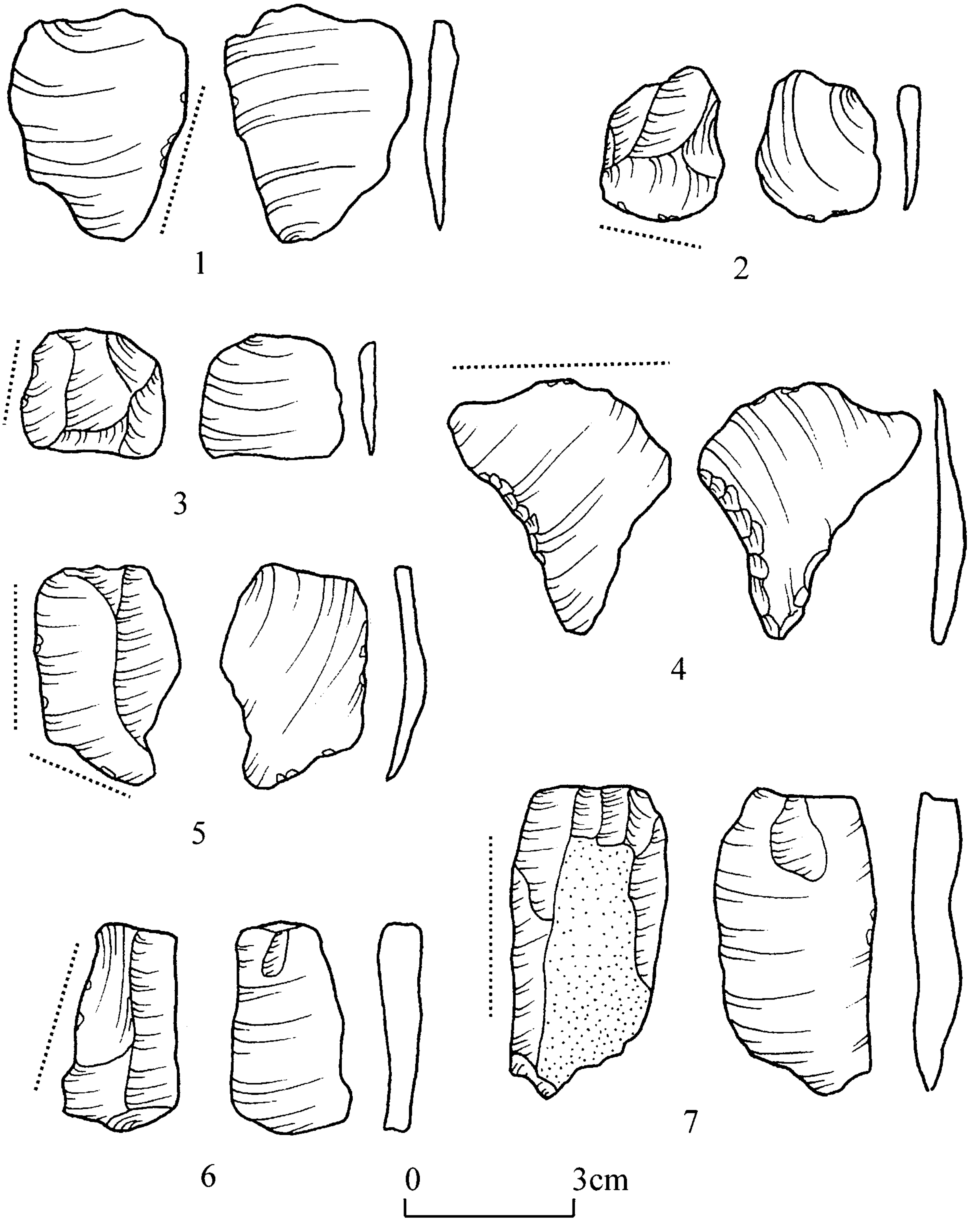

Figure 8. Experimental tools used for processing sugar cane, taro leaves, ginger, banana leaves, croton, aibika, and fern.

striations (Plates 62A–B). The next 15 and 30 minutes of tool use produces more intensive edge rounding, developed polish and more dense, shallow and mostly sleek and intermittent striations (Plates 63B, 64B). Although wear increases with time, these tools were still relatively sharp and useable and could have built up more wear.

Cutting ginger. Cutting ginger (*Zingiber officinale)* for five and 15 minutes results in the formation of discontinuous, small bending and feather scars. Shallow, sleek, rough-bottomed and intermittent striations run parallel to the edge (Plates 65, 66A). Light edge rounding and well-developed polish can be observed after 15 minutes of use (Plate 66A).

Cutting green rattan skin. Cutting green skin from vine of siliceous rattan (*Calamus* spp.) which was used for the

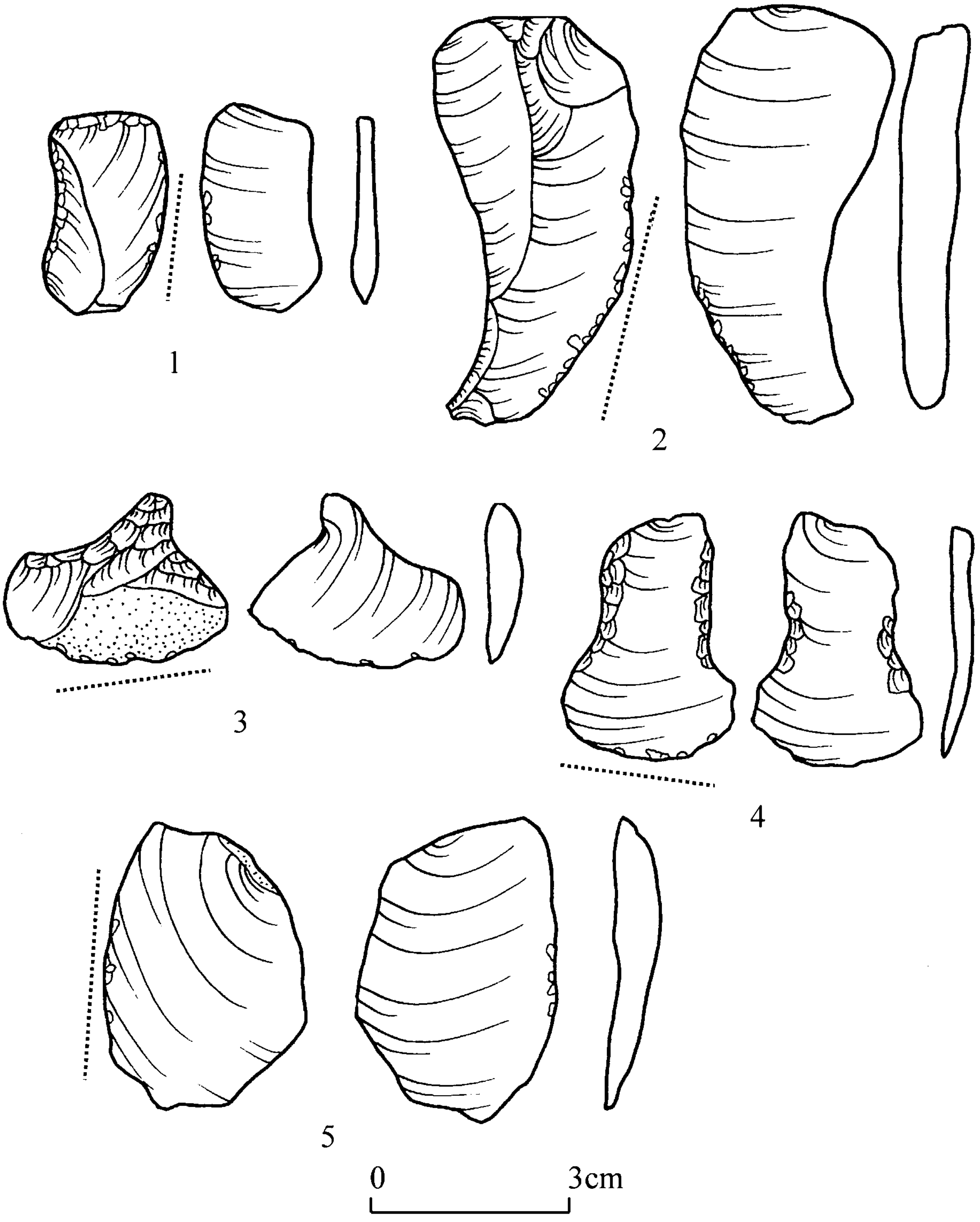

Figure 9. Experimental tools used for processing coconut meat and pandanus leaves.

manufacture of plant string (Plate 67A) produces small, irregular, bending and feather scars, slight edge rounding, very light polish and a dense net of shallow, sleek and intermittent striations after five minutes of use (Plate 67B).

Cutting and slicing pandanus leaves and stems. *Scars*. Cutting and slicing stems and thorns from green leaves of *Pandanus* spp. (Fig. 9.3–5, Plates 68A, 70A) are indicated by a more distinctive set of wear attributes that form after 15 minutes of use. A continuous distribution of small scars with bending and feathered terminations occurs mainly on one side of the edge (Plates 68A, 69A).

Striations. Patches of shallow and deep sleeks, rough-bottomed and intermittent striations are preserved on some areas along the edge. They are separated from each other and oriented both slightly diagonally and also parallel to the working edge (Plates 68B, 69A–B, 71A).

Edge rounding and polish. Edge rounding varies from very slight to slight (Plate 68B) and patches of developed polish can be observed on some small parts of the edge after 15 minutes of use (Plate 68B, 69A). 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 well-developed polish (Plate 71A).

Scraping and slicing coconut meat. Processing coconut meat by obsidian tools (Fig. 9.1–2) does not produce developed wear patterns even after 30 minutes of use. Discontinuous scars with bending and feather terminations occur as a result of contact with the shell during scraping or slicing actions (Plates 73, 74A). The scars are small in size and irregular in shape and occur along one side of the edge. Isolated sleeks, deep intermittent and rough-bottomed striations with diagonal and parallel orientation have a patchy distribution alone the edge and are associated with areas of use scarring (Plates 73, 74A–B). The working edge is usually very slightly or slightly rounded (Plate 74A) and rare patches of very light polishes may be observed under 200× to 500 × magnifications (Plates 73, 74B). Despite continuous use for 30 minutes, the working edge of the tool maintained its sharpness and could still be used.

Summary. Experiments with working green leaves and stems of both non-woody and woody plants show some similarities in the formation of wear patterns on tools. First, 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. Scars are often distributed in a discontinuous manner. Second, rare to common striations of shallow, sleek types are prevalent, and much more rarely, rough-bottomed or intermittent types occur. Finally, there are obvious stages in the formation of rounding and polish that depend on the duration of tool use (e.g., Plates 52–54, 62–64). Although wear increases with time, only after 30 minutes a combined set of scars, striations, rounding and polish forms that is distinctive of the mode of use and, to a lesser extent, the material worked. Similarities in wear patterns, however, do not exclude some specific differences in polish development and the type and appearance of striations on tools used: for instance, in the extraction coconut meat (Plates 72–74) or the processing of croton or ginger (Plates 62–66). However, in the archaeological context such peculiarities of wear patterns on the tools is difficult to correlate precisely to the particular species of plant processed unless diagnostic residues are present (e.g., Plates 55, 57B, 67C). In this 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.

Tubers

Scraping/slicing raw tubers. *Scars*. Previous experiments using stone tools for processing tubers, such as raw and roasted taro, yam and sweet potato, showed that discontinuous, non-distinctive scarring patterns occur at the beginning of use (Fullagar, 2006b:200, Kamminga, 1982:55). These results are supported by my experiments with raw tubers using obsidian tools (Fig. 10, Plate 75A). Scraping/slicing taro (*Colocasia esculenta*), yam (*Dioscorea esculenta*) and sweet potato (*Ipomoea batatas*) for five or 10 minutes produces scattered small bending and feather scars (Plates 76A–B, 79, 81A). With continued use, the number of scars increases slightly (Plate 80).

Striations. Isolated, long and shallow sleeks, rough-bottomed and rare intermittent striations are slightly angled to the edge and sometimes intersect each other (Plates 76A–B, 79–80, 81A).

Edge rounding and polish. Patches of slight to medium edge rounding and light to developed polish may be formed after 10 to 15 minutes of use (Plate 75C). Simple slicing, in comparison with scraping and scraping/slicing raw tubers, results in more pronounced edge rounding and polish development on some parts of the edge and scar intersections (Plate 80).

Scraping/slicing roasted tubers. *Scars*. In cases where sand and soil adhere to the surface of tubers, (e.g., freshly dug from the ground or having been roasted on open fires) (Plates 77A–B) abrasive agents cause all the main wear variables to form over a shorter period of use. Scraping roasted taro with the tool oriented at 90° to the tuber (Plate 77C) results in small to very small bending scars, a few stepped and, rarely, feathered scars, which are mainly oriented in perpendicular or slightly diagonal directions (Plates 77F, 78A). The scars are usually restricted to the surface of the tool having the closer contact with worked material, although a few isolated scars may occur on the opposite face. The appearance of scars on both faces is caused by "forward" and "back" actions during scraping.

Striations. A moderate number of perpendicular striations dominate on areas with well-developed polish. They are mainly the wide, shallow, sleek type, although some rough-bottomed and rare intermittent types may occur (Plates 78A–B). Straight and slightly convex edge shapes of the tools are more efficient for scraping and slicing.

Edge rounding and polish. Slight to medium edge rounding forms after five to 15 minutes of use (Plate 77F). The intensity of rounding increases after 30 minutes of use (Plates 78A–B). Bright and smooth, continuous merging polish is very distinctive and strongly contrasts with the fresh unused surface (Plates 77F, 78B).

Summary. The following set of variables appear to be characteristic of wear on tools used for processing tubers for more than 15 minutes: (1) low intensity of 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. This diagnostic combination of wear variables on experimental tools in association with residue data (e.g., Plates 75D, 77E, 81B) can be used in the functional identification of prehistoric tools which were involved in processing taro and other tubers.

Soft elastic materials

The 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 1). This group of materials has not been widely involved in previous experimental research,

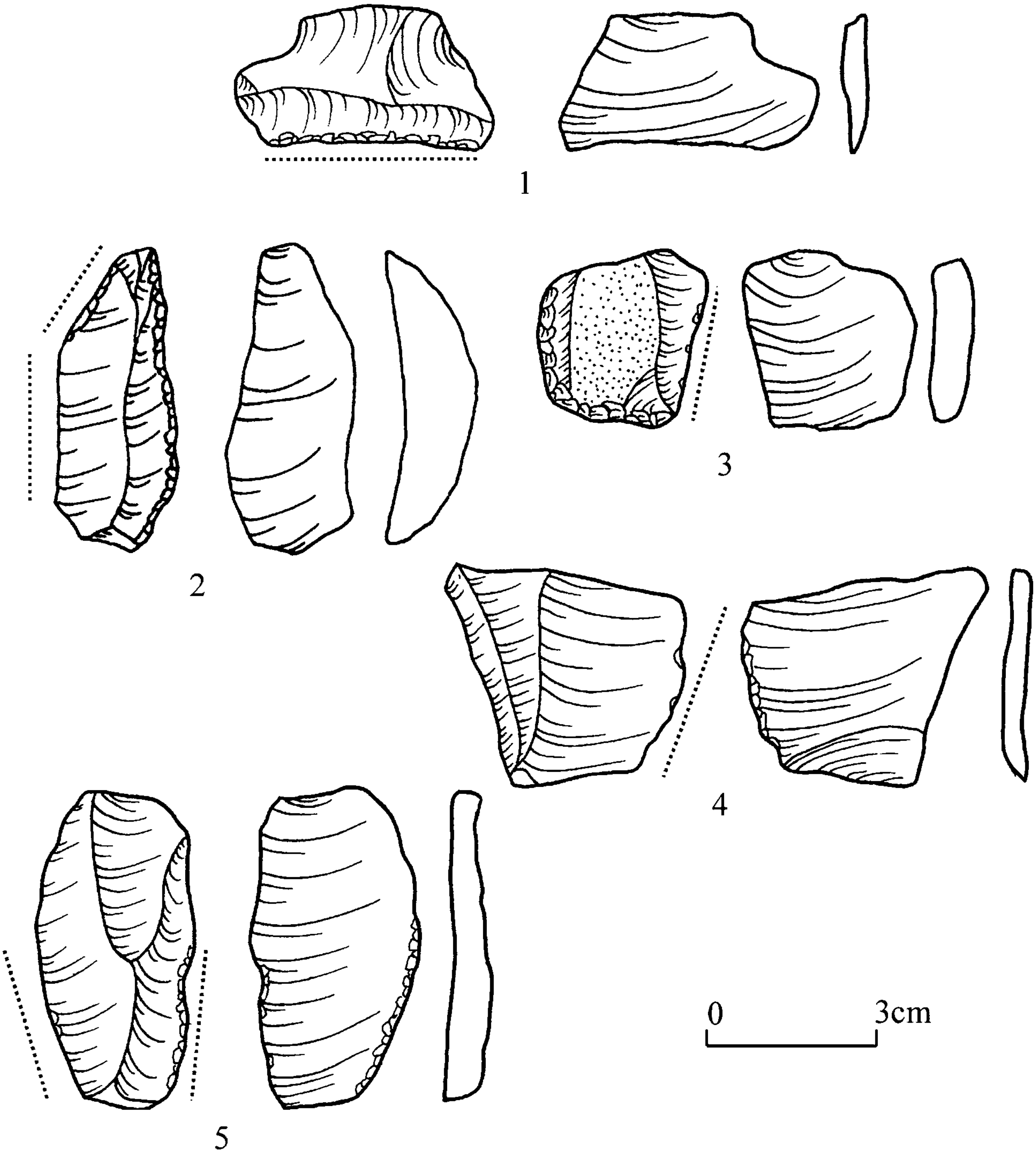

Figure 10. Experimental tools used for processing taro and yam.

although some obsidian tools have been tested on animal skin and meat (Aoyama, 1995; Kamminga, 1982:45–47), fish (Fullagar, 1986:285; Hurcombe, 1992:44; Kononenko, 1986; Lewenstein, 1981) 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 the human body, a common practice among Pacific peoples (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). Since such experiments have not been previously conducted, use-wear data obtained from both experimental tools (Fig. 11.1–4) and from prehistoric artefacts may provide insight into the history of these social activities.

Cutting and piercing chicken skin. *Scars*. The experiments indicate that edge sharpness is an important attribute for cutting and piercing chicken skin, and shaving the human face. Although acute edges of <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 to 30 minutes of use (Plates 82–85). Piercing skin with flakes having a triangular cross-section involved vertical pushing and rotative actions that occasionally

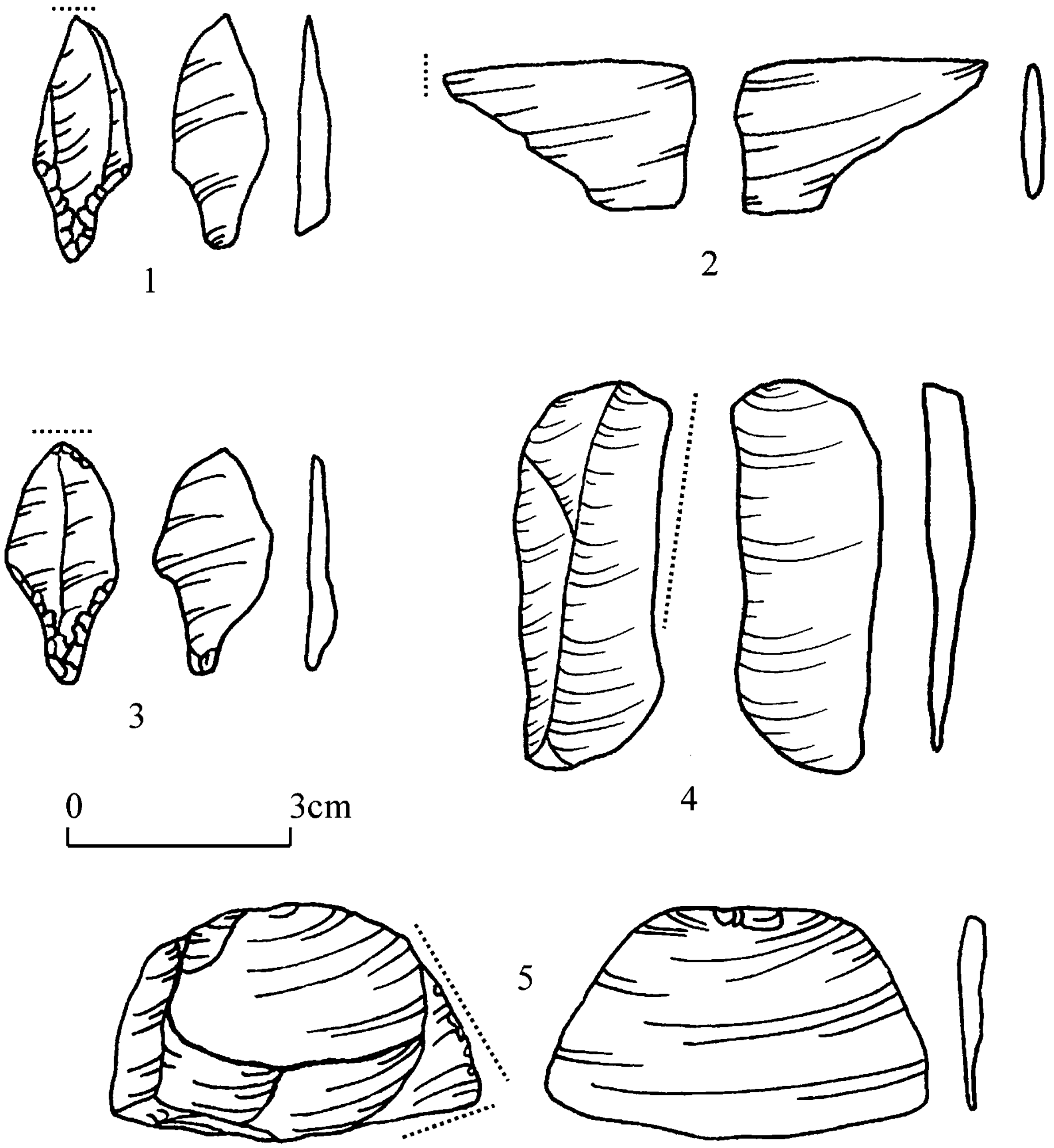

Figure 11. Experimental tools used for processing skin and fish.

lead to small spalls snapping off. Kamminga (1982:45) emphasised that a tip-snapping spall is a common feature of skin awls. Chicken skin used in these experiments is thinner than most mammalian skin and, therefore spalls rarely occur.

Striations. In some cases patches of continuous, small scars on the edge are associated with a concentration of short and shallow, intermittent striations diagonally oriented to the working edge (Plate 83A). Usually, however, striations are much less common and are mostly represented by isolated, long and shallow sleeks which are more easily visible under higher magnification (Plates 84A–B). They are parallel or slightly diagonal to the edges and perpendicular to the pointed tip.

Edge rounding and polish. 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 polish which can be observed under >200× magnification (Plates 84B, 85A).

Shaving the human face produces a very dense layer of organic residues which cover the edge in one to two minutes (Plates 86A, 87A–C, 88A–C, 89). Edge modification resulting from use for three to five minutes is very light with only a few bending microscars distributed in a discontinuous manner on one side of the edge (Plates 88D, 89B). 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 (Plate 87D). Very rare spots of more intensive rounding and patches of smoothed, developed polish are visible under 500× magnification (Plate 86B).

Gutting/cutting fish. Experiments with parrot fish (*Scaridae*), salmon (*Oncorhynchus gorbuscha*) and wrasse (*Labridae)* indicate that gutting/cutting action is more efficient using a sharp, slightly convex, edge with the angle ranging between 15° and 55° (Table 1, Fig. 11.5, Plate 90A).

Scars. 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 (Plate 90D) and are rarely observed on the other side of the edge even after 25 minutes of use (Plate 91C).

Striations. Striations are characteristic 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 90B–D, 91A–F). Isolated, long and shallow, rough-bottomed striations are prevalent. Long sleeks and short, shallow, intermittent striations are relatively rare.

Edge rounding and polish. A slightly rounded edge is typical of the tools used for 15 minutes (Plates 90C–D) and abrasion and spots of very light or light, smoothed, undeveloped polishes are observed on prominent points along the profile of the edge (Plates 90B–D). With increasing use-time, up to 25 to 30 minutes, patches of developed polish are formed (Plates 91D–F). Smooth, bright polish extends from the higher zones of microtopography into surface depressions and contrasts with the unaltered surface of a tool.

Summary. 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 form useful indicators for identifying prehistoric artefacts used for tattooing, scarification and medical treatments of the human body.

The shaving experiments demonstrate the limited ability of use-wear analysis to identify artefacts used to shave human skin. However, in conjunction with residue studies, it may be possible to make a tentative identification of the most intensively used artefacts. Men who performed the experiments noted that flakes with thin and sharp edges are efficient at this task for only a very short time (2 to 5 minutes) before the edges became blunted.

Experiments with fish processing tools indicate that more than 30 minutes of use is required to produce identifiable wear patterns, although Hurcombe (1992:44) noted that more than 20 minutes use produced a surface alteration. This means that any artefact exhibiting such wear must have been used for a similar task for a relatively long period. In addition to wear features, distinctive animal residues on the working edge, such as tissue, blood and greasy film (e.g., Plates 90E–F, 91B) may contribute significant information for functional interpretation.

Hard dense materials

Experiments in working marine shell with obsidian were conducted by Fullagar (1986:189), Kamminga (1982:141–142) and Kononenko (1986). For this study additional experiments by sawing and scraping of cockle shell (*Katylesia* spp.), cowrie shell (*Cypraeidae* spp.) and half-dry white clays were conducted (Table 1, Fig. 12.1–4).

Sawing shell. *Scars*. The first one to two minutes of sawing shell results in intensive bending and less feather scarring with poor definition of flake scar boundaries because the edge is crushed. Almost immediately, use fractures occur on both sides of the edge so that the working edge of the tool is thickened and becomes very irregular in both plan and profile views (Plate 92A).

Striations. Initially, deep intermittent and rough-bottomed short striations (Plate 93A) were subsequently flattened by abrasion. Irregular and deep cracks oriented perpendicularly to the edge appear on some parts of the surface (Plates 93A–B).

Edge rounding and polish. 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 92B, 93B, 94A–B). After 15 minutes of use, the edge becomes blunt (Plates 93A–B) but subsequently continuous microscarring and autoabrasion processes prolong the useability of the edge to some extent. However, after two hours sawing, the tool completely loses its efficiency (Plates 95A–B).

Scraping shell. *Scars*. Scraping shell for 10 minutes 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 96A–B).

Striations. Perpendicular and diagonal striations of all types appear but rough-bottomed and intermittent striations dominate (Plate 97A).

Edge rounding and polish. An intensive edge rounding, polish and striations are formed on prominent areas and scar intersections and do not extend into surface depressions (Plate 97B).

Summary. Thick, intensively abraded and rounded edges with well-developed smoothed polish 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.

Scraping clay. Scraping clay with thin flakes which have acute edges is highly effective action to produce powder, but only for the first five to 10 minutes. After 15 minutes, intensive rounding, abrasion and polish dramatically thicken and dull the working edge, rendering it useless (Plates 98–99). The texture and distribution of polish on the working edge of tools used for working half-dry clay has similar characteristics to those of shell-working tools, but the abrasive nature of clay results in a smoother and more flattened appearance of the polish. There are also obvious differences in the types of striations that are commonly present (Plates 98A, 99A). Clay produces mostly thin,

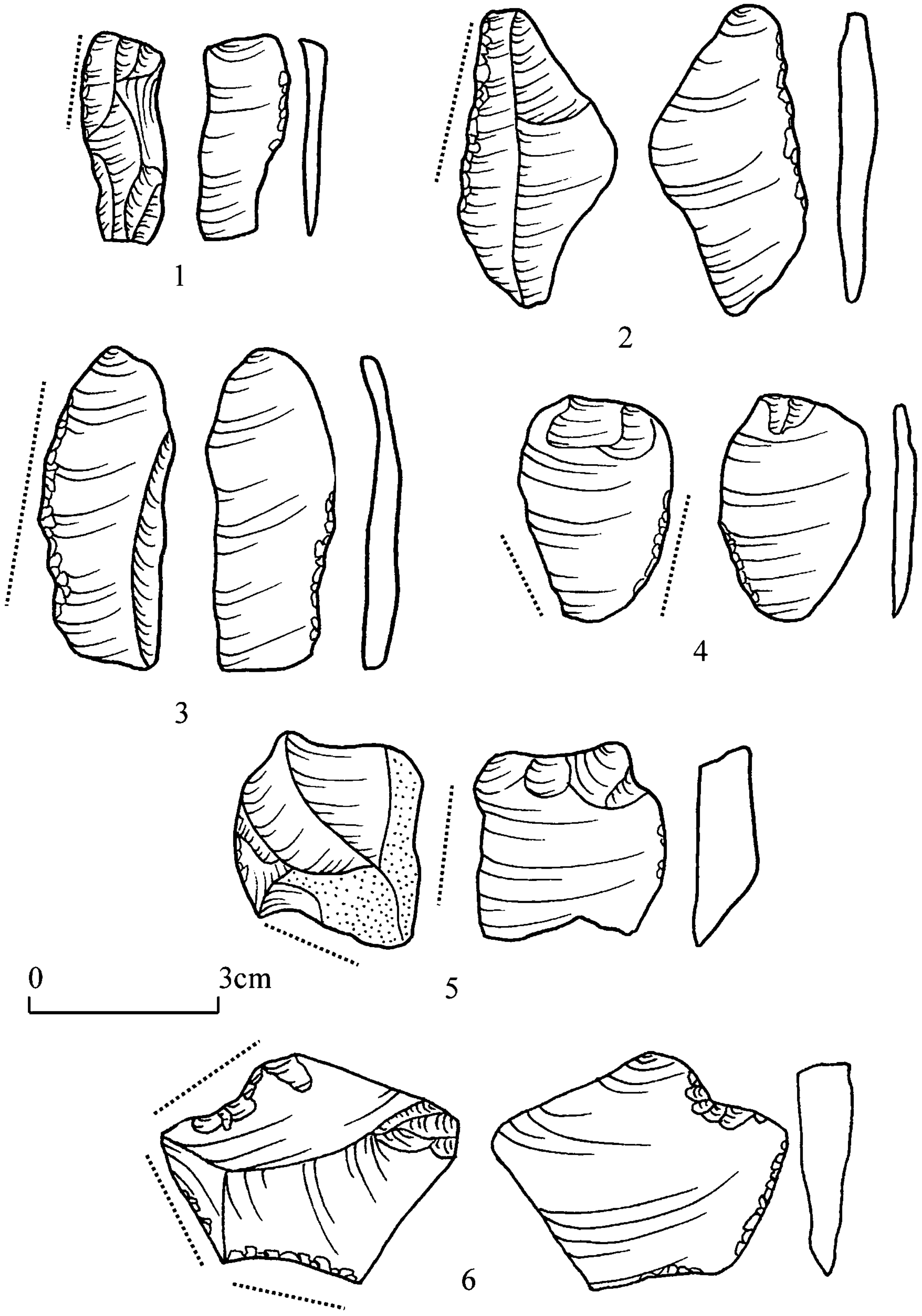

Figure 12. Experimental tools (1 to 4) and artefacts from FAO (5 and 6) used for processing shell and clay.

long sleeks with rare occurrences of deep rough-bottomed striations oriented perpendicularly and slightly diagonally to the edge.

Summary. Very distinctive wear patterns on obsidian tools, used either for working shell or clay, form after a short period of use. This suggests that prehistoric artefacts with similar wear variables were probably used for about 10 to 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.

Use-wear comparisons

Use-wear patterns on obsidian tools obtained through task-oriented experiments with hard and soft wood, palms and bamboo, grasses (e.g., sugar cane, fern) tubers, skin and shell are comparable with previous use-wear data provided by Aoyama (1995), Davenport (2003), Fullagar (1986, 1991), Hurcombe (1992), Kamminga (1982) and Lewenstein (1981). However, a series of experiments related to 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 using a variety of actions produce specific types of wear on the experimental tools which have not been previously recorded. Overlapping patterns of wear variables observed on the tools used for processing some materials which have similar densities and silica contents (for example: palms, bamboo and soft siliceous wood) indicate that identification of the material which was worked by prehistoric tools can be made in a broad sense, although further residue studies would allow more precise identification of species.

Residues

One aim of the experiments was to gather 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). These include oily film, plant and animal tissue, starch granules, needle-like residues (raphides), resin-like residues, blood-like residues and white-coloured residue. The experiments support the previous research (e.g., Fullagar, 2006b:199, Shafer & Holloway, 1979:396) that shows that abundant residues usually accumulate in the region located several millimetres away from the working edge (e.g., Plates 44C, 77D). However, some residues are also compacted into microfractures and other small cavities and depressions located immediately on the edges. Since they are difficult to remove by cleaning, these residues are often observed and have good potential for archaeological research (e.g., Plates 34A, 47A).

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 or yellow smears which often incorporate other plant residues (e.g., Plates 3A, 11A, 37A). The texture and distribution of films may sometimes indicate the mode of use (e.g., Plates 36A, 49A, 50A). This means that, before cleaning, some artefacts may host films of residue 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 (e.g., Plate 1A). However, more commonly, deposits of tissue, often with cell wall structures, are embedded into scars and other surface depressions (Plates 41A, 68C–D, 71C, 100, 101).

Experiments demonstrate that starch residues contained within the tissue are commonly found on tools used to work palms (Plates 3D, 13), some species of soft and hard wood (Plates 20B, 23D, 35B, 41C, 43B) and non-woody plants (Plates 55, 57B, 58B, 66B). Starch granules have a distinct dark extinction cross that is visible under cross polarized light. In addition, they often have shapes that are taxonomically distinct unless they have been heated or otherwise damaged (Barton & Fullagar, 2006:50; Fullagar, 2006a:217). Starch residues extracted from experimental tools were placed on microscope slides (Plates 70F, 75D) and stored for taxonomic identification by specialists in the future.

Four 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*) produced needle-like residues (Table 2, Plates 1D, 8B, 12, 44D–E, 67C, 75D, 102C). These residues are probably crystalline forms of calcium oxalate called raphides. Raphides are particles formed in plants to provide a defensive mechanism. Their shapes can sometimes be taxonomically distinct (Crowther, 2009; 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, offer exciting possibilities for functional assessment of artefacts and for obsidian assemblages in particular.

Resins from the breadfruit tree (*Artocarpus altilis*) were used in replication experiments as fixatives for hafting some stemmed tools (Plates 70C, 102A–B). Resins that do not dissolve in water have adhesive properties and are widely used by indigenous peoples as glue or cement (Parr, 2006:186; Robertson, 2005:65–66). Resins on the experimental tools are distributed as thick patches or as smeared areas and have a glassy and highly reflective appearance with a range of colours. 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 (Plate 102C). Some resins resist decomposition so they are likely to be preserved on archaeological specimens.

White-coloured plant residues can be observed on some experimental tools involved in processing *Pandanus* spp., some wood species such as erima, hibiscus, ton, an unidentified species of soft wood and the non-woody aibika. These residues have a bumpy texture with no clear form and shape (Plates 60B, 71B). 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. Determination of the chemical composition of residues could be especially helpful in their identification. The distribution of white-coloured residues near the used edges and their association with the surface microtopography implies 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 (Plates 87C, 104–105). People using obsidian tools occasionally cut their hands unintentionally with the sharp edges while working. This results in blood residues being left on the surface of tools (e.g., Plates 21B–C). Blood residues appear microscopically as thinly smeared, highly reflective films (Plates 88B–C, 104A), or as a thicker film with polygonal cracking (Plates 21B, 104B), often termed "mud-cracking" due to shrinkage of the drying residue (Fullagar, 1986:184, 2006a:219; Loy, 1983; Robertson, 2005:70–71). Sometimes blood residue has a droplet-like appearance embedded within scars (Plate 104A). 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 (Morgan *et al.*, 2009) which are best observed on glass slides at high magnification using darkfield incident illumination (Plates 21C, 104D–E).

Residues from gutting/cutting fish consist of proteinaceous films, black and rainbow coloured tissue and blood (Plates 90E–F, 105A–F). Individual red cells of fish blood, in contrast to human red cells, have a nucleus (Plates 105D–E) that generally indicates a non-mammalian origin (Morgan *et al.*, 2009).

A coloured mixture of skin tissue, hairs and blood residues is formed in one to two minutes on tools used for shaving the human face (Plates 87C, 88C, 104C). 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 and is likely to consist mainly of calcium carbonate (Fullagar, 1986:189; Robertson, 2005:81–82) (Plates 92A, 93B, 96B). Since they are embedded into altered surfaces, these residues are difficult to remove by cleaning, unless chemicals are applied.

Tools used in experiments for scraping clay also contain white coloured smears and powdery residues (Plates 98B, 99C). The clay used in the experiments was obtained from limestone deposits and so consists of carbonates of lime and magnesium. As with shell-working, these residues are difficult to remove from the working edges suggesting that similar carbonate materials may well survive on archaeological tools.

The range of residues extracted from experimental tools and stored on glass slides represents significant reference material that can be used in future studies. Some of these residues, for example, white-coloured plant residues, have not been recorded in previous studies of experimental and archaeological obsidian tools. Further study of these types of residues may assist in the functional interpretation of artefacts.

Hafting wear

Methods of holding experimental tools include hafting (a tool inserted into or attached to a handle) and prehension (a tool is hand-held) which can produce wear patterns and residues on the tool (Keeley, 1982; Rots, 2003, 2005). Hafting wear is usually located on the surfaces opposite the working part of the tool. Two characteristic features of hafting use-wear reported previously are scarring and isolated spots of polish on the tool 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. In this experimental project, most of flakes were wrapped during use although some small stemmed tools were inserted into a wooden handle and bound with plant string (Plates 106A–E, 109A–B).

The obvious signatures of a wooden handle on the experimental tools are (1) patches of scars and abrasion on the edge of the handle (Plates 107A, 108A) and (2) areas with intensive abrasion and light polish on the surface (Plates 107A, 108B). Spots of rough abrasion with obvious striations of all types are more common on the tool surface (Plates 70C, 71F) than are patches of very light polish with isolated, long and deep striations (Plate 108B). Scarring on the edges of the hafted area is usually accompanied by closely packed, rough-bottomed, intermittent, and occasionally flaked striations, which are slightly angled or perpendicular to the edge (Plates 70B, 71E, 107A). The wear variables present on areas impacted by a wooden haft are similar to the abrasion, polish and striations which were observed on the woodworking tools.

Sometimes scars, striations and abraded spots on the hafted surface are covered by tissue with starch grains and resins adhering to the tool surface (Plate 70C). The presence of resin is a potentially good indicator that tools were hafted (Hurcombe, 1992:74; Kealhofer *et al.*, 1999; Keeley, 1982:799).

Several forms of hafting were studied. In addition to the use of wooden handles, flake tools were wrapped with plant leaves or string to protect the user from a sharp edge (e.g., Plates 16, 26B, 44A, 51, 70A, 109A–B). 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 occur at on some surface locations. Sometimes a few long and thin striations occur in association with surface spots that are abraded. However, light abrasion and randomly distributed striations on ancient artefacts 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 residues from wrapping materials are essential indicators 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 the hafted area.

Experiments with hafted and hand-held tools revealed that the time-consuming procedures involved in making wood handles and fastening tools in them was not efficient. Relatively short stems with thick cross-sections begin to loosen quickly, and fall out from the handle after five to 10 minutes of use. However, the retouched stems were very comfortable to hold in bare hands and this probably gives a plausible reason why intentionally manufactured small stemmed artefacts were used without hafting for various activities during the Middle Holocene in West New Britain. In contrast, a highly efficient holding mechanism was produced by wrapping sharp flake tools in green leaves, such as banana and pandanus. Pandanus and bamboo phytoliths have been found as residues on the surface of tools from Garua Island (Kealhofer *et al.*, 1999) which further supports the suggestions made on the basis of experimental data.

Taphonomic experiments

The purpose of these experiments was, first, 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. Second, they examined the degree of mechanical and chemical damage on both unused and used flakes. Experiments were conducted in Sydney, Australia in acidic soil within basically a sandy clay environment. Artefacts were placed into two contexts: surface exposure (Plates 110A–C) and shallow burial (Plates 110D, 112A). The size of flakes and tools left on the ground surface varied from large (5.5×4×1 cm) to small (2×1.5×0.5 cm). Before the experiments, the flaked surfaces of samples were photographed in the region near the edge on both ventral and dorsal sides of the tool and typical surface features were recorded. The samples, including nine 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 containing small amounts of rough grained 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 magnification.

The results show that residues on the tools placed on the surface were essentially reduced in abundance and dramatically altered in appearance (e.g., Plates 111A–B and 111C–E). A similar trend in the survival of residues was observed on the surface of buried artefacts used for processing plant materials (e.g., Plates 112D–E and 112F). However residues on buried tools were better preserved when they had been embedded within microscars (Plate 112C). This may be explained, not only by the limited impact of natural factors (rain and wind) on artefacts buried in the soil (Langejans, 2010; Lu, 2006:81), but also because the dense residues trapped in the depressions, pits and cracks of the natural obsidian surface were protected.

During the first two days, samples left on the surface were moved 10 to 15 cm down the slope from their initial location by soil disturbance caused by rats or bandicoots. Such physical movements resulted in the formation of randomly distributed, isolated, long and deep sleeks and short intermittent striations (Plate 114). In contrast, the surfaces of the buried flakes do not have striations except for rare single sleeks (e.g., Plates 115A–B).

The most important result of these experiments is that initial chemical damage occurs on the obsidian flake surfaces. Chemical etching appears on the ventral surface as a series of small, shallow pits and shallow, slightly concave channels with relatively rough bottoms and irregular sides in plan view (Plates 113A–C). 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 showed 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 results need to be taken into account when experimental wear patterns are compared with wear variables on ancient artefacts.

Discussion

The stages of formation of the main types of wear on obsidian tools were analysed on a range of worked materials for a number of different use-time periods. A set of diagnostic wear variables within each use-material category was defined. From a use-wear perspective, the experimental results clearly indicate some consistency, particularly in relation to plant species used in experiments. For example, all palms, pandanus, species of soft wood such as malas and *Calophyllum*, and some grass species including bamboo and cane are characterised by high silica content (Fullagar, 1991) and this creates some similarities in wear patterns on the tools. In an archaeological context, such similarities will make it difficult to identify exactly which plant species were worked unless identifiable residues are preserved. Fullagar in his previous analysis of obsidian artefacts from Garua island (Kealhofer *et al*., 1999:541) divided the plant processing tools into groups of worked materials: (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 the experimental results of this project show that on the basis of wear patterns the plant material worked can be identified in broad categories which include several families or genera of plants. The experiments described in Part 4 clearly demonstrate that grouping processed plants into palms, soft wood, hard wood and hard palms and non-woody plants is appropriate but this grouping cannot be always applied to the reconstruction 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 similar that it is not possible to distinguish these materials from each other 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).

Similarities among these plant types mean that the wear patterns detected on prehistoric artefacts can be only compared with those categories of plants and other materials which produce distinctive and diagnostic wear patterns experimentally. These categories are: (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 (greens which include leaves, stems and grasses), (6) non-woody plants (tubers), (7) soft elastic materials (skin and fish) and (8) dense, hard materials (shell and clay). The rate of formation of diagnostic wear traces also depends on the duration of use and the mode of use. Generally, use-wear patterns on obsidian tools result from processing particular categories of materials and can be defined by using a combination of wear characteristics.

Processing siliceous soft wood, palms and bamboo. This task generates moderate to intensive edge scarring with smoothed and rounded scar ridges, intensive edge rounding, well-developed, very smooth and flattened polish, mostly shallow and short, densely packed, sleek, rough-bottomed and, rarely, intermittent striations. Identifiable wear builds on most used tools during the first 5 to 10 minutes and, after 15 minutes of use, the efficiency of tools usually decreases significantly. This short use-life leads to a high rate of discard and must be taken into account in assessing prehistoric artefacts. Comparable wear patterns were observed by Hurcombe (1992, plates 3 and 4).

Processing non-siliceous soft wood. This type of tool use creates moderate to intensive edge scarring, medium to intensive edge rounding, developed and well-developed but less smooth and flattened polish, distinctive long, deep and mostly sleek and rough-bottomed striations that tend to be well separated from each other. Diagnostic wear on the tools forms after 15 to 20 minutes and the tools can be used further with slightly less efficiency for up to 30 minutes. A whittling action usually requires a slightly longer duration of use to form identifiable wear patterns than does scraping and sawing. Similar wear patterns on obsidian woodworking tools were described by Aoyama (1995:133, fig. 9, pattern b) and Hurcombe (1992: plates 9–11).

Processing siliceous hard wood and hard palms. This action produces very intensive edge scarring, patches of intensive edge rounding, patches of well-developed, smooth and flattened polish, shallow, short and densely packed sleeks, rough-bottomed and intermittent striations. Because of the high density and hardness of these siliceous worked materials, the edge is immediately modified by scars, rounding and polish, rendering the tool inefficient after five to 10 minutes of use. Hurcombe's experiments with processing hard wood for two, five and 10 minutes (1992: plates 5–7) demonstrate similar patterns of wear formation.

Processing non-siliceous hard wood. This tool use results in the edge usually becoming highly fractured by scars. Very light or light rounding can be observed where microscars intersect each other but these are only rarely preserved and comprise small areas. The same areas may contain patches of light or developed polish, with a few isolated long, deep rough-bottomed and sleek striations but, more commonly, intermittent striations appear as patches of densely packed short scratches. The areas close to the edge are often characterised by light attrition that contrasts with the smooth natural surface of obsidian. Reliable diagnostic wear in the form of intensive edge scarring and patches of rounding, polish and isolated striations appear after 15 to 20 minutes of use. Further use of the tool is inefficient although the wear pattern on the edge may be more pronounced after 30 minutes of use.

Processing non-woody plants (greens, leaves and stems). This task creates edge damage in the form of small scars and microscars. It is less intensive than the scarring pattern on the edges of woodworking tools. Light to medium edge rounding, light to developed polish, a few to a moderate number of striations of shallow, sleek types are prevalent, and rough-bottomed or intermittent types rarely occur. There are obvious stages in the formation of rounding and polish that depend on the duration of tool use. Some patches of weakly developed polish may contain very light striations after 10 to 15 minutes of tool use. However, processing non-woody plants for 15 to 30 minutes by obsidian generally does not produce intensive wear in the same way as it does on tools used to work palms and wood. After 30 minutes the nature of scarring patterns, types and distribution of striations, rounding and polish characteristics form a diagnostic combination of wear. After 30 minutes of use, most of the tools still maintained relatively sharp and useable edges.

Processing non-woody plants (tubers). This tool use creates only a low intensity of use-fracturing by small bending and feathered scars. Slight to medium edge rounding forms from between 5 and 15 minutes of use. The intensity of rounding increases after 30 minutes of use. Developed and well-developed, smooth, continuous and merging polish, and a moderate number of long and shallow striations, well separated from each other, are all present. The relative efficiency of tools decreases after 30 minutes of use but the edge usually preserves its sharpness.

Processing soft elastic materials (skin). This action forms irregular and discontinuous microscars. Small scars and small snapping spalls are rare on skin cutting and piercing tools even after 25 to 30 minutes of use. A thin line of slight to medium edge rounding and patches of light to developed smoothed polish can be observed under more than 200× magnification, striations are much less common and are mostly represented by isolated and long and shallow sleeks which are more easily visible under higher magnification. A diagnostic combination of wear variables occurs if the tool was used for more than 30 minutes. Comparable results were obtained by Aoyama's experiments involving cutting meat with obsidian tools (1995:133, fig. 6, pattern *I*, fig. 9, patterns *f* and *i*).

Processing soft elastic materials (fish). This activity produces continuous or isolated small to medium sized banded scars and some feathered scars. Patches of light to medium edge rounding, patches of light to developed polish, low density of well isolated, long and shallow, rough-bottomed and sleek striations, and short, shallow, intermittent striations are all present. 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. Similar wear patterns were observed by Hurcombe (1992: plate 45).

Processing dense, hard materials (shell). The wear on obsidian tools for this activity includes very intensive edge damage with dense, stepped and bending scars and crushing. Thick, intensively abraded and rounded edges, well-developed, smoothed and flattened polish occur. A dense net of shallow striations of all types is present but rough-bottomed and intermittent striations dominate. Diagnostic wear patterns form during 5 to 15 minutes use, after which the efficiency of the tool dramatically decreases.

Processing dense, hard materials (clay). This task causes very intensive edge scarring, intensive edge rounding, abrasion, well-developed polish and a dense net of striations is formed during first five to 10 minutes. The texture and distribution of polish on the working edge of tools used for working half-dry clay has some common characteristics with shell-working tools, but the abrasive nature of clay results in a smoother and more flattened appearance of polish. There are obvious differences in the prevalent types of striations. Clay produces mostly thin, long sleeks with rare occurrences of deep rough-bottomed striations. Because of the very fine abrasive properties of clay, the surface within scars often contains similar types of striations. After 15 minutes, intensive rounding, abrasion and polish all dramatically thicken and dull the working edge ending its ability to be used efficiently.

Conclusion

In conclusion, the replication experiments have allowed the documentation of diagnostic characteristics in scarring, striations, rounding and polish specific for each of a range of organic and inorganic materials. The presence of indicative combinations of these use-wear attributes enables obsidian tools involved in processing different substances to be differentiated. Comparison between the use-wear produced by all varieties of plants, however, showed that only a general identification of the worked species can be made on the basis of use-wear alone. This result is partly due to differences in the density and silica content in the various plant species used in the experiments. Further studies of residues present on the tools may allow more precise identification of individual species. The classification of use-materials proposed here should be applicable to the analysis and interpretation of archaeological assemblages.

The stages of formation of diagnostic sets of wear for each category of use-material provides a valuable approach in the assessment of the use-life history of prehistoric obsidian artefacts and, by inference, past discard behaviour. Since the experimental data substantiate an obvious relationship between wear formation and duration of use, they provide the basis for a general estimation for the length of time prehistoric artefacts were used: (1) short term and intensive use for less than 15 minutes generating identifiable wear patterns resulting from working palms, wood and hard dense materials, (2) moderate use which suggests a use-time of between 15 and 30 minutes during which well-developed wear variables are formed on palm and woodworking tools and identifiable wear occurs on 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.

The experimental data contribute highly useful information for interpreting archaeological assemblages derived from expedient technologies. The detailed photographic record of use-wear and residues presented in this research provides an extensive comparative source for other scholars working on obsidian artefacts and may also stimulate the planning and performance of new sets of specific experiments.

The experimental program was designed to investigate wear formation on obsidian tools derived from processing a range of materials from the study area on Garua Island, Papua New Guinea. This has provided comparable data for an identification of tool function and a comprehensive interpretation of lithic assemblages from the archaeological site in the wider context of understanding subsistence and settlement patterns. The methodological approach adopted in this study was aimed specifically to assess the middle and Late Holocene obsidian assemblages found at the FAO site on Garua Island. Parts 5 and 6 further describe the development of the methodology used in the functional analysis of obsidian tools as well as illustrating how the general principles derived from the experimental program are applied to the interpretation of obsidian tools derived from an archaeological context. Part 5 briefly outlines what is currently known about the prehistoric occupation of the area under investigation, its geographical setting and describes the environmental resources probably available to human populations during the middle and Late Holocene. The archaeological context of tool assemblages studied in this project is also described. Part 6 presents the results of the functional study of prehistoric artefacts and their association with subsistence practices, domestic activities and settlement patters during the middle-Late Holocene.

Part 5 Archaeological case study: Garua Island and FAO Site in the Middle and Late Holocene

Garua Island, with its abundant obsidian sources, has produced a large quantity of prehistoric stone artefacts widely distributed across the landscape providing evidence of human occupation over long time scales (e.g., Torrence, 2002a; Torrence & Stevenson, 2000). The prehistory of this island is closely connected to the unique experience of people who colonised the vast expanses of the Pacific in the late Pleistocene and Holocene periods. The middle and Late Holocene (6000–2000 years ago) occupation of the island coincided with dramatic changes in human behaviour occurring about 3300 years ago in the Bismarck Archipelago. The archaeological record is often thought to demonstrate these changes as a widespread 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).

Garua Island is an ideal place to study the changes that took place during the middle and Late Holocene since it has been extensively researched over a number of years. In contrast to other areas of the Bismarck Archipelago, intensive research by Specht & Torrence identified a number of sites containing evidence of both the middle and Late Holocene periods of occupation on the Willaumez Peninsula in West New Britain, Papua New Guinea (e.g., Specht, 1974; Specht & Torrence, 2007; Specht *et al*., 1988; Torrence, 1992, 2002a, 2004a,b; Torrence & Stevenson, 2000; Torrence *et al*., 1996; Torrence *et al*., 2000). Long-term research on Garua Island, conducted by Torrence and her team, has provided extensive data for reconstructing different aspects of human behaviour (e.g., Araho *et al*., 2002; Lentfer & Torrence, 2007; Torrence, 2000, 2002a,b; Torrence & Summerhayes, 1997; Torrence & Stevenson, 2000; Torrence *et al*., 2000; Torrence *et al*., 2009). Specific attention has been paid to the organisation of obsidian raw material procurement, the technology of production, and, the use and discard of stone tools across the landscape (Torrence, 1992, 2002a; Torrence & Summerhayes, 1997; Summerhayes, 2000, 2003, 2004; White, 1996). Torrence (1992:121) has proposed that the main limitations to the form of tools, the strategy of their manufacture, and the pattern of use and discard was the degree 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, and, technological and obsidian characterisation studies 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).

Preliminary use-wear/residue study of stone artefacts by Fullagar (Fullagar, 1992, 1993a,b; Fullagar *et al*., 1998; Kealhofer *et al*., 1999) provided data for the proposal that multi-functional and single purpose tools were used primarily for processing plant materials and were associated with a limited range of activities at sites. This, he argued, indicated a high level of mobility of human population during the Middle Holocene. In contrast, Late Holocene tools were used more expediently and in a much larger range of activities performed at sites and this suggests a gradual decline in mobility over time (Fullagar, 1992:139–140). This view of gradual changes in tool-use strategies and mobility patterns, although supporting a hypothesis of cultural continuity in human behaviour, was formed using a limited range of use-wear data obtained from selected artefacts from middle and Late Holocene sites in the Kandrian region, on the Arawe Islands, in the Talasea area and on Garua Island (Fullagar, 1992, 1993a,b; Fullagar *et al*., 1998; Kealhofer *et al*., 1999). The reconstruction of many aspects of daily activities and associated subsistence and settlement patterns, however, requires full-scale on-site use-wear and residue analysis of lithic assemblages from well-defined cultural deposits which has not been practicable in the Pacific archaeology (Fullagar, 1989).

For this project, the FAO site, which is located on Garua Island, was chosen because airfall tephras derived from several volcanic eruptions have preserved a series of ancient ground surfaces at the site (Torrence, 2002a; Torrence & Stevenson, 2000; Torrence *et al*., 2000). This means that the site has excellent stratigraphic and temporal control, sufficient chronological depth and numerous stone artefacts to facilitate the observation of changes over time, in this case, the transition period from the middle through the Late Holocene. A systematic use-wear/residue analysis of obsidian artefacts recovered from FAO site provides the opportunity for improving existing knowledge of the strategy of tool use and the day-to-day activities of the people who inhabited the island's landscape during the transition period. These activities were closely related to the available resources and the dynamic changes to the local landscape over time. Methodologically, the archaeological and environmental context of the lithic assemblages under study is critical for the functional study of prehistoric tools (Keeley, 1974). It is for this reason that brief descriptions of the geographical setting and the marine and terrestrial environment surrounding the site on Garua Island are given below. Following this essential background information, the archaeological context of the excavated artefacts described, together with the stratigraphical sequence of deposits, and, the chronology and spatial distribution of the obsidian artefacts is outlined. Finally, the approaches to the sampling and organisation of functional data are described and the surface preservation of obsidian artefacts from different chronological periods are characterised.

Environmental background

The purpose of this section is to provide the background data needed to characterise the nature and structure of potential resources that would have had an impact on tool-use activities, settlement organization and mobility patterns of inhabitants on Garua Island. The island sits within the seascape of Garua Harbour adjacent to the Willaumez Peninsula in the province of West New Britain in Papua New Guinea (Figs. 1, 13). The maritime and terrestrial environments of the island offered a range of opportunities for past human economic activities. The island, about seven square kilometres in area, is separated from the Willaumez Peninsula by a channel which is 800 m wide and 3 m deep at low tide (Royal Australian Navy Hydrographic Charts, 1979:545, 1992:676; Royal Australian Survey Corps, 1975: 8987). The local setting is dominated by the two peaks of

Mount Hamilton at some 240 m above sea level and Mount Baki at about 140 above sea level. Torrence & 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 & Boyd, 1996, fig. 2b). There are only two relatively large coastal plains both of which are associated with their main catchment areas. One of plains is drained by Malaiol stream, and is the largest on the island (Specht & Torrence, 2007; Torrence, 1993:8–9; Torrence & Boyd, 1996:15–16). There are at least another 12 stream catchments on the islands (Torrence & 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 & Torrence, 2007:133–135; Torrence & Boyd, 1997:14; Torrence & Webb, 1992:4). Coastal slopes mostly rise directly from the sea or beach, or are located within a few hundred metres of the beach (Specht & Torrence, 2007).

The coastline of the region has a complex history due to two interrelated factors which occurred during the Holocene: eustatic sea level changes and tectonic uplift (Specht & Torrence, 2007). The characteristics of Holocene sea-level change were consistent throughout the Pacific region (Chappell, 1982; Lambeck *et al*., 2002). The data demonstrate the slow fall of the sea level from its high stand some 7,000 to 5,000 years ago to about 1.3 m 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 (Woodroffe & Horton, 2005, fig. 4). At the time of the Mid-Holocene High Stand sea level, Garua Island would have had slightly less land area and, therefore, there was less opportunity for beach, inter-tidal and coastal settlements. 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 Mid-Holocene High Stand sea level the area of active coral reef immediately around Garua Island would have been

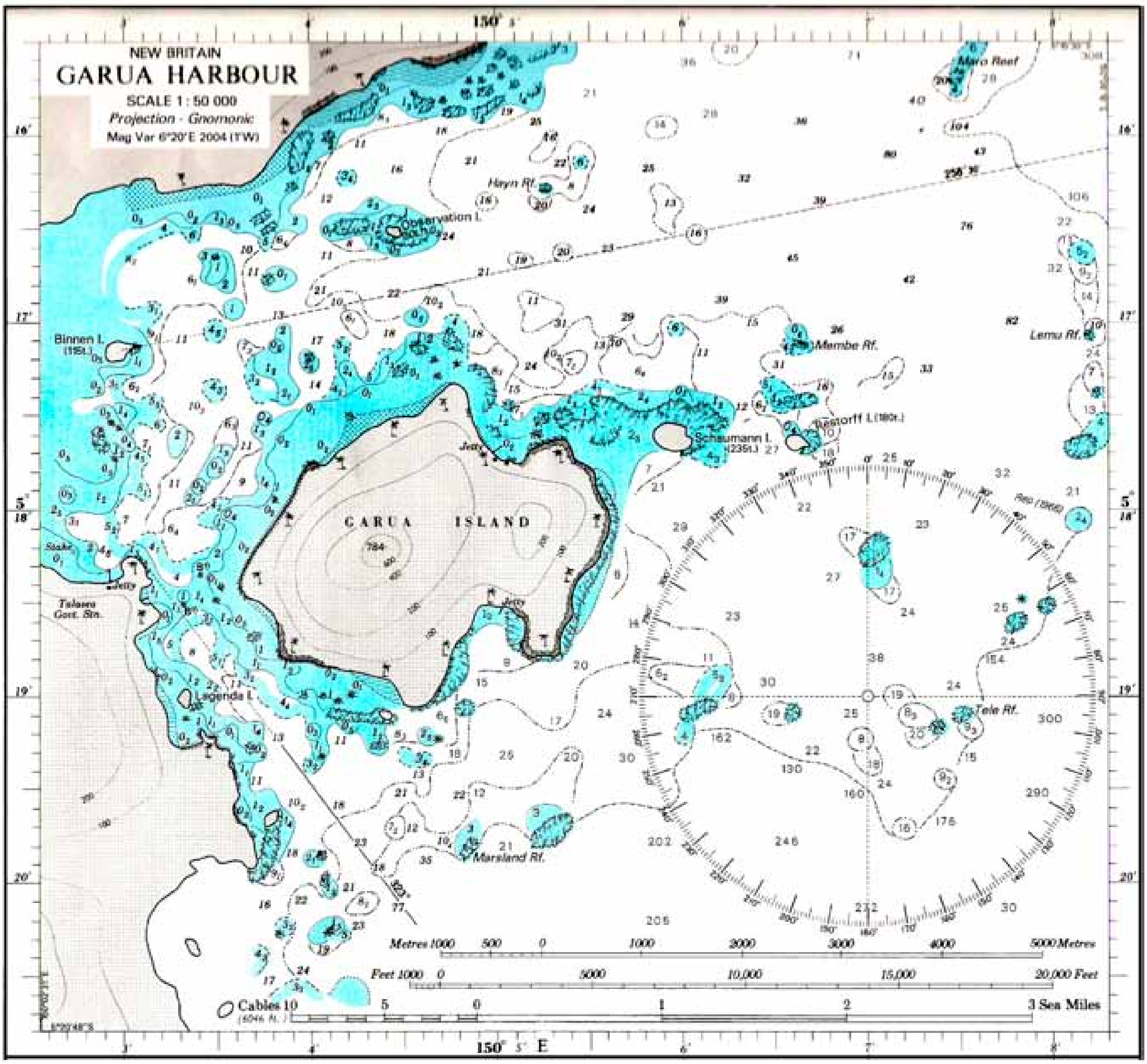

Figure 13. Map of Garua Island. Hydrographic chart—RAN 1992:676.

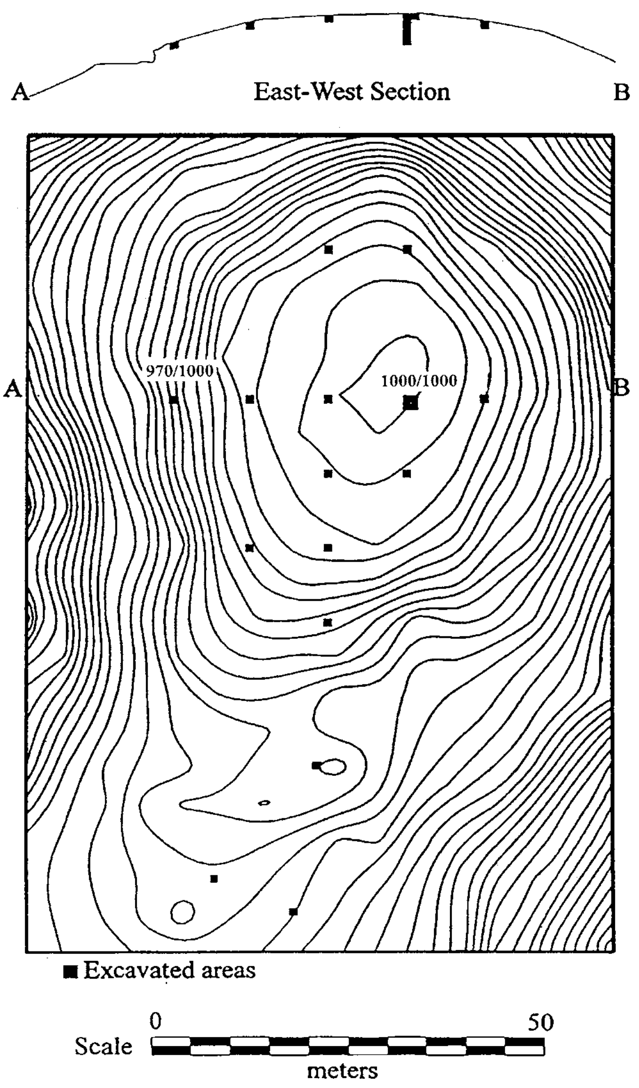

Figure 14. Contour map of FAO; based on Therin, 1994, fig. 1.3.

considerably more extensive and, consequently, the marine biota richer and more productive than in the Late Holocene.

Site FAO is located on the top of a coastal hill with 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 (Fig. 14). And this elevated area would have been an ideal place for a small hamlet.

Garua Island is situated between the two major active volcanic centres at Witori and Dakatau in West New Britain and is associated with hazardous environments resulting from high volcanic and seismic activities. Severe volcanic disasters during the Holocene, generated by five large eruptions, periodically altered the landscape (Torrence *et al.*, 2009). Airfall and redeposited tephras emanating from these eruptions changed the micro-topography of the island by in-filling low-lying areas as well as altering the shape of slopes and the coastal plain (Specht & Torrence, 2007:134). However, the main landforms on the island generally did not undergo dramatic change.

Airfall tephras from the major eruptions formed the distinctive sedimentary history of the island and clearly delineate four cultural phases of occupation (Boyd *et al.*, 2005; Lentfer & Torrence, 2007; Machida *et al.*, 1996; Torrence *et al.*, 2000). Tephra from the W-K1 eruption dated between 6160–5750 cal. BP, according to Bayesian modelling (Petrie & Torrence, 2008) is not preserved in the stratigraphic sequence at FAO, suggesting a period of erosion following its deposition (Lentfer & Torrence, 2007:92–93; Torrence *et al.*, 2000:230–231). In contrast, the W-K2 tephra up to 60 cm thick is present at FAO some 2 m below the present surface. This event is dated between 3480 and 3150 cal. BP (Petrie & Torrence, 2008). Subsequent tephras present in the deposit at FAO are W-K3 (1750–1550 cal. BP) and Dakatau (1345–1275 cal. BP) (Petrie & Torrence, 2008).

The immediate impact of Holocene volcanic eruptions on the environment and on human populations depended on their magnitude, scale and frequency. The W-K2 eruption was one of the largest in the Holocene. The airfall tephra would have destroyed all vegetation creating "a virtual desert" (Torrence *et al.*, 2009:517) and caused depopulation of the area for a long period of time (Torrence *et al.*, 2009:523). Re-settlement the area following the W-K2 might have taken approximately 250 years after the eruption (Parr *et al.*, 2009). Recent Bayesian modelling estimates that Garua Island was abandoned for about 120 years after the W-K1 event and for about 140 years following the W-K2 eruption (Petrie & Torrence, 2008:738).

The re-occupation of the island by a human population following severe volcanic disasters was closely related to the time period required for regeneration of the biomass (animals and vegetation). 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 *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 & Torrence, 2007; Therin *et al.*, 1999). The lengthy periods of environmental stability between volcanic events were characterised by tropical vegetation fluctuating between early pioneer and regrowth forest (Boyd *et al.*, 2005:390). Following the W-K1 eruption people occupied the site when vegetation was dominated by grasses and forest regrowth. The process of forest development was interrupted by human activity in the form of deliberate forest clearance and burning (Lentfer & Torrence, 2007:100). However, environmental modification at FAO itself did not preclude the continuous and further development of a closed tropical rainforest environment elsewhere on the island. There is evidence of undisturbed forest in the area surrounding the site (Parr *et al.*, 2001:127). Similarly, following the W-K2 eruption people reoccupied FAO when the landscape was covered by grasses and pioneer regrowth forest (Lentfer & Torrence, 2007:97). Later in the sequence there was a break in the vegetation recovery process, caused by human activity associated with clearance and burning.

Despite the long-lasting environmental impact of both the W-K1 and W-K2 volcanic eruptions, 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 & Boyd, 2005; Lentfer & Torrence, 2007). This suggests that the environmental conditions and resources that recovered after each volcanic event were generally similar on Garua Island. At the time people returned to the 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.

The present landscape of Garua Island has been greatly modified by coconut plantations established since the 1920s (Boyd *et al*., 2005:387). Ethnobotanical data from New Britain, and particularly from the Willaumez Peninsula and West New Britain (Floyd, 1954; Lentfer, 1995; Powell, 1976; Seeto, 2000), available palaeoenvironmental information from Garua Island and the Isthmus region (Boyd *et al*., 2005; Kealhofer *et al*., 1999; Lentfer, 2003:301–303; Lentfer & Torrence, 2007; Parr *et al*., 2001, 2009) and archaeological remains from the middle and Late Holocene sites in the Bismarck Archipelago (e.g., Gosden *et al*., 1989; Kirch, 2000:109; Kirch *et al*., 1991; Specht, 2003; Spriggs, 1991, 1997:79, 117; White *et al*., 1978) 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.

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 3) all demonstrate that the general structure and distribution of vegetation has not changed dramatically over time. Many economically useful species of plants would have been widely accessible and were probably used in much the same way as they were used in relatively recent times (Floyd, 1954; Lentfer, 1995; Powell, 1976).

The lowland rainforest habitats in West New Britain support a diverse fauna including marsupials, rats, fruit bats, land birds, reptiles and insects which are hunted and provide fat and protein for the diet supplemented by domesticated pigs, chicken and dogs (Seeto, 2000). The natural resources of the reefs and the sea were also important sources of food for human populations (e.g., Golson, 1991; Gosden *et* al., 1989; Kirch, 1997:31, 2000:56; Kirch *et al*., 1991; Ono, 2003; Specht, 2003; Spriggs, 1991, 1997:51–82). The likely range of marine resources being involved in the subsistence of the population of the Bismarck Archipelago during the middle and Late Holocene allows the suggestion that Garua Island, surrounded by reefs and the deep waters of Kimbe Bay and having a rich diversity of marine life (Seeto, 2000), was an attractive place for human occupation. The subsistence strategies of the island's inhabitants would have been oriented towards the exploitation of 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. The staple carbohydrate basis of the diet was probably comprised of starchy plants such as taro, yams and bananas seasonally supplemented by breadfruit. Vitamins would have been provided by nuts, fruits and greens which occur widely in the lowland rainforest environments (Kirch, 1997:212–217). In addition, 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., Machida, 1991; Specht, 1981; Specht *et al*., 1981:48; Torrence *et al*., 1992; Summerhayes, 2000:15).

The abundance and accessibility of aquatic resources and the relatively small catchment area containing terrestrial resources provided by the island would have led to a low level of mobility of human populations. The temporal consistency in basic marine and terrestrial resources would necessarily result in common features in the dynamic relationship between subsistence strategy, tool-using behaviour and settlement patterns within the hazardous environments of the study area. The extent to which use-wear/residue data are able to provide reliable information about the interaction between human activities and the natural environment are examined in Part 6. The following section describes the archaeological context of the middle and Late Holocene obsidian tool assemblages at FAO.

Excavations at FAO

The FAO site was first discovered in 1989 by Richard Fullagar and Robin Torrence and then tested by Jim Specht in the same year. The section in the test pit revealed a five-layer sequence containing two tephra layers that separated the cultural deposits (Specht *et al*., 1989). Excavations at FAO were undertaken by Torrence in 1992 and 1993 (Torrence, 1993; Torrence & Webb, 1992) and additional test pits were dug in the surrounding area in 1997 (Torrence & Boyd, 1997). The excavation of twenty test pits occurred within an irregular-shaped area which extended some 90 m from north to south and about 40 m across from east to west (Fig. 15). Excavations followed the 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 three millimetre mesh screens. When sediments became too clayey and thick, they were carefully hand sorted. Most artefacts were washed in the field, stored in clean plastic bags and transported to Australia for analysis. A sample of some 10 obsidian artefacts was collected during the excavation of each spit specifically for residue and use-wear analysis (Torrence, 1993; Torrence & 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).

The full sedimentary sequence of the site, comprised of several layers of buried soils alternating with tephras, is represented in the stratigraphic profile of the north face of the 1000/1000 test pit (Fig. 16) (Boyd *et al*., 2005:387, Lentfer, 2003:280; Lentfer & Torrence, 2007:86; Therin *et al*., 1999:443–444; Torrence *et al*., 2000:230–231). The Middle Holocene cultural deposit at FAO occurs in stratigraphic Layer 6. The Late Holocene cultural deposit at the site corresponds stratigraphically with Layer 8 (Fig. 16). Four radiocarbon dates (Table 4) and a series of obsidian

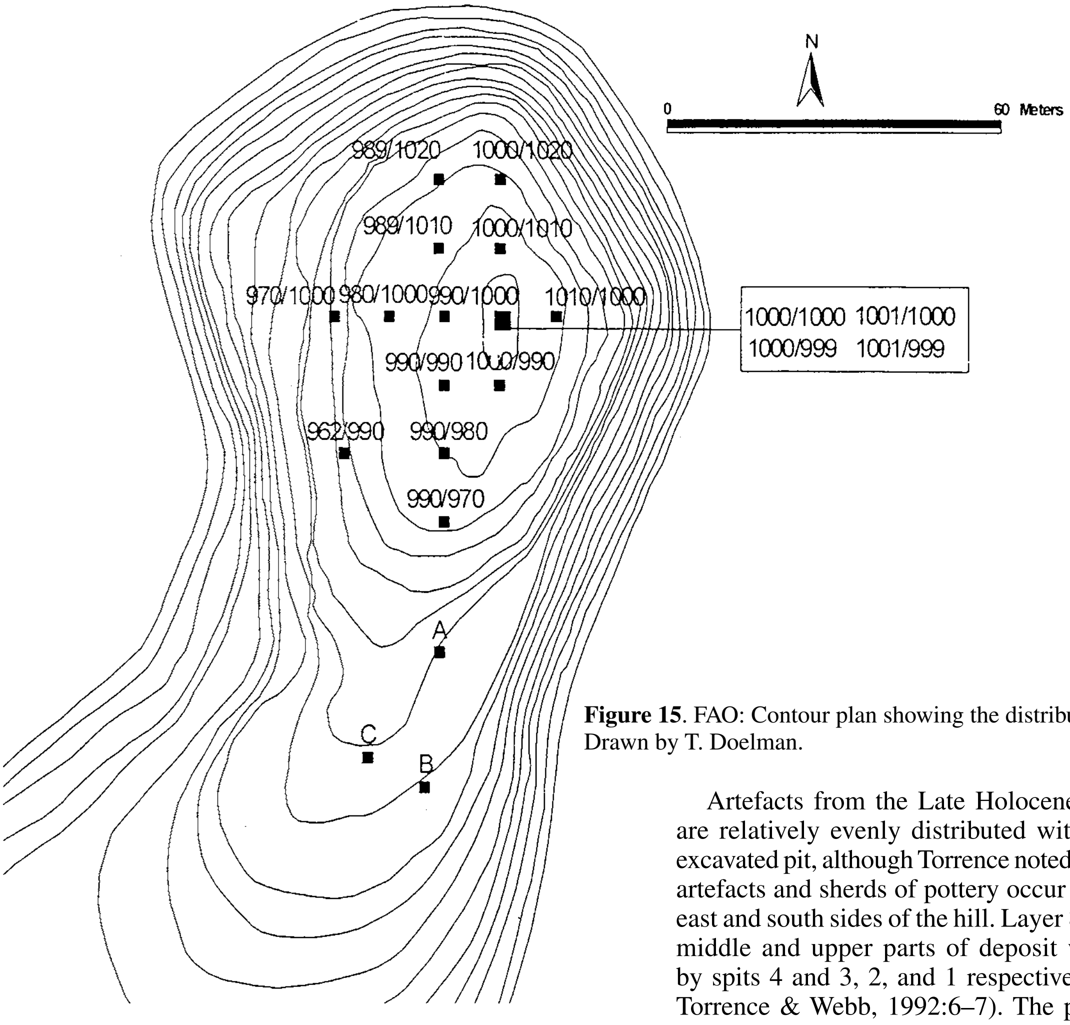

Figure 15. FAO: Contour plan showing the distribution of excavated pits. Drawn by T. Doelman.

hydration determinations (Torrence & Stevenson, 2000) confirm the chronological sequence.

The density of obsidian artefacts within the buried stratigraphic layers at FAO varies and indicates some differences in discard behaviour and the activities of inhabitants in each of the two chronological periods of occupation (Kononenko, 2008a). Layer 6 contained a distinct concentration of artefacts in both the lower (spits 3 and 4 with some artefacts from spit 5) and upper parts (spits 1 and 2) of pits 1000/1000 and 970/1000 (Table 6.2) indicating sporadic and repeated occupations during the Middle Holocene (Lentfer & Torrence, 2007:100). The distribution of discarded artefacts in the upper part of Layer 6 provides some information about the intra-site structure in the form of three areas of obvious concentrations of artefacts that immediately preceded W-K2. The first area is marked by a thick layer (20 cm deep) of obsidian waste in the 1000/1010 test pit (Fig. 15). Technological analysis showed 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 manufacture of obsidian artefacts (Symons, 2003; Torrence, 1993:5). The second concentration of finds is in the 1000/1000 pit which is considered as the central part of the site (Torrence & Webb, 1992:6–7). Finally, numerous artefacts were found in the 970/1000 test pit which is situated on the sloping edge of the relatively flat terrace, about 30 m west of the centre (Fig. 15). This has been interpreted as a refuse area or dumping ground (Torrence, 1993:5).

Artefacts from the Late Holocene deposit, in Layer 8, are relatively evenly distributed within the layer in each excavated pit, although Torrence noted (1993:5) that obsidian artefacts and sherds of pottery occur less frequently on the east and south sides of the hill. Layer 8 comprises the lower, middle and upper parts of deposit which was excavated by spits 4 and 3, 2, and 1 respectively (Torrence, 1993:5; Torrence & Webb, 1992:6–7). The presence of numerous 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 deposit following the eruption (Table 5), clearly shows that the site was occupied before the event and abandoned after it. 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 (Table 5). Spatial patterns of discarded artefacts within each stratigraphic unit, 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 also repeatedly re-used during the Late Holocene as it was in the previous period (Kononenko, 2008a).

Based on the examination of patterns of artefact discard, phytoliths and starch analyses of sediments and residues on the tools, it has been proposed that FAO was a domestic occupation site during both middle and Late Holocene occupations (Fullagar, 1992; Therin *et al.*, 1999; Torrence *et al.*, 2000). This is further supported by analysis of the spatial distribution of artefacts (Table 5) that indicates that the site was repeatedly re-occupied for a relatively prolonged period of time reflecting similar strategies in settlement patterns and activities during both the middle and Late Holocene (Kononenko, 2008a). In order to test these assumptions, a detailed use-wear/residue analysis of numerous obsidian artefacts has been conducted in conjunction with a description of their morphological and technological features as these are related to the patterns of use.

FAO Obsidian assemblage

Use-wear/residue analysis was carried out on all artefacts found within seven test pits: 1000/1000, 1000/999, 1001/1000, 1001/999, 990/1000, 980/1000 and 970/1000 (Fig. 15). These pits are located 10 m from each other in a grid extending from the centre of the site to the west end of the terrace (Fig. 15). Of the 1395 artefacts found in these pits, 832 belong to the Middle Holocene period, and 563 to the Late Holocene period. The results of the use-wear/residue analysis of all these obsidian artefacts revealed 190 tools with wear traces, including 102 tools from the Middle Holocene assemblage and 88 tools from the Late Holocene assemblage.

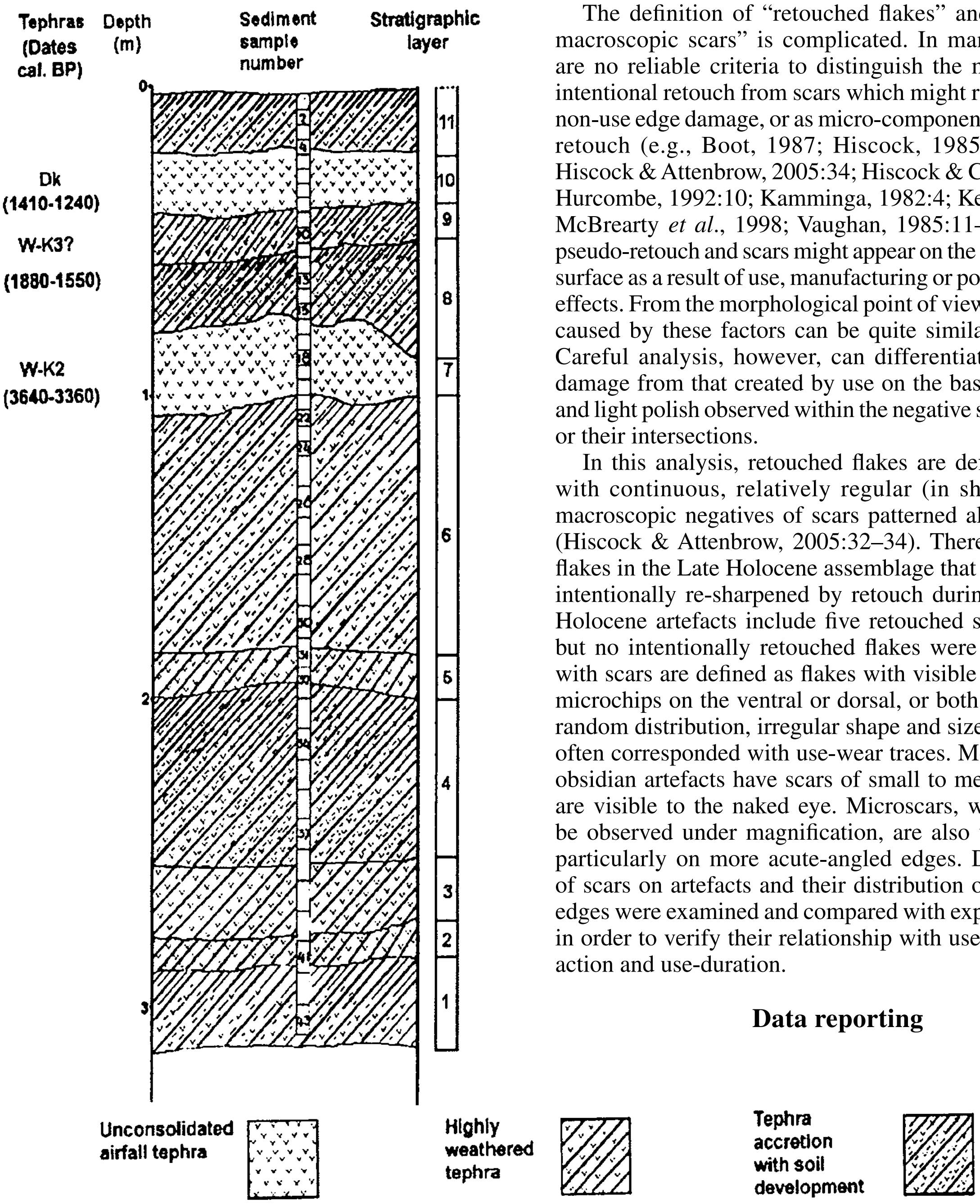

Figure 16. Northern Section of FAO 1000/1000; based on Lentfer & Torrence (2007, fig. 2).

The obsidian assemblage at FAO is generally characterized by a flake technology. Morphologically and technologically, there are only a few well-defined classes of artefacts, such as stemmed tools, retouched flakes and blades, all associated with the Middle Holocene period. Late Holocene artefacts are represented by flakes and, rarely, cores (Torrence, 2002a). All studied artefacts were initially grouped into categories according to their morphological features: cores, flakes, flakes with scars, or retouched flakes, blade-like flakes and stemmed tools.

Flakes and blade-like flakes were divided into groups according to their size: (*1*) microflakes (< 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), and (*4*) large flakes (> 4×3×0.3–0.5 cm).

The definition of "retouched flakes" and "flakes with macroscopic scars" is complicated. In many cases there are no reliable criteria to distinguish the morphology of intentional retouch from scars which might result from use, non-use edge damage, or as micro-components of deliberate retouch (e.g., Boot, 1987; Hiscock, 1985, 2004, 2007; Hiscock & Attenbrow, 2005:34; Hiscock & Clarkson, 2000; Hurcombe, 1992:10; Kamminga, 1982:4; Keeley, 1980:24; McBrearty *et al*., 1998; Vaughan, 1985:11–12). Retouch, pseudo-retouch and scars might appear on the brittle obsidian surface as a result of use, manufacturing or post-depositional effects. From the morphological point of view, edge damage caused by these factors can be quite similar to use-wear. Careful analysis, however, can differentiate taphonomic damage from that created by use on the basis of striations and light polish observed within the negative surface of scars or their intersections.

In this analysis, retouched flakes are defined as flakes with continuous, relatively regular (in shape and size) macroscopic negatives of scars patterned along the edges (Hiscock & Attenbrow, 2005:32–34). There are only two flakes in the Late Holocene assemblage that were probably intentionally re-sharpened by retouch during use. Middle Holocene artefacts include five retouched stemmed tools, but no intentionally retouched flakes were found. Flakes with scars are defined as flakes with visible small chips or microchips on the ventral or dorsal, or both, surfaces. The random distribution, irregular shape and size of these scars often corresponded with use-wear traces. Most of the used obsidian artefacts have scars of small to medium size and are visible to the naked eye. Microscars, 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 edges were examined and compared with experimental data in order to verify their relationship with use-material, use-action and use-duration.

Data reporting

The results of the use-wear/residue study are presented in a series of tables organised by individual FAO test pits (Tables 6–16). The morphological attributes of the artefacts are presented in the first half of the tables. Each table includes the following data: catalogue number of the artefact, number of the excavated spit, tool type (flake, blade-like flake, stemmed artefact and core), size of tool (large, medium and small), and shape of the edge (irregular, straight, concave and convex). In the case of a tool having more than one edge these are distinguished as edge a, b and c, etc.), edge angle of artefacts based on the measurement of the edges modified by use (very thin, less than 15°, medium, between 15° and 55°, and thick, more than 55°), cortex on the surface of tools, and, surface preservation (low pitted, medium pitted, heavy pitted).

The second part of each table presents data for the wear variables determined on artefacts together with an interpretation of their past function: scar type (bending, feather, step, continuous and discontinuous), striations (parallel, diagonal, perpendicular, crossed, dense or isolated), edge rounding (slight, medium and intensive), polish development (very light, light, developed and well-developed), the mode of use, the material worked, the level of confidence in the assessment of a tool function: definite use (*d*), probable use (*p*) and uncertain use (*u*), the duration of tool use (short-term, moderate, and long-term use) and the hafting pattern, if observed, (wood handle or wrapped), and, residue types found on the working edges, references to the plates taken from experimental tools.

For each test pit the association of tools with material worked is represented by Tables 17–18. The relationship between the material worked and the mode of use of tools within each chronological period is described in Tables 19–20. In addition, technological and morphological characteristics of tools used for working a variety of materials and the duration of their use are presented in Tables 21–22. These tables provide the basis for the summary in Table 23.

Surface preservation

Variation in the properties of obsidian, even from a single source, may create different 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 Willaumez Peninsula region in West New Britain, Papua New Guinea 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 outcrops varies depending upon differences in the number of air bubbles, density of small phenocrysts and internal thin fractured layers included within them (Specht *et al*., 1988; Torrence *et al*., 1992). The experiments conducted in Kimbe showed that these inclusions may affect the predictability of fracture paths during flaking and may later cause unexpected breakage of tools during their use. Some broken artefacts with wear traces found at FAO are compatible with this observation.

Freshly flaked surfaces of obsidian from the Willaumez Peninsula sources are very smooth and bright, but they usually contain irregularities created by crystals within the amorphous silica, ripple marks and stress fissures (Plates 116A–B). These features are clearly visible on prehistoric obsidian artefacts and can be easily distinguished from wear or damage traces (Plates 117–118).

Physical damage on the edge or 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 are a result of manufacture or post-depositional damage, from those produced by human use. Taphonomic edge damage on flakes at FAO is usually represented 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 (Plates 119–120). Most of these fresh scars have occurred recently, perhaps due to recovery, transportation, bagging and storage. Unintentional abrasion and striations which appear on the surface as a consequence of natural or post-depositional factors are normally not patterned in their distribution and are clearly visible (Plates 116–121). If these features are distributed close to the edge, however, they may mask some use-wear variables.

The acidity of the ground conditions causes etching of obsidian surfaces. Chemical alteration of obsidian surfaces, in the form of numerous, roughly hemi-spherical pits which are unequally distributed on the surface, was observed on all artefacts from FAO (Plates 117–118, 122–125). In some cases, the flaked surface of obsidian exhibits "flowing" aspects (Plate 124). This indicates that some combination of natural 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. As noted in Part 4, the experiments indicate that traces of initial chemical damage can occur in only 22 months (Plates 113B–C). 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, 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.

The 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 (e.g., Plates 122B). This may be explained by the nature, distribution and preservation of residues. These residues are attached and embedded into the surface and could act as protective cover against chemical etching.

Although the degree of chemical damage may vary on each artefact, there is a general relationship between the degree of surface alteration and age. The surfaces of most Late Holocene tools (77.3 %) are low pitted (e.g., Plates 117A–B) and about 16 percent of tools are medium pitted, although there are some tools (6.8 %) with heavily pitted surfaces (e.g., Plate 125). In contrast, tools with heavy (43.6 %) and medium (37.6%) pitted surfaces dominate in the Middle Holocene (e.g., Plates 118A–B, 122A–B). It should also be stressed that there is a relatively high percentage (18.8%) of tools with low pitted surfaces (e.g., Plates 120–121) in this chronological period. These data indicate that the surface alteration may act as an additional chronological indicator for stone assemblages found in similar environmental conditions.

Conclusion

Garua Island possessed a number of highly desirable natural attributes and provided resources which attracted human populations from the middle through to the Late Holocene. The strategic advantage provided by the island's isolation, shelter and safe access to deep water provided by Garua Harbour allowed access to the exchange routes across and around the Bismarck Sea. The abundance of lithic resources in the form of accessible obsidian sources and accessible topography providing arable land for garden plots were all attractive features. The volcanic soils supported diverse plant resources including edible species and timber. Permanent or semi-permanent sources of fresh water associated with Malaiol Stream and springs were present. Coral reefs provided access to rich marine resources including seafood, shells and other materials. The temporal consistency in basic marine and terrestrial resources during the middle and Late Holocene would necessarily result in common features in the dynamic relationship between subsistence strategy, tool-using behaviour and settlement patterns of the island's inhabitants. Chronologically well-defined cultural deposits with numerous obsidian artefacts at FAO provide a unique opportunity to demonstrate the extent to which use-wear/residue data is able to provide reliable information about the interaction between human activities and the natural environment and the changes that occurred over time. Part 6 presents the results of use-wear/residue analysis of the middle and Late Holocene obsidian artefacts from FAO site.

Part 6 Archaeological case study: result of functional analysis

Here, the patterns of wear on prehistoric obsidian tools are investigated in order to determine the extent to which they can establish the types of activities carried out at FAO using approaches outlined in Parts 3 and 4. These functional data provide the background for the comparison between middle and Late Holocene tool assemblages to test a hypothesis of gradual change and cultural continuity in human behaviour proposed by scholars (Torrence, 1992; Torrence *et al*., 2000).

The microscopic analysis of 1395 obsidian artefacts found within seven test pits at FAO revealed 190 tools, including 102 tools from the Middle Holocene assemblage and 88 tools from the Late Holocene assemblage. Following the comparative analysis of experimental tools reported in Part 4, the wear patterns on prehistoric artefacts are grouped according to their association with categories of worked materials as follows: (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 (tubers), (6) non-woody plants (greens which include leaves, stems and grasses), (7) soft elastic materials (skin and fish) and (8) dense, hard materials (shell and clay). Within each use-material category, the types of use actions and the suggested duration of use are presented along with characteristics of the main forms of wear, namely: scarring, striations, rounding, polish, and residues (e.g., Table 6).

The efficiency of identification of wear patterns and tool function depends strongly on the surface preservation of prehistoric artefacts. Although wear patterns on middle and Late Holocene obsidian tools have many common characteristics, there are major differences in the degree of natural alteration of the surface of obsidian tools. The more intensive chemical damage on Middle Holocene artefacts decreases the level of confidence for the definition of some categories of worked material. However, by combining data on types of wear and residues, the mode of use and, to a lesser extent, the material worked can generally be determined even on tools with altered surfaces. In addition, less damaged surfaces of the Late Holocene artefacts with well identified wear attributes can be used for comparison with particular wear patterns on the Middle Holocene tools. For this reason, the presentation of use-wear/residue results in Part 6 is organised beginning with the Late Holocene tool assemblage and followed by the Middle Holocene tools.

In conclusion, the similarities and differences in functional and morphological characteristics of identified tools and their relationship with used resources and activities in the middle and Late Holocene periods are considered.

Processing siliceous soft wood, palms and bamboo

Late Holocene tools. The tools used for processing siliceous soft wood, palms and bamboo at FAO (Tables 6–11, 19) are mainly represented by medium and small flakes with straight or irregular edges in plan view and edge angles between 15° and 55° (Fig. 17). There are six small flakes with thin, (less than 15°) edges and seven large and medium flakes that have an edge angle of more than 55° (Table 21). Some tools are characterised by convex (five artefacts) or concave (three artefacts) edge profiles. Twelve tools have cortical surfaces. 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 (Fig. 17.8). The following modes of use were utilised: scraping, whittling, sawing, drilling, carving, drilling and a combination of scraping/sawing, scraping/whittling, whittling/sawing and cutting/whittling (Table 19). 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.

Scraping. Scraping 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 126A, 127A). The scraping motion is associated with perpendicular and sometimes diagonal striations (Plates 126B, 133A–B). Sometimes the scraping motion is also indicated by flaked striations (Plate 127C). Patches of intensive edge rounding (Plate 127B) and well-developed polishes (Plate 127D) are preserved on the edges.

Whittling. Whittling 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 128–129). Edge rounding varies from light to intensive and has a patchy distribution along the edge and dense striations are mainly diagonally oriented (Plates 128–129, 130). Because of intensive edge damage, a few patches of developed and well-developed polishes are usually observed (Plate 130A).

Sawing. Sawing is represented by small and medium scars with bending and feather terminations continuously or, rarely, discontinuously distributed along the edge (Plates 126A, 131A). 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 131A, 132A). Patches of intensive edge rounding and smoothed polish is generally found on the best preserved edge areas (Plate 131B, 132A). This polish is usually more widespread on one side of the edge than on the other.

Carving. 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 (Fig. 17.3, Plates 134A–B).

Drilling. One large, pointed flake with an irregular longitudinal profile indicates a rotational mode of use which is associated with drilling (Plates 136A–B).

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 126A–B) or on other tools with only one working edge (Fig. 17.1, Plate 128). There is one large flake (Fig. 17.8) with four working edges which were all intensively used for whittling/sawing siliceous plants (Plates 135A–B). In addition to well determined wear patterns, some parts of the working edges preserve resin-like residues (Plate 135C). These residues and their distribution are possibly related to the working of resinous plants, such as breadfruit (*Artocarpus*

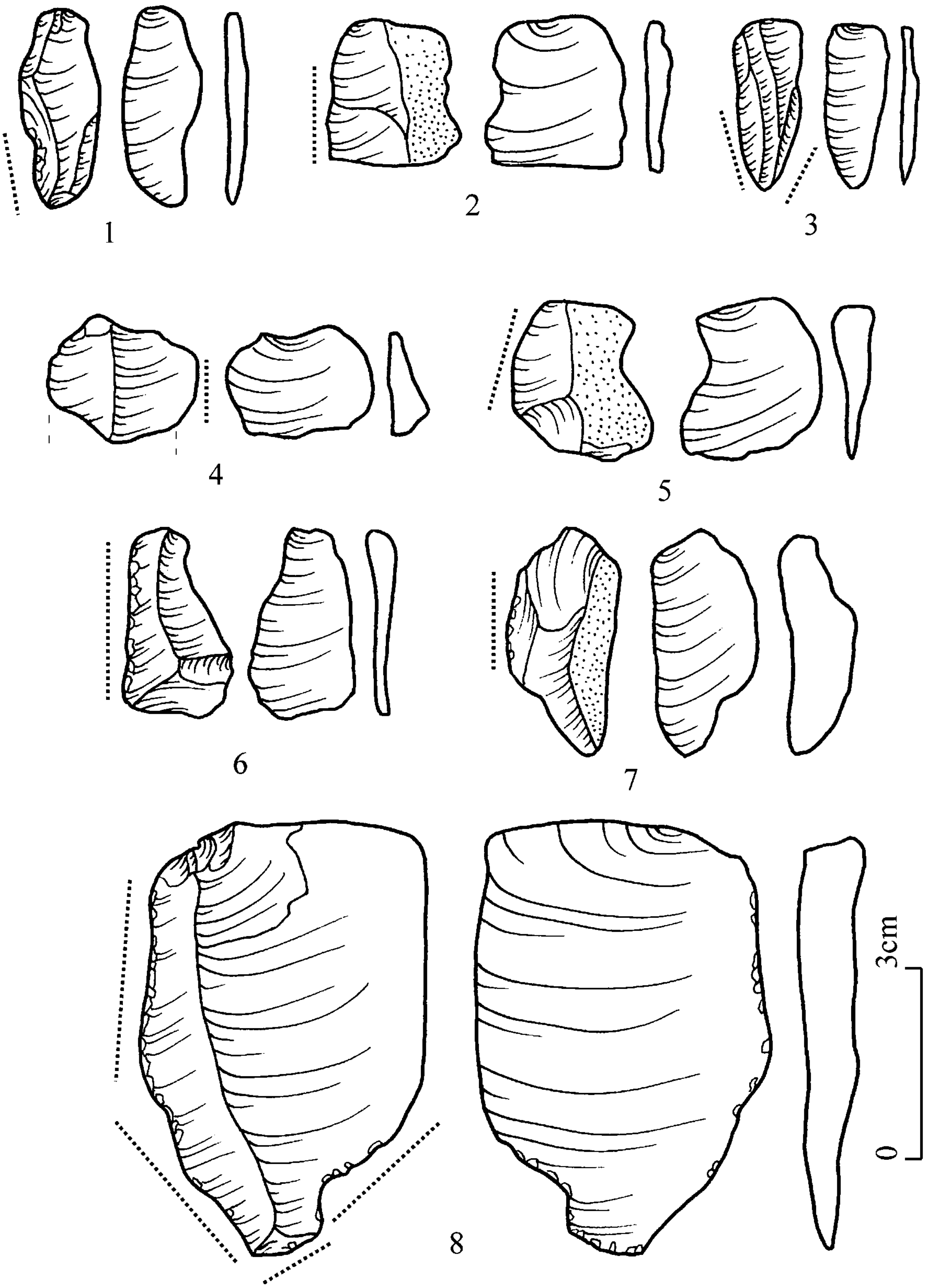

Figure 17. Late Holocene artefacts from FAO used for working siliceous softwood, palm and bamboo.

altilis) or *Calophyllum*, both of 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 phytoliths 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, plant tissue and starch residues (Plate 135D) which were possibly related to the wrapping of the tool.

Residues. The working edges of tools used for processing siliceous soft wood, palms and bamboo often preserved plant tissue (Plates 131A, 133A and 155), some small starch grains (Plates 132B, 135D) and white plant residues (Plate 127A).

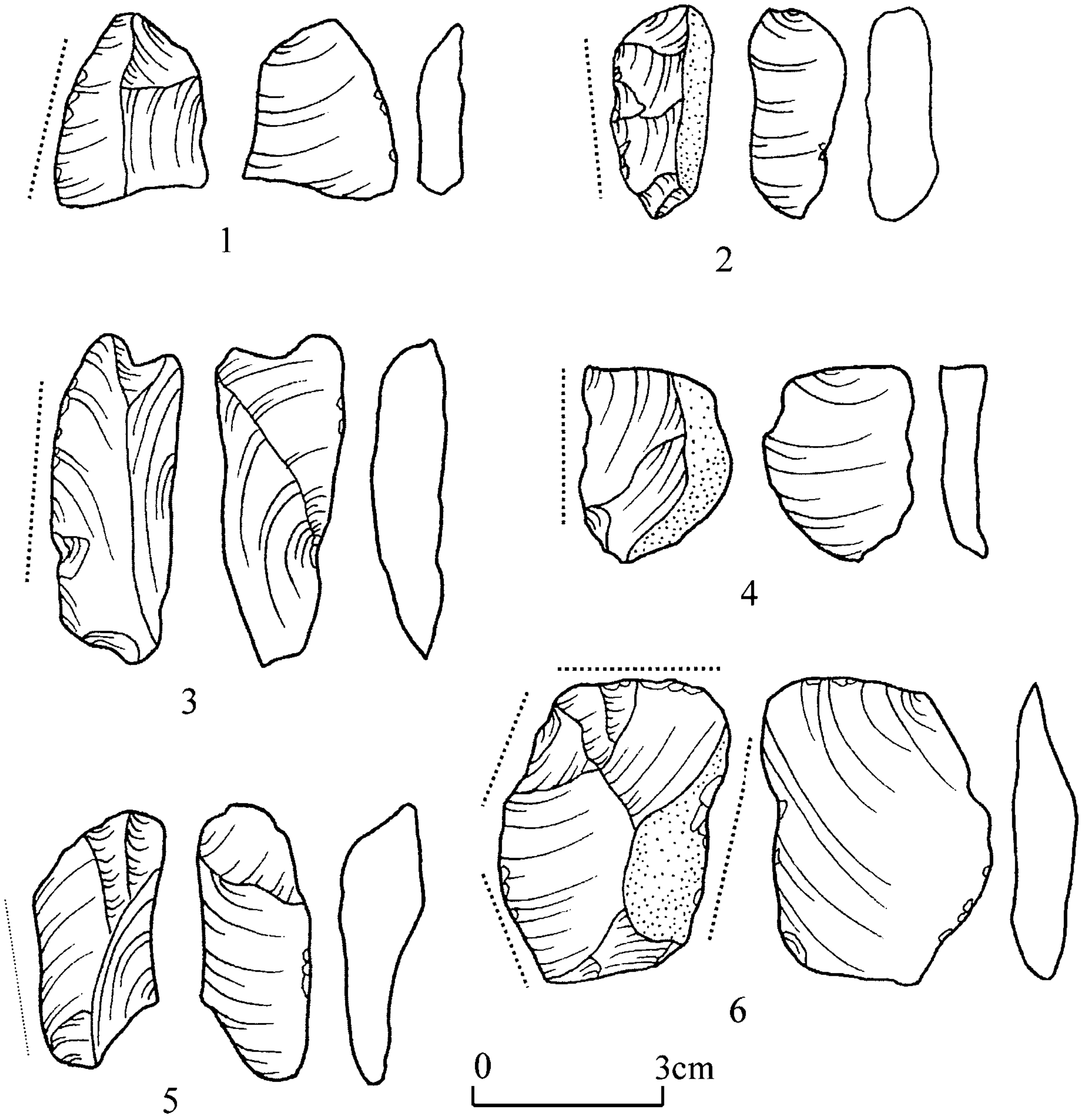

Figure 18. Middle Holocene artefacts from FAO used for working siliceous softwood, palm and bamboo.

Summary. Wear patterns on tools used for processing siliceous soft wood, palms and bamboo are commonly characterised by relatively intensive edge damage consisting of small and medium scars. As a result, scarring causes a patchy distribution of medium and intensive edge rounding and both developed and well-developed polish 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. Well defined striations of sleek, rough-bottomed and intermittent types are common and dense on the surface and are often observed within scars. The wear patterns of this group of Late Holocene tools are comparable with those experimental tools which were used for processing highly siliceous soft wood, palms and bamboo for a short period of time.

Middle Holocene tools. The tools used for working siliceous soft wood, palms 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° (Figs. 18–19). 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 (Fig. 18.6). The preferred modes of use were whittling and sawing/whittling. Sawing, scraping, carving, or a combination scraping/whittling, cutting/scraping and whittling/sawing/scraping, are rare in the assemblage (Table 20).

Whittling. Common features of whittling implements include continuous bending and feather scars (Plates 137A, 144), dense, diagonal striations (Plates 139A–B), medium and intensive edge rounding (Plates 139A–B) accompanied by patches of developed and well-developed polishes (Plates 139B, 144).

Whittling/sawing. Evidence of whittling/sawing actions performed by the same working edge is another common

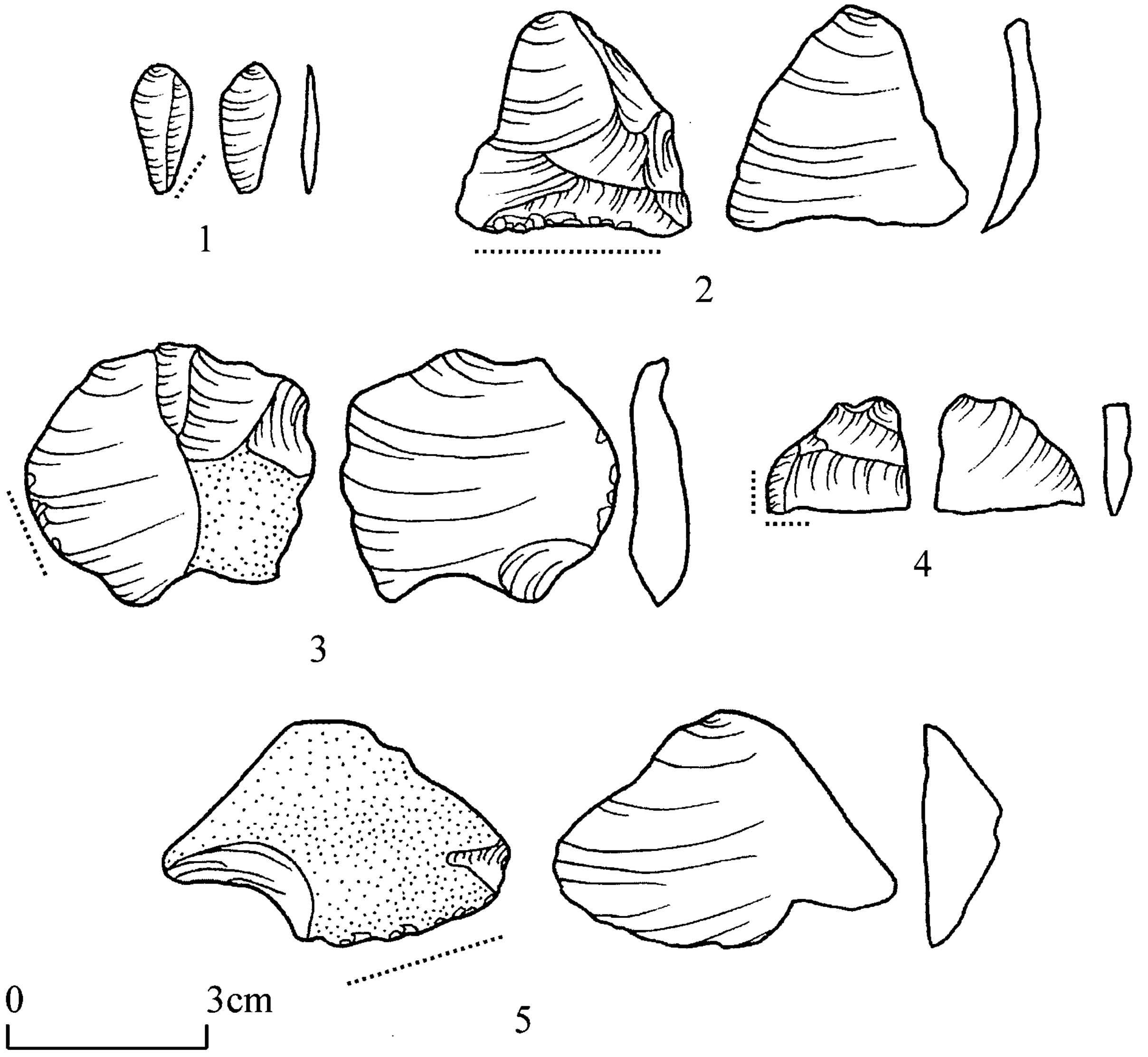

Figure 19. Middle Holocene artefacts from FAO used for working siliceous softwood, palm and bamboo.

feature of Middle Holocene tools (Table 20, Fig. 18.1, Plates 137A–B, 143, 145).

Sawing. Sawing is characterised by small and medium bending and feather scars continuously distributed along the edge (Plates 140–142). Striations are dense and parallel to the edge, shallow and wide, mostly intermittent and rough-bottomed types (Plates 138, 140–142). Medium to intensive edge rounding and well-developed polish have a patchy distribution along the edge (Plates 140, 142).

Scraping. Continuous stepped and bending scars (Fig. 19.2, Plates 146A–B), dense perpendicular and slightly diagonal striations (Plates 146A–B) and patches of intensive edge rounding and well-developed polish (Plate 146A) are observed on the working edge.

Carving. A small flake with a pointed end (Fig. 19.4) has scars, striations, edge rounding and polish (Plates 148A–C) indicating that it was used for carving.

Summary. The Middle Holocene tools which were used for processing siliceous soft wood, palms and bamboo demonstrate similarities in wear patterns with the Late Holocene artefacts. Some tools, however, were intensively damaged by pits resulting in the alteration of striations from sleeks and intermittent types (e.g., Plates 139A–B, 140) to mostly intermittent forms (e.g., Plates 137B, 138, 141), which can sometimes appear as oval depressions (Plate 137C). Despite this, however, some patches of well-developed polish (Plates 137C, 143, 148C) are preserved on the working edge of these tools and this, in conjunction with other wear variables (scarring patterns, edge rounding, striations, residues), allows reliable identification of worked materials and function.

Processing siliceous hard wood and hard palms

Late Holocene tools. There are three large flakes which were used for sawing, scraping and whittling siliceous hard wood and hard palms (Fig. 20.1, 4). The first one has three concave working edges with an edge angle of more than 55°. Two of the working edges of this flake were used for *scraping* (Plate 150A) and the third edge was involved in *sawing* actions (Plate 150B). The second flake (Fig. 20.1)

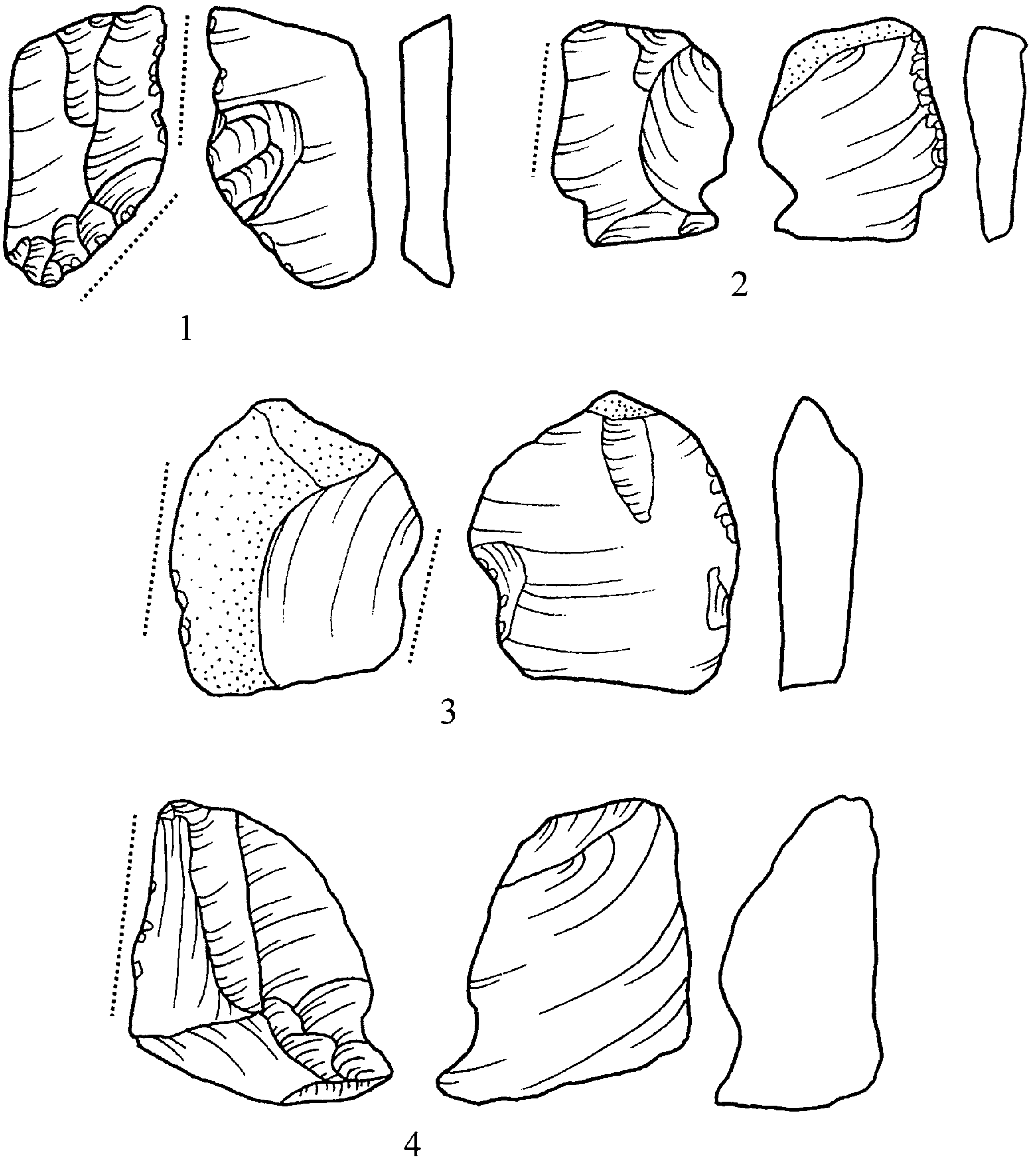

Figure 20. Artefacts from FAO used for processing siliceous hard wood and palm.

on both irregular and straight edges flake has wear patterns indicative of sawing (Plates 149A–C). The working edge of the third flake was used for *sawing/whittling* (Fig. 20.4).

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 (Plate 150B), whereas scraping produced more step scar terminations (Plate 150A). 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 150B). 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 siliceous hard wood and hard palms is the

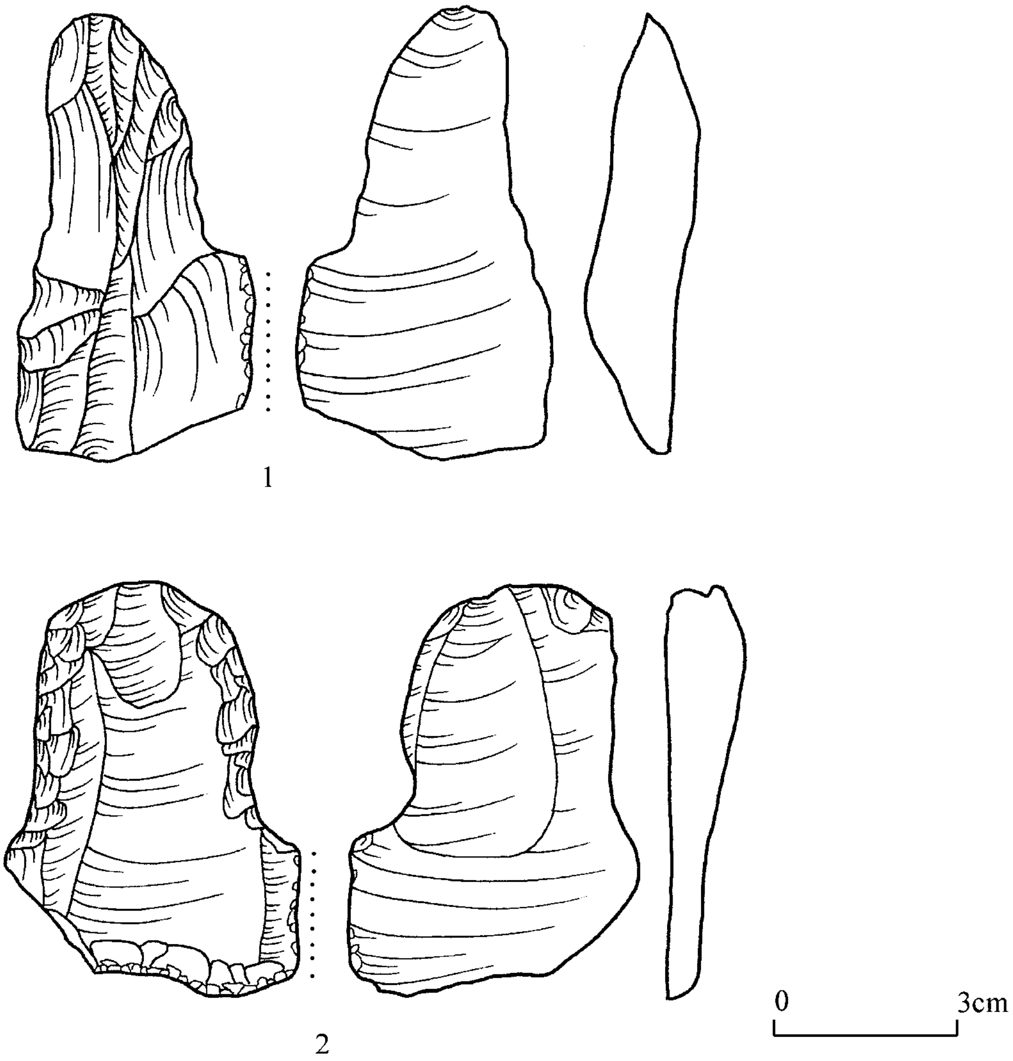

Figure 21. Artefacts from FAO used for processing soft wood and siliceous hard wood and palm.

constant occurrence of isolated, rough, intermittent striations (e.g., Plate 149A) in association with prevalent dense, rough-bottomed and sleek striations (e.g., Plates 149A–B, 150B). The peculiarities of striations on the highly fractured edges in association with patches of intensive edge rounding (Plate 149B) and well-developed polish (Plate 149C) are significant indicators for this category of tools.

Residues. Plant tissue (Plates 149B, 150C) and starch grains are common on these tools.

In relation to the assessment of use-duration of these artefacts, it becomes obvious that most were used for only a short time. As emphasised in Part 4, the formation of diagnostic wear on experimental tools involved in processing highly siliceous wood, palms and bamboo occurred very quickly. Tools can be most effective during the first 5 to 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 period of time.

Middle Holocene tools. A large stemmed tool (Fig. 21.2), six large and two medium flakes (Fig. 20.2–3) were used for *scraping, sawing*, and combined *scraping/sawing and whittling/sawing* siliceous hard wood and hard palms (Table 20). One of the distinctive features of these tools is their thick edge angle (more than 55°) caused by intensive edge scarring (Plates 151A. 152B). 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). In addition to edge scarring, the tools are characterised by patches of intensive rounding and well-developed polish (Plates 151A, 152D) and dense, shallow striations of intermittent, rough-bottomed and rare sleek types (Plates 152A–C). The working edges of these tools preserved plant tissue, starch residues (Plate 151B) and sometimes white residues (Plate 151A), while the hafting area of stemmed tool (Fig. 21.2) retained palm phytoliths (Kealhofer *et al*., 1999) probably derived from the wood handle.

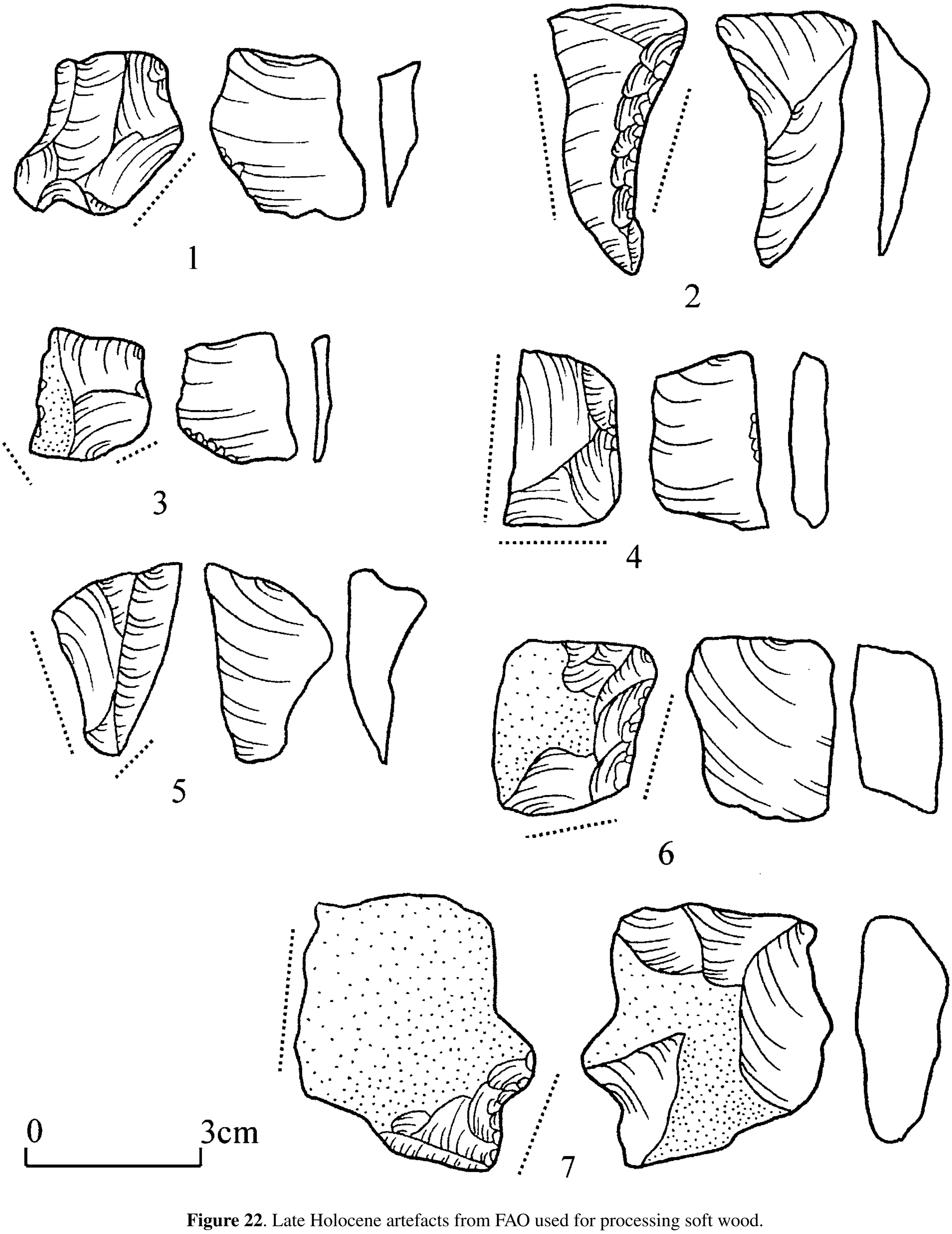

Figure 22. Late Holocene artefacts from FAO used for processing soft wood.

Summary. The highly fractured edges with patches of intensive rounding and well-developed, flattened polish together with dense striations are common wear patterns on tools involved in working siliceous hard wood and hard palms during both middle and Late Holocene. These patterns of use-wear are comparable with those formed on 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 (Fig. 21.2) and one flake broken during use which were probably designed for a more long-term or moderate use but broke prematurely.

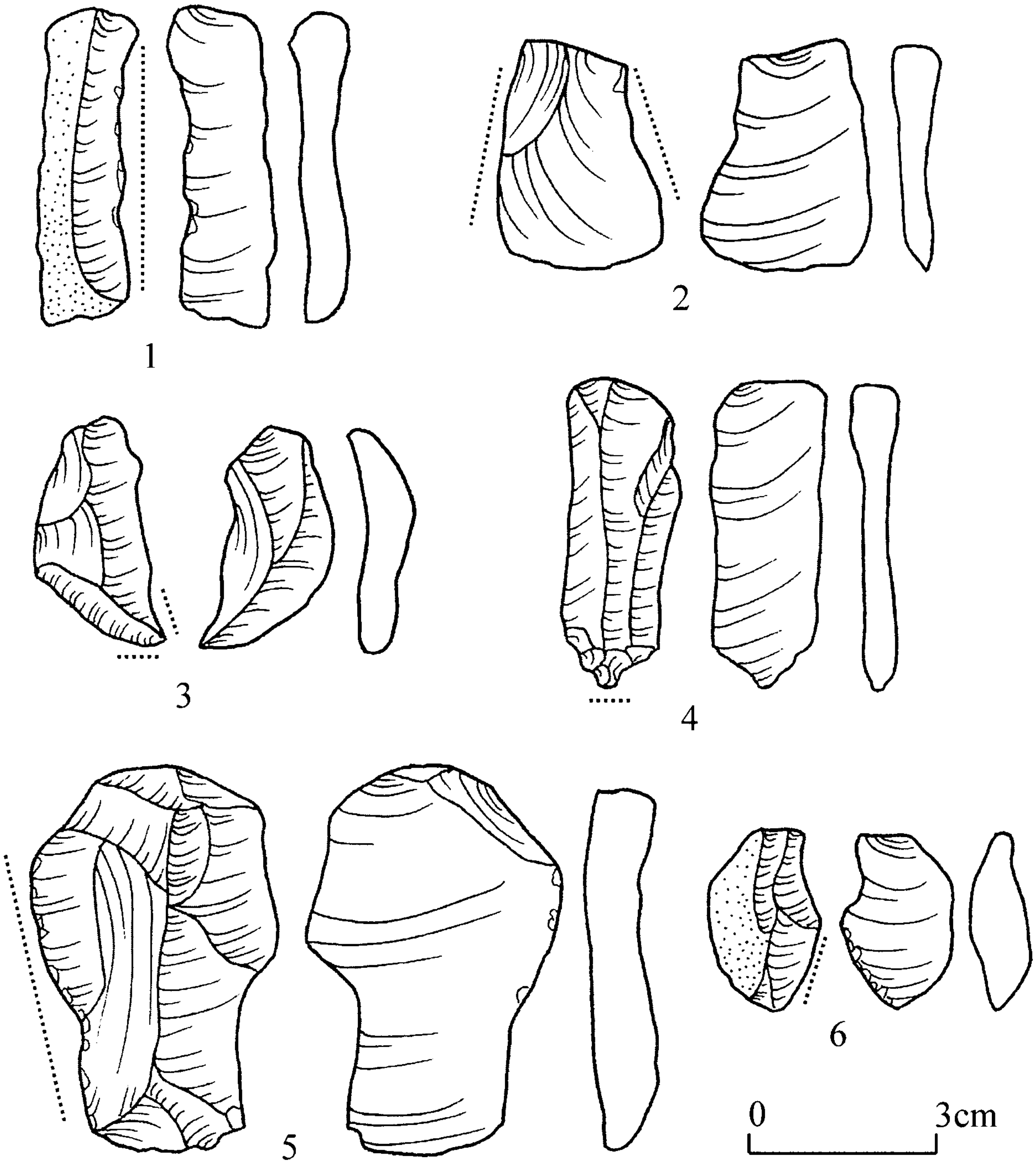

Figure 23. Middle Holocene artefacts from FAO used for processing soft wood.

Processing non-siliceous soft wood

Late Holocene tools. A total of 20 Late Holocene tools were used to work non-siliceous soft wood (Table 19). Medium sized flakes with straight or irregularly shaped edges and edge angles between 15° and 55° were mainly used in this activity (Fig. 22). One tool was broken during use and eight tools have two, three or four working edges. The most common mode of use of these tools is associated with whittling actions (Plates 153–157). A few artefacts were used for carving (Plates 158–160), sawing and scraping activities. There are five artefacts with a single working edge indicating two actions performed by the same edge: scraping/sawing (Plate 161), scraping/whittling (Fig. 22.7) and sawing/whittling (Fig. 22.5, Plate 162).

Whittling soft wood resulted in continuous or discontinuous scarring patterns with bending or feather terminations (Plates 153–154). In addition to scarring patterns, the mode of use is well demonstrated by the orientation of striations and the polish arrangement. Relatively isolated, long, deep sleeks as well as rough-bottomed and intermittent striations generally have a slightly diagonal orientation due to whittling motions (Plates 153–157). Due to the relatively intensive edge damage by scars, some areas with wear have been destroyed. As a result, moderate to intensive edge rounding and developed and well-developed polish mostly have a

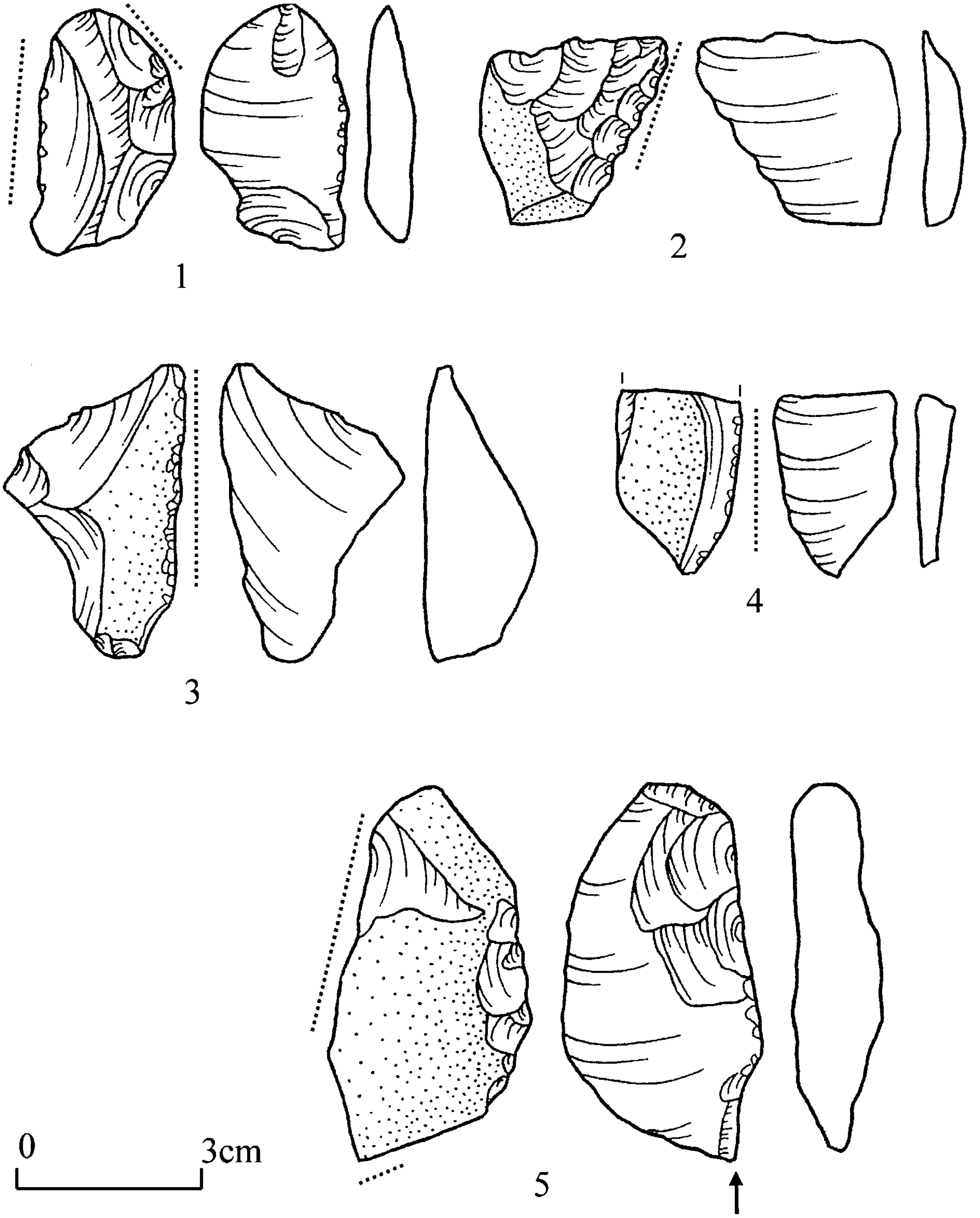

Figure 24. Artefacts from FAO used for processing non-siliceous hard wood.

patchy appearance (Plates 153–155A).

Carving. Mixed scar patterns with stepped, bending and feather terminations on one side of the edge are common on tool edges (Plates 159A, 160A). Carving, as a combination of cutting, scraping and whittling motions, demonstrates relatively complicated patterns of distinctive long and deep striations oriented in parallel, slightly diagonal directions or are crossed (Plates 158–159A–B, 160A–B). Patches of moderate and intensive edge rounding (Plate 158), of developed (Plates 160A–B) and well-developed polish (Plate 159C) restricted to the highest points of the surface microtopography and the scar intersections.

Sawing. Small bending, feather and step scars are distributed mainly in a continuous manner on tools used for sawing actions. Long, deep and well separated, parallel striations (Plate 163), patches of moderate and intensive edge rounding and well-developed polish (Plate 163) are distributed along the edge.

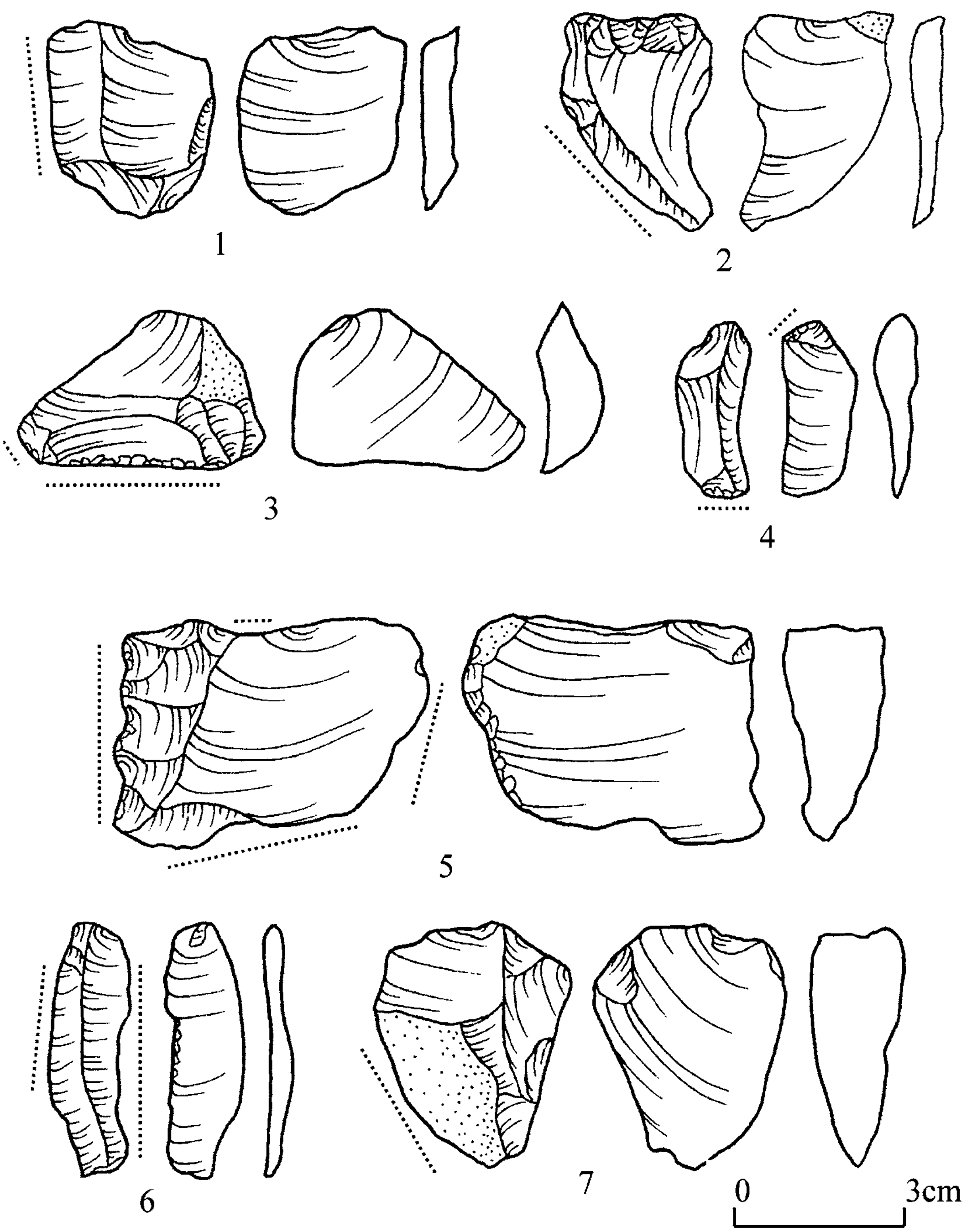

Figure 25. Late Holocene artefacts from FAO used for processing tubers.

Scraping. Mostly stepped and bending scars, perpendicular and slightly diagonal striations, intensive edge rounding and well-developed polish are observed on the working edge (Plates 161A–B).

Residues. There are some tools with plant tissue and starch grains (e.g., Plate 161D).

Middle Holocene tools. Tools used in processing non-siliceous soft wood (22 artefacts) comprised large flakes (14 artefacts) and some flakes of medium size (6 artefacts) with edge angles of between 15° and 55° (Fig. 23, Table 22). Tools with a single working edge are prevalent within this group (19 tools of a total of 22 artefacts). There are only three flakes with multiple working edges (Table 22). The most frequent modes of use are whittling (Plates 164–166) and scraping (Plates 168–169) actions, although carving (Fig. 23.3, Plates 172A–B), sawing (Fig. 23.2, Plate 171), scraping/whittling (Plate 167), scraping/sawing (Plate 170) and whittling/sawing were occasionally performed (Table 19).

Both *whittling* and *scraping* soft wood resulted in continuous or discontinuous scarring patterns with bending, feathered and stepped terminations (Plates 166–167). 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 165B, 167). Striations are relatively isolated, long, deep sleeks, rough-bottomed and intermittent types (Plates 164A–B, 165A, 167, 168–169).

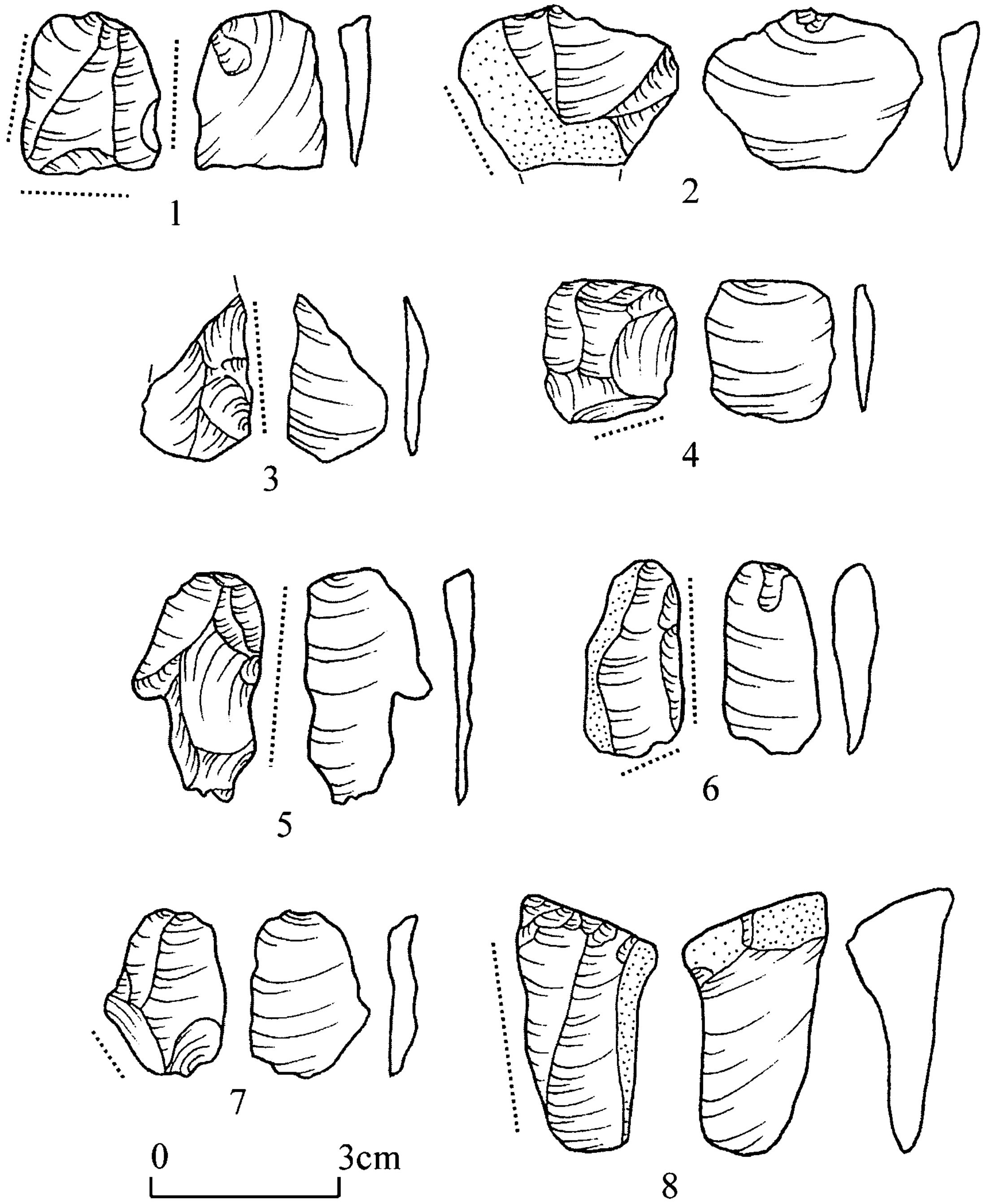

Figure 26. Artefacts from FAO used for processing grasses and leaves.

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 172A–B). Only one tool (Fig. 23.3) was used for carving soft wood for a relatively moderate period of use. All other artefacts were only used for a brief time. *Sawing* motion is indicated by parallel, long and deep striations (Plate 171).

Residues. Used edges often preserved plant tissue (Plate169) and sometimes starch residues. There are some tools with "white" residues (Plate 166) and one tool has black residues which are probably associated with processing resinous woods.

Summary. The processing of soft non-siliceous wood during both the late and Middle Holocene resulted in long, mainly deep striations, well separated from each other despite their relatively high frequency of occurrence. This is contrasted to wear patterns on tools used for working highly siliceous woody plants, which usually produced closely-packed, short, deep and shallow striations with dominate rough-bottomed types (e.g., Plates 127C, 128, 131A). This difference in striations on the tools used for siliceous versus non-siliceous soft wood is well supported by replication 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 palms for 5, 15 and 30 minutes are usually very smooth and more intensively flattened than on woodworking implements used for the same time intervals (e.g., Plates 5–9 and 22A, 23B). 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 to 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.

Processing non-siliceous hard wood

Late Holocene tools. There are three flakes of medium size with an edge angle between 15° and 55° and a fourth with more than 55° edge angle which were used for *scraping* and *scraping/sawing* non-siliceous hard wood (Fig. 24.1, Table 19). Scraping/sawing actions were performed by flakes with multiple working edges (Fig. 24.1). The tools are characterised by intensive and continuous scarring patterns (Plates 173A, 175A–B), patches of pronounced rounding and developed polish (Plates 173A, 174A, 175A) as well as by well-separated, diagonal (Plates 173A–B, 174A) and parallel (Plates 174A–B, 175B), long and deep striations.

Middle Holocene tools. The set includes five large and two medium flakes with thick edges which were used for the working of non-siliceous hard wood (Fig. 24.2–5, Table 20). *Scraping* (Plates 176–177) and *scraping/whittling* (Plates 179A–C) are the prevalent modes of use whilst *whittling/sawing*, and *cutting/whittling* motions (Fig. 24.5, Plates 181A–B) were rarely associated with this category of worked material. Tools with a single working edge are prevalent. One tool (M2124) has two working edges: the straight edge was used for sawing and the concave edge was involved in a scraping action. Signs of intensive use are observed on the tool M1905 (Table 12) with use-wear present on each of its four working edges. Two straight edges of this tool were used in scraping actions (e.g., Plate 179A) and two convex edges are associated with scraping/whittling motions (e.g., Plate 179B).

Wear patterns on the tools are characterised by intensive scarring which is continuously distributed along their edges (Plate 176), patches of pronounced rounding with developed polish (Plates 178, 179A–B) and isolated diagonal (Plates 177–178, 179B), parallel (Plates 180A, D) or perpendicular (Plate 181A), long, deep, rough-bottomed, intermittent and, to a lesser extent, sleek striations. All the tools were used for a short duration of time.

Residues. Plant residues are common on woodworking implements. They are represented by plant tissue and in some cases starch grains (Plates 181A, 177, 179C).

Summary. The working of non-siliceous hard wood results in more intensive edge scarring in comparison with tools used for processing non-siliceous soft wood. The appearance and types of striations and patchy distribution of developed and well-developed polish, however, demonstrate some similarities between tools used for processing soft wood and those used for working hard wood. The patterns of wear on both late and Middle Holocene tools are comparable with those formed on experimental tools used for working non-siliceous hard wood.

Processing non-woody plants: tubers

Late Holocene tools. The processing of non-woody plants was one of the important activities at the site. Seventeen artefacts were associated with this activity out of a total 88 tools (Table 19). Among these 17 tools, 11 were used for scraping, cutting and slicing tubers (Figs. 25, 27.1) and six tools were involved in cutting, slicing and, in rare cases, scraping greens (leaves, stems and grasses) (Fig. 26.1).

There was no preference as to flake size: large, medium and small flakes were equally involved in this activity (Table 21). An exception is a large flake (Fig. 25.5) with four working edges, one of which was resharpened by retouch. This tool was used intensively over a long time for scraping/slicing tubers (Plates 187A–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) (Table 21). 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 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) that 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 (Plate 184A). Scraping actions demonstrate more stepped scars (Plate 186A) 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 189A), medium (Plates 184A, 185A) or intensive (Plates 182A–B) rounding which indicates short-term, moderate or long-term use of a particular tool. This wear pattern is well correlated with polish development: light (Plates 186A–B), developed (Plates 184A–B), and, well-developed (Plates 182C–D, 183A–B, 185A–B, 187B, 188B). 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 182B, 185).

The polished areas contain a few to a moderate number of slightly diagonal (Plates 182B–C), parallel (Plate 188B) or, more often, a combination of crossed striations (Plates 184A, 185A–B). Scraping actions usually produce a number of perpendicular striations (Plates 183A–B). Most striations are clearly separated from each other and are deep and shallow sleeks and intermittent types, although rough-bottomed types may be observed as well.

Residues. Many used tools preserved plant tissue (Plate 187B), starch grains (Plates 184C, 185C) and white/yellow residues (Plate 184B). Of particular interest is a flake with a slightly concave working edge (Fig. 25.3), that was probably used for scraping/slicing over a relatively long period of time.

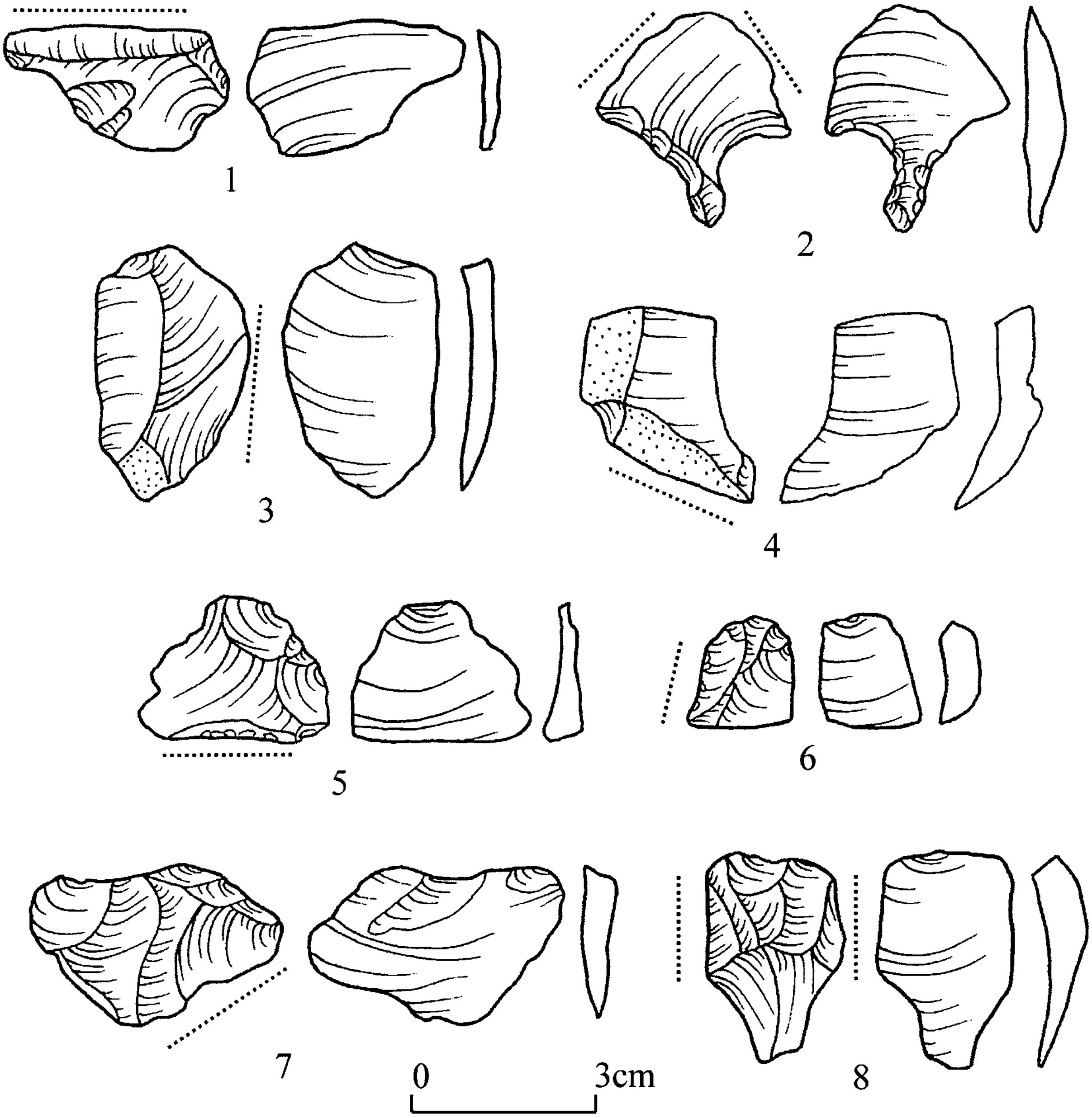

Figure 27. Artefacts from FAO used for processing tubers.

A number of large starch grains preserved on the surface of the tool were preliminarily identified as yam (*Dioscorea*) (Kealhofer *et al*., 1999:543). The microscopic examination of this tool also revealed some needle-like residues on the edge. In addition, phytoliths of bamboo leaves were found on the surface of the 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) and were probably related to the mode of hafting by wrapping.

Middle Holocene tools. Within the Middle Holocene tool assemblage, the processing of 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 were used for cutting, slicing and scraping greens (leaves, stems and grasses) (Table 20).

Tools for working tubers (Fig. 27.2–6) are mostly represented by medium sized flakes with an edge angle between 15°and 55° (Table 22). An exception is a medium sized stemmed tool with a thin convex working edge (Fig. 27.2). Despite its heavily altered surface, some spots on the edge preserved identifiable wear patterns (Plates 194B–D) which are comparable with wear variables on both Late Holocene tools with well preserved surfaces (e.g., Plates 182B–D) and experimental tools (e.g., Plates 77F, 78B). The edge and surface of the stem have some spots with light polish and isolated striations which indicate that the tool was probably hafted into a wood handle (Plate 194E). This interesting evidence of hafting wear may also 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 194F).

Tools do not reflect user preferences in the shape of the edge: straight, irregular, convex, and, concave edges were almost equally used to undertake tasks (Table 22). There

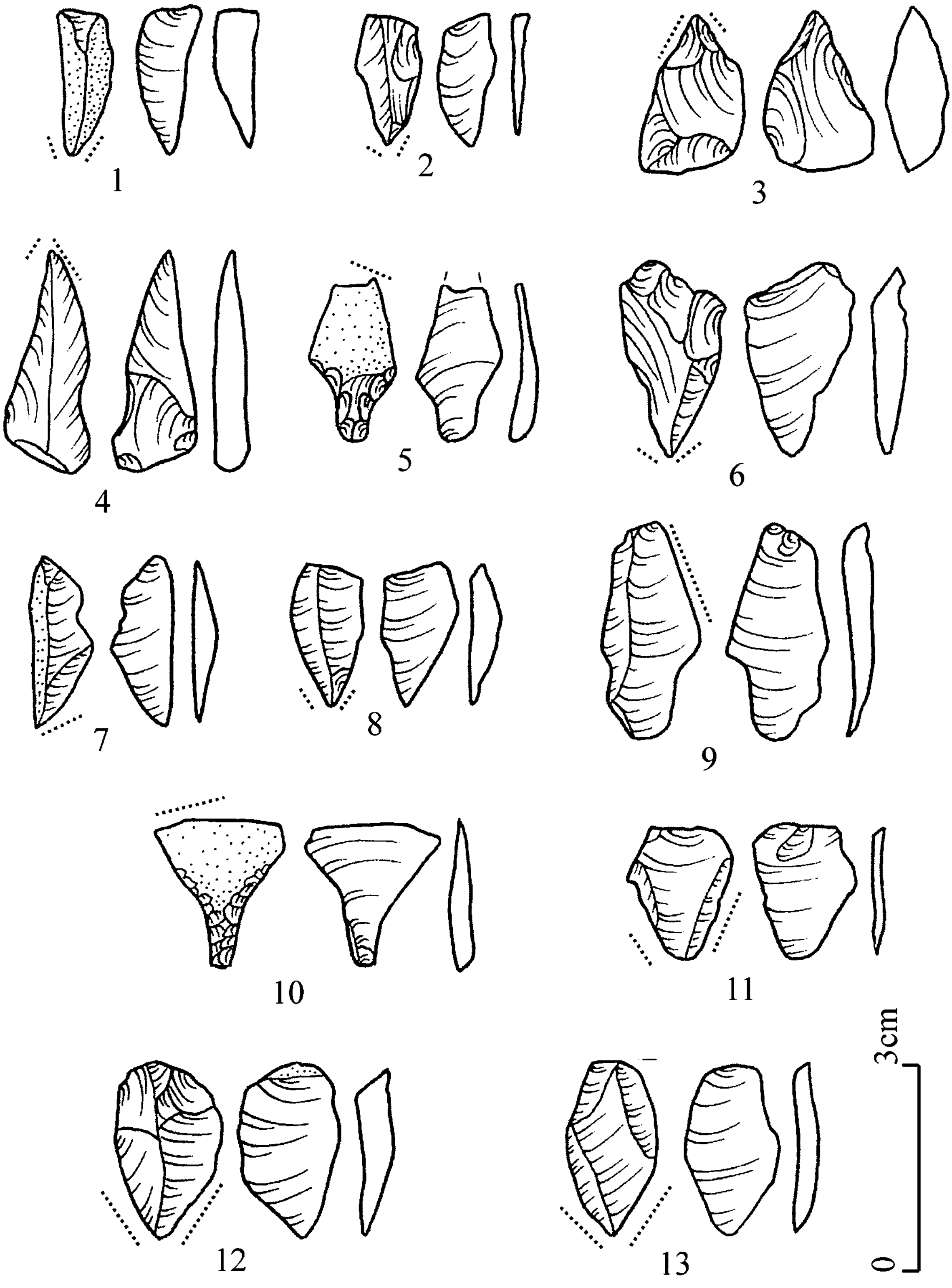

Figure 28. Artefacts from FAO used for working skin.

are no tools with multiple working edges in this group and only three artefacts have acute edge angles (less than 15°).

Tools used to work relatively soft plants, like tubers, exhibit small or very small bending, feather and, rarely, step scars. They are discontinuous or, in the case of intensive use, are distributed continuously along the edge (Plates 195A, 198A–B, 199A). The working edges are characterised by some light rounding (Plate 196A), but more often by medium and intensive rounding (Plates 199A, 200A). As with the edge rounding, light (Plate 196A), developed and well-developed polish (Plates 194C–D, 199B, 200B) may have a relatively continuous distribution. A small or moderate number of striations, clearly separated from each other, may have slightly diagonal (Plates 194B, 196A), parallel (Plate 199A) and perpendicular orientations (Plate 194C), or, they can cross each other (Plate 195A) thus reflecting variable modes of use.

On the basis of both diagnostic wear patterns observed on the tools and comparative experimental data, it is possible to suggest that most of the tools from the Middle Holocene layer reflect their use in processing tubers for moderate time periods. The determination of function of these tools is also supported by the frequent presence of starch residues on the working edges (e.g., Plates 196B, 197A–B). Plant tissue and white residue (e.g., Plate 195B) are also common. Phytoliths found in the hafting area of artefact M367 suggest that this tool was wrapped during use (Kealhofer *et al.*, 1999:543).

Summary. In general, the set of wear variables observed on tools which were used for processing non-woody plants such as tubers 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 slightly merging polish distributed relatively continuously along the edge. These variables are comparable with experimental data which also demonstrate that a diagnostic combination of wear variables can form on tools after more than 30 minutes of use. It is reasonable to propose that tools for processing tubers were used for much longer time periods than the woodworking implements because most of the tools examined have identifiable wear variables. The wear patterns on only three flakes from this category of tools are associated with short-term use, while nine tools indicate moderate use, and five artefacts represent long-term use.

Processing non-woody plants (greens): leaves, stems and grasses

Late Holocene tools. Wear patterns on tools used for working greens by cutting, scraping, cutting/slicing, scraping/slicing and cutting/splitting (Fig. 26.1, Table 19) 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 (Plates 189A, 192–193). Secondly, for greens a few to a moderate number of striations of shallow, sleek and rough-bottomed types are prevalent and, much more rarely, intermittent types may be present. Striations have mainly slightly diagonal orientation (Plates 189–193) although some parallel (Plate 189A) or crossed (Plates 192–193) can be seen. Finally, the edges are usually very slightly or slightly rounded (Plates 189A, 192–193). The surface alteration by polish on tools is less extensive for greens and the polish does not have a merging appearance (Plates 190, 192).

Middle Holocene tools. Medium flakes with straight and acute edges (Table 22) were used to work greens by cutting, cutting/slicing and scraping/slicing (Fig. 26.2–8, Table 20). The acute edges of the tools preserved small scars and microscars with bending and feather terminations which are often discontinuously distributed along the edge (Plate 201A). Long and occasionally short, deep, sleek and rough-bottomed striations, accompanied by some intermittent types, are well separated from each other and of a moderate number (Plates 201A, 202A, 203–204). A slightly rounded (Plate 201) or medium rounded (Plates 203–204) edge often corresponds with light to developed polishes (Plates 202A, 203). The polish is less extensive and rarely has a merging appearance. Residues on the tools include plant tissue embedded into scars (Plate 201), starch grains (e.g., Plate 202B) and, sometimes, white residues (e.g., Plate 202A).

Summary. The late and Middle Holocene tools used for processing non-woody plants, such as leaves, stems and grasses, have common features in scarring patterns, types of striations and polish development. The comparison between wear attributes on experimental tools which were used for cutting and whittling fern (Plates 58A, 59), cutting croton (Plates 62–64), cutting/slicing pandanus leaves (Plates 68–71) and scraping/slicing coconut meat (Plates 73–74) and the artefacts from the FAO site indicates similarities in wear patterns. These similarities make it possible to suggest that some prehistoric tools could have been involved in the performance of tasks similar to those for which experimental tools were used in processing greens.

Processing soft elastic materials: skin and fish

Late Holocene tools. The use-wear/residue analysis undertaken revealed that a relatively small number of flakes (8 samples) were involved in processing soft elastic material (Table 19). *Piercing and cutting skin* was performed by small and medium flakes with pointed tips (less than 15°) formed by thin, straight or irregular edges (Fig. 28.1–4, Table 21). As a result of use, two of these tools have snapped tips.

All of these tools exhibit a common pattern of use-wear. Small scars and microscars are discontinuously distributed along the working edge. In some cases, patches of continuous small scars are observed (Plates 205, 207A). The profiles of the working edges are slight to medium rounded or are relatively intensively rounded (Plates 205, 206B, 207A). Smooth, developed and merging polish is present as a thin line along the edge (Plates 206B–C, 207B). Some isolated, deep and shallow sleek striations and, more rarely, rough-bottomed and intermittent types are orientated slightly diagonally (Plates 205, 206A, 207A) or are perpendicular to the tip (Plate 206B), reflecting penetrating, rotating and cutting (Plate 206A) motions.

Residues. Some blood-like residues are preserved on two tools (Fig. 28.3–4). These dark-red residues (Plate 206C) gave a weak positive reaction to Hemastix (a presumptive blood test) (Loy, 1983:1269) indicating the presence of 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 84–85).

It is possible to suggest that the tools identified as having been used for piercing and cutting soft skin which also preserved mammal blood residue could have been utilized in the performance of some special tasks related to the human body or soft animal skin (Kononenko & Torrence, 2009). From ethnographic records of 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, and circumcision (Specht, 1981).

There are three flakes of medium size with edges of angle between 15° and 55° which were used for *gutting/cutting fish* (Fig. 29.1–3). 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 208A). These scars were apparently formed as a result of contact with fish bone or scale. Usually medium rounded edges (Plates 208A, 209B) 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 (Plate 208B).

Smoothed and polished areas are associated with parallel and slightly diagonal striations that are often accompanied by randomly oriented intersecting striations (Plates 208A, 209B). They are mostly represented by isolated long, deep and rough-bottomed or sleek types, although some intermittent striations can be observed as well (Plates 208A, 209A). These distinctive wear patterns on the archaeological flakes are compatible with those produced on experimental tools used for processing fish (e.g., Plates 90–91).

Residues. In addition to wear features, distinctive residues on fish working tools were observed. They include blood-like residue (Plates 208B–E, 209A, C–D), from which blood cells with nuclei were extracted (Plate 208F), animal tissue (Plates 209E–F), and white, black and rainbow coloured residues (Plates 208A, C–D, 209A, 209C–D). Similar types of residues and blood cells with nuclei are also preserved on experimental tools used for gutting/cutting fish (e.g., Plates 90B, 90F, 105E–F).

Middle Holocene tools. 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) The *piercing, cutting and shaving of skin* is represented by two small stemmed tools, one blade-like flake, seven medium and four small flakes (Fig. 28.5–13). Most of the flake tools have pointed tips formed by acute straight-sided edges (Table 22).

The acute edges of tools involved in this activity usually preserve microscars and, rarely, small scars which are discontinuously distributed along the edge (Plates 210, 214A, 215). The edge profile is slightly rounded (Plates 210A–B, 213A), or medium rounded (Plates 211A, 212A, 214A) and is associated with light and developed merging polish (Plates 210C, 211B). A small number of isolated, deep and shallow sleek striations (Plates 210A–B, 211A) and, rarely, examples of rough-bottomed and intermittent types (Plates 213A–B) are present. Striations are oriented slightly diagonal or perpendicular to the tip and indicate penetrating, rotating and cutting motions.

One small stemmed tool (Fig. 28.5), which was used for cutting/piercing skin, has a partly broken working edge with preserved dark-red and rainbow-coloured residues embedded into its surface and which has been altered by polish (Plates 212A–B). The stem of this tool has some spots with striations, plant tissue and starch residues (Plates 212C–D) indicating that the artefact was probably hafted in a wooden handle. The second small stemmed tool with a straight and acute edge (Fig. 28.10) was probably wrapped, allowing it to be held, and used for cutting very thin and soft skin.

Residues. The tip of one piercing tool (Fig. 28.7, Plates 210A–F) preserved a spot of black residue which changed colour under higher magnifications. According to Fullagar (Fullagar, R. pers. comm., 23 May 2006) this residue deposit might represent a mixture of charred plants which could be used for pigments during piercing and cutting of skin. Some blood cells were extracted from this tool (Plate 210F). Similarly, some spots with red residues on the tool M2129 (Fig. 28.12) may indicate a mixture of blood and a bright red mineral like ochre (Plate 214B). The residue gave a weak positive reaction to *Hemastix*™ (a presumptive blood test).

There are two flakes (one medium and one small in size) with acute edges which were probably used for *shaving* the human face (Figs. 28.11, 13). A few bending and feather microscars are distributed in a discontinuous fashion on one side of the edge (Plates 216D, 217A–D). A thin line of light edge rounding (Plates 217A, C–D) and very rare spots of smoothed, merging, light and developed polish are visible under high magnifications (Plates 216B–C). A few perpendicular and slightly diagonal long sleeks and rough-bottomed striations can be observed (Plates 217A–D).

Residues. Residues similar to skin tissue, as well as red, white and black residues are observed on some spots on the edge (Plates 216B–F, 217D–F). Similar residues and wear variables were formed on experimental tools used for shaving human faces (e.g., Plates 87C, 88B–C).

Large and medium sized flakes (seven samples) are identified as tools used for *gutting/cutting fish* (Fig. 29.4–9, Table 20). Flakes with a single working edge were preferred for this function (Table 22). The 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 along the edge (Plate 218A, 220A, 222A). Medium rounded edges (Plates 218A–B, 220B) preserved light and developed polish that extend from the higher peaks of microtopography into surface depressions (Plates 219A, 222B). Parallel (Plate 220A), slightly diagonal (Plate 218B) and intersecting striations (Plate 222A) reflect a relatively wide range of motions. Striations are mostly isolated, long, deep rough-bottomed, intermittent and sleek types. Sometimes striations can be observed within scars (Plate 219B). These distinctive wear variables are comparable with wear patterns observed on experimental tools which were used for processing fish (e.g., Plates 90–91).

Residues. Residues preserved on fish working tools include animal tissue, blood-like, rainbow-coloured and white residues (Plates 218B–D, 221B, 222B). Similar types of residues are also observed on experimental tools used for gutting/cutting fish (e.g., Plates 90E–F).

Summary. Wear patterns and type of residues on skin and fish processing tools from the Late Holocene are similar to those from Middle Holocene. The comparison of wear and residues on this group of tools with experimental tools used for piercing and shaving skin and gutting/cutting fish demonstrates many common features that support the functional interpretation of artefacts. According to 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.

Processing dense, hard materials: shell and clay

Late Holocene tools. Despite its heavily pitted surface, one large flake (Table 21) with an edge, which is irregular in plan view, was probably used for *sawing* dense, hard material, probably shell. The thick working edge is intensively

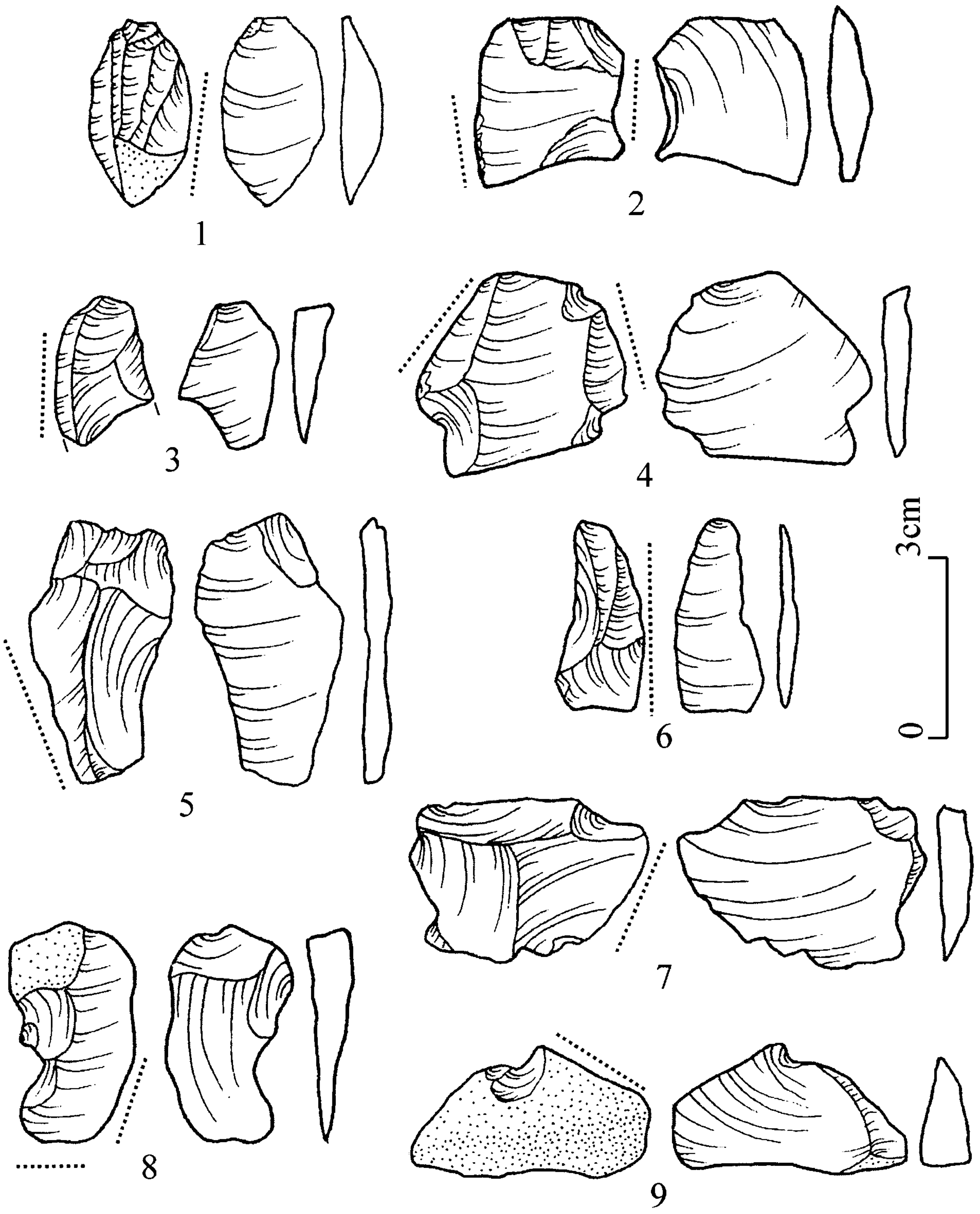

Figure 29. Artefacts from FAO used for processing fish.

damaged by bending and rare feather scars with poor defined boundaries because of the crushing effect (Plate 223A). Dense, shallow and, rarely, deep, rough-bottomed and intermittent, short striations are oriented parallel to the edge (Plates 223A–C). The edge is intensively rounded (Plates 223A–B). The surface is covered with striations having been flattened by well-developed polish, but this polish does not extend into the surface depressions (Plates 223D–E). Some white coloured smears are embedded into the tool surface of the working edge (Plate 223F). This pattern of wear and residues is similar to that observed on experimental tools used for sawing shell (e.g., Plate 93B).

Middle Holocene tools. There are 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 (Fig. 12.5–6, Table 22). The working edge of one of the tools involved in *scraping shell* (Fig. 12.6) is severely damaged by bending and step scars (Plates 224D–F). The edge profile is rough and intensively rounded (Plates 224B–C) and exhibits well-developed and flattened polish (Plates 224A, C, E–F). Dense and mainly shallow and short, rough-bottomed, intermittent and, rarely, sleek striations are slightly diagonal to the edge (Plates 224A, D). White coloured residues are embedded into the surface which is altered by polish (Plates 224B–C). Both the wear pattern and residue on this tool are similar to those observed on the Late Holocene shell working tool (Plate 223) and experimental tools used for processing shell (e.g., Plates 94–97).

The second large flake has some peculiar wear patterns and was probably used for *scraping clay* (Fig. 12.5, Table 22). As with the shell-working implement, the edge of this tool is extensively damaged by small, step and bending scars with poorly defined boundaries (Plate 225A). The intensively rounded edge profile contains patches of well-developed polish which, in contrast to the polish on the shell-working tool, has a more smooth and flattened appearance (Plates 225B–D). There are also some differences in the types of striations. They are mostly long, shallow sleeks with rare occurrences of rough-bottomed and intermittent types (Plate 225A), indicating the working of more abrasive material than shell. White and yellow coloured residues are embedded into the surfaces (Plates 225C–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 98–99).

Summary. Both shell working tools and a scraper for clay are characterised by thick, intensive edge damage, well-developed polish and dense striations. This wear pattern is easy to recognise within tool assemblages. Experimental tools used for working shell and clay produce similar wear patterns during first five to 10 minutes. After 15 minutes of use, the efficiency of the tools dramatically decreases and they are discarded. This suggests a short-term use of the late and Middle Holocene artefacts which were involved in working shells and clay.

Comparative analysis

The results of use-wear/residue examination of obsidian tools clearly show that similar categories of plant and non-plant materials, with the exception of clay, were used during both middle and Late Holocene occupations. There are, however, some minor differences in the intensity of use of particular materials, the way in which they were processed and in the selection of tools used in the performance of particular tasks. These differences become apparent when the percentages of tools involved in a range of activities in the middle and Late Holocene are compared (Table 23). Two artefacts (Table 17: M1934, Table 18: M2125) which showed kinds of wear, but did not have the reliable combination of main wear variables necessary for a functional interpretation, are excluded from the comparison. In addition, there are some difficulties in interpreting small proportional differences in tool classes because of the sampling issue: the percentages of tools used in each category of worked material might have changed if artefacts from all excavated test pits at the site would have been microscopically examined. This means that the number and percentage of tools used to compare particular activities at FAO represent a general trend showing the similarities and differences in human behaviour over time.

The data presented in Table 23 show that a much larger proportion of Late Holocene tools at FAO were used in woodworking activities (69.3% versus 55.9%) than in the Middle Holocene assemblage. Most of the Late Holocene implements were involved in processing siliceous soft wood, palms and bamboo (39.8%) and a much smaller percentage of tools (22.7%) was used for working non-siliceous soft wood. Species of hard wood, both siliceous and non-siliceous, were used relatively rarely (6.8%). In contrast, Middle Holocene tools indicate their association with working mainly non-siliceous soft wood (21.6%) and, to a lesser extent, siliceous soft wood palms and bamboo (18.8%). In addition, hard siliceous and non-siliceous species of wood were more widely used during the Middle Holocene occupation (15.8%) than in the Late Holocene period.

In both periods woody species of plants were worked by tools using similar modes: whittling and scraping, and, to a lesser extent, sawing and carving (Tables 19–20). Carving soft wood, palms and bamboo, however, was more widely undertaken during the Late Holocene (7.9% versus 2.9%) than it was in the Middle Holocene period.

Most woodworking implements in both Late Holocene and Middle Holocene periods were used for a short period of time: 63.6% and 59.8% accordingly. 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% of tools have multiple working edges compared to only 19.3% of Middle Holocene tools. This frequency pattern demonstrates the more expedient and less intensive use of Middle Holocene flake tools (Tables 21 and 22).

A distinctive morphological feature of Middle Holocene woodworking implements is the intentional selection of large flakes for the performance of tasks. These comprise 48% of a total 102 tools. In contrast, only 26.1% of tools were large flakes in the Late Holocene assemblage and most tools were medium (42%) and small (31.8%) sizes (Tables 21–22). The selection of large flakes with strong and relatively thick edges during the Middle Holocene probably related to the wider use of species of hard wood in this chronological period in comparison with the Late Holocene.

There is an obvious trend indicating that, in contrast to the Late Holocene period, a greater number of Middle Holocene tools were involved in the processing of non-woody plants (tubers and greens): 23.5% versus 19.3% in the Late Holocene tools (Table 23). Tubers in both periods were processed in the same way: by scraping, scraping/slicing, and, cutting/slicing (Tables 19–20). Tools from both the late and Middle Holocene periods had a moderate duration of use (Tables 21–22). However, only the Late Holocene set includes tools with multiple working edges and evidence of long-term use (Table 21). This suggests that Middle Holocene tools were used more expediently in this activity in comparison with those of 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 from a Kombewa flake which was used as a scraping/slicing implement (Table 13). 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 21).

A higher percentage (17.6%) of Middle Holocene tools was involved in processing soft elastic material than in the Late Holocene period (9.1%). Piercing and cutting skin in both chronological periods was accomplished by small and medium sized flakes with thin and sharp edges which were only used for moderate and, rarely, short time periods (Tables 21–22). The shaving of human faces is only detected in the Middle Holocene tool set (Table 20). The difference between the two chronological 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 (3.4% for the Late Holocene tools and 6.9% for the Middle Holocene tools) (Table 23). Gutting/cutting fish during the Middle Holocene 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 are characterised by relatively sharp but stronger edges (between 15°and 55°) and show signs of a moderate duration of use in both Late Holocene and Middle Holocene periods (Tables 21–22).

Working dense, hard material, such as shell, was accomplished by large flakes in both chronological periods. The wear patterns indicate that a thick edge angle (> 55°) apparently resulted from their short-term use.

Both middle and Late Holocene assemblages demonstrate the preference for flake tools (76.4% and 81.8%), although a few implements in the Middle Holocene assemblage are represented by blade-like flakes and stemmed tools (Table 22). There are numerous tools with cortex preserved on the dorsal surface: 39.2 % Middle Holocene and 33 % Late Holocene (Tables 21 and 22). This suggests that, first, complex technological strategies were not involved in the manufacture of the flake tools, with the exception of the rare stemmed tools in the Middle Holocene assemblage. Secondly, the selection of flakes to perform a particular activity was based on the morphology best suited for the specific task (e.g., size of flake, edge shape and edge angle). These facts, together with their mostly short-term use (59.8 % Middle Holocene and 63.6 % Late Holocene) (Tables 21 and 22) indicate the obviously expedient manufacture and use of tools in both chronological periods and this contrasts with the proposal that expedient technology is characteristic of Late Holocene assemblages (Torrence, 1992:120–121).

It is apparent from the comparative analysis of both functional and morphological data that the set of activities undertaken and resources utilised at FAO were generally similar for the middle and Late Holocene periods. A slight change may be observed in the proportion of tools used for processing some materials (e.g., a wider use of hard wood, a higher percentage of tools for processing non-woody plants and soft elastic materials in the Middle Holocene) and also in some technological and morphological preferences in the selection of obsidian flakes for the performance of specific tasks (e.g., preferable use of large flakes for woodworking activity in the Middle Holocene). The interpretation of these data addresses a number of questions about prehistoric human behaviour and these questions will be considered in Part 7.

Part 7 Reconstructing past behaviour

This section considers the broader implications of the study. First, using functional data and available archaeological information, ecological evidence and ethnographic analogies, various types of daily activities, intra-site structure and settlement patterns during the middle and Late Holocene are reconstructed. Second, the hypothesis of changes in mobility and cultural behaviour associated with the arrival of new settlers with Lapita pottery is explored. Finally, the implications of these research results for the application and further development of functional studies are reviewed.

The functions of obsidian tools at FAO are associated with two basic spheres of human endeavour: subsistence and domestic (or craft) activities (Kononenko, 2007). The first category, subsistence, includes usually all those artefacts that were used for food procurement and food processing (e.g., Andreeva *et al.*, 1986:149–150; Fullagar, 1994:213; Hong & Kononenko, 2005; Juel Jensen, 1994:48, 166; Kononenko, 1987:160, 2001, 2003:104–108, 2008b; Kononenko & Kajiwara, 2003:133–139). Artefacts associated with domestic activities comprise a functionally diverse group of tools which were primarily employed in the manufacture and maintenance of other items made from a variety of plant and non-plant material (e.g., Aldenderfer, 1991; Emery & Aoyama, 2007; Juel Jensen, 1994:48). Domestic activities also include some social activities which can be implied in the light of the establishment of specific uses of stone tools. Tools used in domestic activities were not directly associated with subsistence, although many could potentially have been indirectly used for food procurement and food processing (for example, flakes used for scraping/cutting soft wood, palms, bamboo to produce knives for cutting taro or fishing spears). Unfortunately, use-wear/residue analysis can only identify use-action and use-material but cannot precisely identify the type of item produced by the stone tool. This objective limitation of the functional assessment of tools necessitates that use-wear and residue data be employed at a generalised interpretational level supported by archaeological, ecological and ethnographic information (Boyd *et al.*, 2005; Fullagar, 1994; Juel Jensen, 1994:164; Lentfer & Torrence, 2007; Parkinson, 1999; Specht, 1981). This means that changes between middle and Late Holocene subsistence practices and domestic activities can be inferred on the basis of the nature and type of activities at FAO reconstructed by the functional data on obsidian tools.

The spatial distribution and density of tools, actually identified by use-wear/residue analysis, and of production debris varies significantly in different parts of FAO and suggests the existence of discrete activity areas. This observation allows further investigation into each period of how activities were undertaken, and, whether they were carried out separately or combined. It also allows the identification of some general trends in the internal structure and function of the site (Carr, 1991; Keeley, 1991; Kirch *et al.*, 1991; Kooyman, 2000:133; Kroll & Price, 1991; O'Connell *et al.*, 1991; Odell, 1980). The consideration of the location of FAO in relation to other contemporary sites on the island, and its surrounding 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 & Stevenson, 2000).

Archaeological sites on Garua Island yielded very little organic material. Consequently other sources of information had to be found to reconstruct, first, resource availability; second, the ways in which resources were procured and used; and finally, the extent to which obsidian tools were involved in processing those resources. The use of ethnographic and ethnoarchaeological information in 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 & Dye, 1979; Roscoe, 2005; White, 1967; White & Thomas, 1972). It is also argued that these analogies from external sources can be used on a generalised level to assist archaeological inferences if there is a link with the identifiable technological aspects of human activities (e.g., Andrefsky, 1998:6; Conte, 2006:242–244; Gosden, 2005:95–97; Sillitoe, 1988:11; Sillitoe & Hardy, 2003; Terrell, 2003:70–74; White & Thomas, 1972:276). The making of analogies with recent behaviour are reasonable because the basic properties of tropical environments, the physical properties of raw materials used and the physical needs and capacities of humans restrict the number of potential technological solutions. This proposition provides the basis for the attempts to use available ethnographic data from the Pacific region to interpret the function of obsidian artefacts from FAO.

Subsistence activities

Wear patterns and residues on obsidian tools and palaeo-environmental data (Boyd *et al.*, 2005; Jago & Boyd, 2005; Lentfer, 1995, 2003; Lentfer & Torrence, 2007; Parr *et al.*, 2001) show that during both the middle and Late Holocene subsistence activities at FAO were likely to have been based on the wide scale exploitation of the available local marine and terrestrial resources in conjunction with gardening activities (Boyd *et al.*, 2005:388–389; Lentfer & Torrence, 2007:101). Two categories of stone tools associated with food processing activities were identified FAO. One group of obsidian artefacts was used for processing tubers and the others were involved in processing fish (Table 24).

The Middle Holocene. Food processing activity is represented by 15 tools used for scraping, slicing and cutting tubers and by seven tools with distinctive use-wear patterns indicating gutting/cutting fish (Table 24).

The relatively small number of obsidian tools involved in tuber processing, suggests that most plant food processing implements at FAO were probably made of bamboo or soft wood and this is consistent with finding numerous flakes used for fine woodworking activity which could have been involved in the production of those implements (Table 23). Ethnographic data provide evidence 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 & Fullagar, 1988:7–8). 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 actions resulted in the preservation of starch residues on used tools with particular use-wear characteristics. Fullagar (1992, 1993a,b, 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 although tool assemblages at FAO do not support Fullagar's suggestion. It may be explained by the wider use of tools made of wood rather than obsidian and by the possibility that some cooking and food processing activities could have been performed off-site: for example, in gardens or on the beach.

Obsidian flakes used for fish processing at FAO are the only direct evidence for the exploitation of marine resources. 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 found at the site. Archaeological data from some early and Middle Holocene sites in the Bismarck Archipelago indicate that fish were caught, processed and then transported from the sea to inland sites over distances of between three to about ten kilometres (Marshall & Allen, 1991:89; White *et al.*, 1991:56). This suggests that some processes were involved in the preparation and preservation of seafood to avoid the effects of the tropical climate on very perishable food resources. It is known from ethnographic and historical sources that after capture, fish 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 & Hornell, 1937:145; Kirch, 1997:215–216; Roscoe, 2005:566; Whiting & Reed, 1938:182). These kinds of fish preparation and preservation processes would definitely have required tools made of stone and shell.

Unfortunately, with the exceptions of food processing tools related to tubers and fish, use-wear/residue analysis does not provide direct 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 palaeoenvironmental reconstruction, can be used as indirect indicators of resource use activities that could have taken place on Garua Island during this time period. 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, all had their origins in the late Pleistocene period and these processes continued into the Middle Holocene (Allen, 2000, 2003; O'Connor & Chappell, 2003; Spriggs, 1997:61; Summerhayes, 2007). The further gradual intensification of the use of plant resources stimulated the development of arboricultural and horticultural activities during the Middle Holocene (Allen, 2000; Kirch, 2000:85–88; Lentfer & Torrence, 2007; Torrence, 1992, 2002a; Torrence *et al.*, 2000).

The results of use-wear/residue analysis of obsidian artefacts, when considered in the light of the range of available marine and land resources on and around Garua Island (Part 5), allow the suggestion that subsistence activity at FAO was centred on the procurement and processing of marine resources, harvesting and processing plant resources and, possibly, gardening (Lentfer & Torrence, 2007). The presence of nutshells 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 & Torrence, 2007:100–101). Previous use-wear/residue examination of some obsidian artefacts (Barton *et al.*, 1998; Fullagar, 1993a,b; Kealhofer *et al.*, 1999) identified the presence of starch grains on the working edges possibly related to the processing of taro. 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 & Torrence, 2007; Pavlides, 2006; Torrence, 2002a; Torrence *et al.*, 2000).

The Late Holocene. The trend which emerges from the comparison of middle and Late Holocene assemblages (Table 24) indicates that the percentages of tools involved in Late Holocene subsistence activities diminished slightly: 16% versus 21.8% in the Middle Holocene. Of these tools, 12.6% were used for processing tubers and 3.4% were involved in fish processing. Despite the smaller number of subsistence related tools, similarities in wear patterns and residues, some of which were identified as palm, bamboo and probably yam (Kealhofer *et al.*, 1999:543), on obsidian tools allow the conclusion that subsistence activities at FAO during the Late Holocene were probably also equally based on the wide scale exploitation of the available sea and land resources and gardening (Boyd *et al.*, 2005:388–389; Lentfer & Torrence, 2007:101).

This is supported by recent data obtained through the study of plant microfossils and the sedimentary history of the FAO site. The data indicate that there were no significant differences in landscape and resource 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 & Torrence, 2007; Petrie & Torrence, 2008). However, the introduction of the fishtail palm *Caryota rumphiana* and the slight increase in banana phytoliths is considered to constitute evidence of more intense gardening practices (Lentfer & Torrence, 2007:100). Many charred fragments of *Canarium,* coconut and other nutshells 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 & Stevenson, 2000:325–330). In addition, faunal data from some Late Holocene sites in the Arawe Islands, New Britain (Gosden *et al.*, 1989:583–584; Spriggs, 1997:120–121) make it is possible to suggest that some domestic and wild animals were also involved in the subsistence practices of the inhabitants of the FAO site.

This proposed pattern of Late Holocene subsistence at FAO is consistent with the generalised model of the Late Holocene 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., Gosden & Pavlides, 1994; Gosden *et al.*, 1989; Green, 2002; Kirch, 1997:195–226; Spriggs, 1997:84–87).

Domestic activities

The Middle Holocene. Of the total of 101 identified obsidian tools at FAO, 79 (or 78.2 %) were used in domestic activities during the Middle Holocene. Among them, the most represented category is that of woodworking implements (56.4%). Based on 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 24). 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 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).

Use-wear/residue study of obsidian artefacts, environmental reconstruction (Part 5) and ethnographic analogy taken all 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 woodworking activity played an important role in the daily lives of inhabitants.

Ethnographic data from Melanesia demonstrate that, at European contact, stone flakes were used in the manufacture of wooden tools for food processing, fishing equipment, weapons, consumption utensils and for building shelters and watercraft. Tasks were performed by stone tools in similar use modes to those identified on obsidian prehistoric artefacts on Garua Island. These include cutting 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 & Hardy, 2003; White, 1967, 1968; White & Thomas, 1972; Whiting & 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). Stone flakes were also used in other areas of Papua New Guinea for paring rattan strand for binding and weaving (Sillitoe, 1988:46–47, 503), preparation of lashing equipment, strings and clothing from softer parts of plants (Parkinson, 1999:345–346; Sillitoe & Hardy, 2003:561). Some of the Middle Holocene tools at FAO show wear patterns indicating their association with processing greens, such as leaves, stems and grasses. They were probably used for similar tasks. However, it is difficult to differentiate these tools, as a particular category, from those which were involved in food processing, for example, scraping coconut flesh (Kirch, 1997:215; Parkinson, 1999:42). Further experimental study and detailed residue analysis is required to determine particular wear patterns on this category of tools.

Another aspect of non-subsistence activities at the site during the Middle Holocene is indicated by implements associated with working soft elastic material which include 11 identified tools (10.9%). Although it is possible that some tools might have been used for cutting and piercing animal skin (for example: reptile skin for hand drums) (Nilles, 1943:116), a more plausible explanation is given by Specht (1981; Specht & Fullagar, 1988) and Fullagar (Fullagar *et al*., 1998) that sharp obsidian flakes were commonly used in conjunction with the human body: i.e. for tattooing and scarification, cutting and shaving human bodies for personal adornment or medical treatment. 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 flakes 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 flakes (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 colouring 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 of shell artefacts such as fish hooks, adzes, rings, disks and points (Golson, 2005; Gosden, 1991b; Smith, 2001; Spriggs, 1997:52; Szabo & O'Connor, 2004) at middle and Late 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 *et al*., 1998). Shell artefacts 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 ethnographically known (Sillitoe, 1988:382). Obsidian in West New Britain was relatively recently employed for cutting turtle carpace (Specht, 1981:348). An obsidian scraper at FAO indicates that shell processing activity took place on Garua Island in the Middle Holocene. This may have been associated with the manufacture of shell tools (e.g., adzes, fish hooks) and shell ornaments (e.g., armbands, crescents, pendants).

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

The Late Holocene. The set of tools used in Late Holocene domestic activities at FAO is similar in many respects to those of the Middle Holocene kit (Table 24). However, there are some differences in the proportion of tools involved in different activities that may indicate some changes in the organisation of tool use and the strategy of resource exploitation during the middle and Late Holocene.

The first difference is that 70% of the Late Holocene tools were involved in woodworking activities in contrast with only 56.4% of the Middle Holocene tools being used for similar activities. Second, most Late Holocene woodworking implements were used for processing siliceous and non-siliceous soft wood, palms and bamboo (65.2%) and rarely hard wood and palms (6.8%). Again, in contrast, during the Middle Holocene, species of hard wood and palms (15.8% of woodworking tools are associated with their processing) and soft non-siliceous wood were used relatively more often for daily needs (Table 24). In addition, working siliceous soft wood, palms and bamboo was a less extensive activity in the Middle Holocene (18.8% of tools) than in the Late Holocene (40.2% of tools).

The behavioural significance of these differences in the use of woody plants is 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 compared to those of the Late Holocene. Although there is no direct evidence, it is possible to suggest that some of these tools could have been used for the manufacture of different parts of canoes (e.g., prows, paddles, bows) and rafts (Cassidy *et al*., 2004:118–122). The location of Garua Island suggests that its re-occupation after the W-K2 eruption would have been achieved by seafarers with the cultural experience to settle small islands. Unoccupied land on an island undergoing post-volcanic forest regrowth would be attractive to people arriving by watercraft. These early settlers might have carried garden plants for cultivation and food production and, possibly, also transported animals in order to create the same cultural landscape they left behind (Kirch, 1997:109–115). Watercraft such as paddling and sailing canoes as well as different types of rafts were also essential in the procurement of marine resources and the performance of exchange activities especially for the distant transportation of obsidian over expanses of open sea (e.g., Allen, 2003; Anderson, 2000, 2001; Kirch, 2000:112–114; Specht, 2002; Summerhayes, 2003; Torrence & Summerhayes, 1997).

Construction and maintenance of watercraft could be one of the important activities of the island's inhabitants. 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 become increasingly available within the rainforest environment of Garua Island as it gradually recovered after the W-K2 volcanic events (Boyd *et al*., 2005; Jago & Boyd, 2005). The problem is how to distinguish the building of watercraft from other woodworking activities disclosed by the available archaeological record. The logs for canoes obtained from the forest could have been dragged to the seashore where watercraft were built (Haddon & Hornell, 1975:152–156, 303) and this can explain the absence of tools for chopping wood at the site. Some important components of watercraft, for instance, paddles, breakwaters and other timber parts, would need to be replaced many times during the 20 to 30–year life of the main hull (Haddon & Hornell, 1975:155). Consequently, it is more than possible that some obsidian tools were used to work wood to create a range of timber products needed in the use of watercraft. These activities 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 FAO site during the Late Holocene. 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 quite useful in the further explanation of this period of occupation.

In contrast to the previous chronological period, in the Late Holocene the number of tools used in working soft elastic material decreased: from 10.9% in the Middle Holocene assemblage to 5.8% (Table 24). These tools are associated with piercing and cutting actions performed on the skin. The presence of residues of mammalian blood on two tools, in conjunction with particular wear patterns and experimental data, suggests that these tools may have been involved in tattooing and scarification. Tattooing is considered to be an important symbolic component of the Late Holocene Lapita Cultural Complex and this 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 & White, 2001). The presence of the Late Holocene obsidian tools used for piercing and cutting skin at FAO is consistent with this proposition. However, functionally identical tools found at the site in the Middle Holocene context suggest that tattooing was possibly practiced in the region before the appearance of the Lapita people (Kononenko & Torrence, 2009).

Summary. Functional interpretation of tool assemblages 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. This conclusion 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. 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 used tools support the proposed interpretation of FAO as a consumption site throughout its role during both chronological periods (Therin *et al*., 1999:456–457).

The general similarities between subsistence practices, domestic and social activities during the Middle Holocene and Late Holocene can be explained by some common factors in both time periods. First, the physical limitations of obsidian as a raw material has restricted the number of possible technical and functional solutions to the performance of particular tasks creating 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 & Boyd, 2005; Lentfer & Torrence, 2007). Finally, the subsistence needs and capacities of inhabitants living in the island's environmental conditions were broadly the same over time.

FAO Site structure and settlement patterns on Garua Island

The structure of the site and patterns of human behaviour in both chronological periods are reconstructed and compared using the data from the spatial distribution of (*1*) actually used tools and (*2*) discarded flaked debris within the occupation levels, and (*3*) phytolith distribution within the sediments indicating the surface disturbance by human activity (Boyd *et al*., 2005; Lentfer, 2003; Lentfer & Torrence, 2007; Parr *et al*., 2001). There are some limitations, however, which need to be taken into account when spatial patterns of artefact distribution are identified. The first limitation is that FAO site comprises an area of some 10,000 square metres (Torrence & Stevenson, 2000:326) and was excavated by test pits measuring 1×1 m and located at 10 m intervals. One larger area of excavation measuring four square metres in area and located in the centre of the site is the only exception to the test pit excavation strategy. The second limitation is that Middle Holocene deposits were only completely excavated by two test pits (1000/1000 and 970/1000) 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 & Webb, 1992:6–7). Finally, no organic or structural remains were discovered at the site. These three factors complicate the reconstruction of the FAO intra-site structure and its interpretation should be considered as a general trend in human behaviour during the middle and Late Holocene.

Methodologically, the distributional approach assumes that, if particular tasks were performed at different activity areas throughout the site, then consequently, the tools employed in these activities would have a distribution pattern reflecting this behaviour (e.g., Rigaud & Simek, 1991). However, the spatial distribution of artefacts can be influenced by 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) and these should be taken into consideration when the organisation of prehistoric activities are examined (e.g., Carr, 1991; Gosden, 1991a; Keeley, 1991; Kelly, 1992; Kent, 1991:34; Rigaud & Simek, 1991; Stevenson, 1991). Many of these factors at FAO site, and particularly at the last stage of Middle Holocene occupation, did not however play an essential role because of the rapid deposition of large quantities of airfall tephra from the W-K2 (Machida *et al*., 1996) which sealed the occupational ground and ended this stage of human occupation of the site.

The most apparent activities represented in the archaeological record are knapping and tool manufacturing. Flaking debris resulting from tool production activity is likely to have been deposited at or very near where the knapping took place within the site (Ahler, 1989). In contrast, the distribution of used tools is somewhat different and may have been the result of tools being carried by people and discarded in areas away from where they were used. It is important to emphasise, that if formal tools within artefact assemblages are extremely rare, as has been observed in the Middle Holocene period, or absent altogether, as recorded in the Late Holocene period, the determination of the relationship between tool distribution and activity patterning is almost impossible without use-wear/residue studies. The distribution of functionally identified tools, in contrast to that of flaking debris, is able to provide more precise data about the use of space within the site, but this issue has to be seen in a much wider context of human behaviour (Keeley, 1991). For instance, the cleaning of intensively used domestic areas can affect the distribution of discarded tools in two ways. First, cleanup material will accumulate in the special disposal area which will contain a wide, though mixed, variety of tools in high densities and larger tools will also be found (Keeley, 1991:258). Second, as a result of cleaning, the activity area is likely to contain only a low-density of remnant small tools, and their fragments, which had survived the cleaning of the site (Keeley, 1991:258; O'Connell *et al*., 1991:67). Regular cleanup behaviour is a characteristic of sites which are occupied for a greater length of time than it is of short-term camps. Cultural remains simply do not accumulate during relatively brief periods of occupation and groups which moved camp frequently may have rarely engaged in intensive refuse cleanups (Gregg *et al*., 1991:150; Stevenson, 1991:270). The various stages of an occupation may also generate different patterns of refuse disposal and the use of space within the site. It is a common in the re-occupation of a site for people to avoid camping on the debris of previous occupations or on the accumulated refuse from prior cleaning activities (Keeley, 1991:258–260; Stevenson, 1991:275–276).

Ethnoarchaeological and ethnographic data obtained through the study of societies in comparable tropical and subtropical regions shows that activity areas within the residential camps of tropical societies usually comprise household, communal, and special activity areas (O'Connell *et al*., 1991:65–68). Household areas are occupied by one group and often include a hut marked by a circle of cleared ground two to six metres in diameter with hearths inside and outside the hut. The activity area around the hut is used for a wide range of domestic tasks, including the preparation and consumption of food and 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 adjacent to the edge of the activity space. Some of the smaller items are trampled into the ground rather than be swept into disposal areas. Communal areas are used for the same range of activities but are used by all members of the group and are also periodically swept clean of refuse. The size of the area varies from four to six metres across and usually does not contain any structures (e.g., Bartram *et al*., 1991:96–97; Hogbin, 1938:175; Kirch, 1997:167; O'Connell *et al*., 1991:67–68; Parkinson, 1999:27). All of this data is useful in gaining an understanding of the distribution of artefacts found within FAO site and in reconstructing the relationship between artefact distribution and the organisation of activity.

Middle Holocene occupation. Evidence of the early stage of the Middle Holocene occupation of FAO is present in only two pits: 1000/1000, spits 3–5, and 970/1000, spits

3–4 (Torrence & Webb, 1993:6–7) (See Part 6). Unexpected functional variability between these pits was revealed by use-wear/residue examination of all the artefacts recovered by the excavations. The artefacts which were concentrated in the central part of the site (pit 1000/1000) comprised mainly the by-products of knapping activity (168 specimens). Only two flakes were tools and these were used for working non-siliceous soft wood (Table 25). This indicates that the area was probably briefly used for flaking activity. In contrast, the suggested "dumping ground" area (Torrence, 1993:5) (970/1000 pit) includes numerous tools (30 tools of the total 119 artefacts) which were involved in woodworking activities, processing tubers, greens and clay (Table 20). The distribution 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 quite differently as a localised space for the manufacture of lithic implements. This suggestion is supported by phytolith analysis of the sediments (Lentfer, 2003:301–304; Lentfer & Torrence, 2007; Parr *et al*., 2001) which shows that the north-western edges of the hill were covered with grasses from the beginning of the occupation indicating the deliberate clearing of the area. In contrast, the south and north parts of the site were covered by palms and herbaceous regrowth.

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 (235 specimens) and tools (21 specimens) representing probably a kind of "communal" area (Fig. 30) where members of the group could perform their daily activities with periodic cleanup of accumulated refuse (Lentfer & Torrence, 2007:100). Tools in this area were used for food processing (tubers and fish), working greens and skin, woodworking and knapping activities (Table 20). All of these activities were related to meeting daily needs and included flake knapping as 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 m away from the "communal area" (Fig. 30). Among the 25 discarded tools of different sizes, woodworking implements are prevalent (16 specimens) although tools for processing food, greens, skin and shell are also present (Table 20).

The space between the "communal" and the refuse areas (980/1000 and 990/1000 pits) contained a relatively low number of artefacts (63 and 72 specimens respectively). Each pit yielded 12 tools and these tools were used for working woody plants, tubers, fish, greens and skin. Interestingly, of the total of 11 small tools involved in processing skin, seven were found within these pits reflecting the kinds of specific social activity which took place around this area (Table 20). A low number of unused flakes within 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 have contained some kind of shelter construction which was surrounded by an area for domestic activities (Fig. 30). This suggestion is supported by the presence of grasses and burnt phytoliths in the sediments indicating the deliberate clearance by inhabitants (Lentfer & Torrence, 2007:101; Parr *et al*., 2001:132).

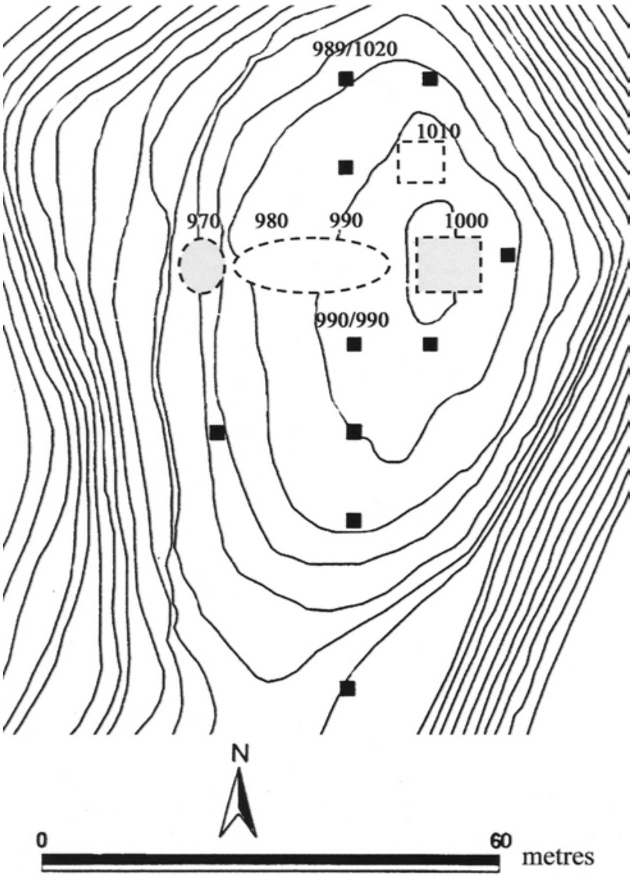

Figure 30. The distribution of activities at FAO during the last stage of Middle Holocene occupation. Dotted area: *lithic workshop* and *living area*. Shaded area: *dumping ground* and *communal area*.

The very dense deposit of obsidian waste recovered in 1010/1000 pit (Table 5) located some 10 m to the north of the "communal" area (Fig. 30) 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 deliberate creation of a specific space outside the main habitation area of the site used either for flaking obsidian raw material or as dumping ground for debris produced by knapping activity.

The suggested intra-site structure at the final stage of the Middle Holocene occupation incorporates a system of spatial organisation involving a "communal" activity area, dumping ground for cleanup material, living or some sort of household area and a lithic workshop. The existence of discrete activity areas indicates a prolonged period of occupation of FAO which was only interrupted by the devastating WK-2 eruption. In comparison with the final period before the eruption, 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

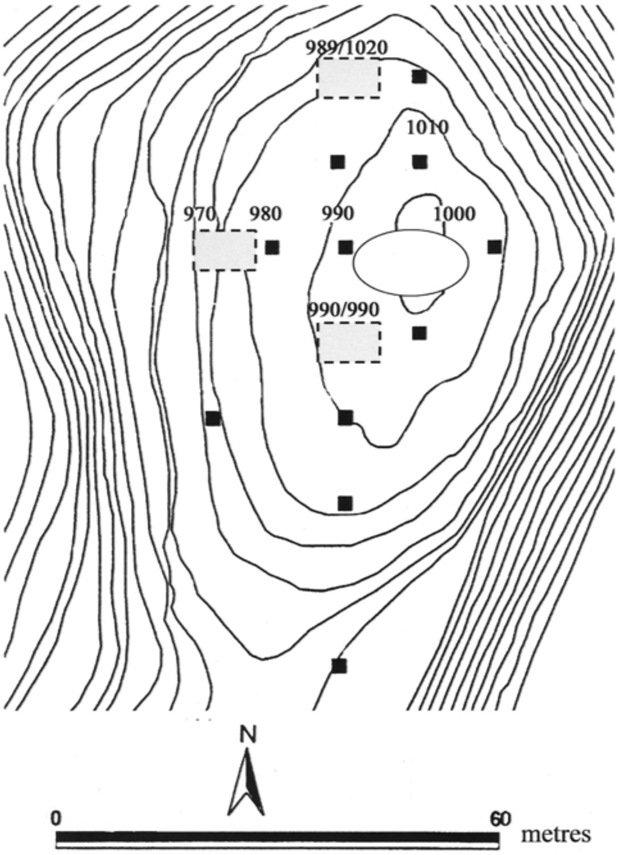

Figure 31. The distribution of activities at FAO during the last stage of Late Holocene occupation. Shaded area: *communal area,* unshaded oval area: *living area.*

spatially (Fig. 30, Table 5) and this indicates 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 later more organised and prolonged occupation which occurred at the end of the Middle Holocene.

Late Holocene occupation. The Late Holocene stratigraphical unit at the site (Layer 8) has been divided into lower, middle and upper parts (Lentfer & Torrence, 2007; Torrence, 1993:5; Torrence & Webb, 1992:6–7). Each of these parts is characterised by differing densities of accumulated artefacts within each excavated unit (Table 5). Use-wear/residue data indicate that the lower part of Layer 8 includes 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, 1001/1000, 1000/999 and 1001/999 pits (Fig. 15). The refuse area shows a high concentration of debitage (199 specimens) and tools (35 specimens). Discarded tools were mainly involved in woodworking activity, although tools used for processing food, including tubers and fish, greens and skin were also present (Table 19). The "communal" area is characterised by a relatively low number of finds which included 58 unused flakes and nine flake tools used for processing siliceous soft wood, palms and bamboo, soft non-siliceous wood and tubers. Two other pits also contained a 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 (Fig. 15, Table 5).

Some changes in the distribution of finds of obsidian artefacts can be observed within the middle part of Layer 8. Firstly, the density of artefacts increases in the northern and southern parts of the sites in comparison with the centre (Table 5). Secondly, the number of artefacts found in the refuse area dramatically drops and this indicates that the cleanup strategy changed. Among 54 discarded artefacts in 970/1000 pit were eight tools used for processing wood, tubers, greens and skin (Table 19). 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 a small number of unused flakes were found in 980/1000 and 990/1000 pits (Table 25) indicating that some occasional tasks were performed outside of the main activity area.

The continuity of the previously observed trend is again apparent in the distribution of artefacts in the upper part of Layer 8: a gradual relocation of activities from the central part to the southern and northern edges of the hill (Fig. 31). The refuse area apparently stopped being used during this period of occupation. It is interesting that, of the total of 32 artefacts found in 970/1000 pit at this level, 11 were used for processing wood, tubers and greens (Table 19), indicating that this part of the site was used for domestic activities, possibly as a "communal" area, during the latest period of occupation (Fig. 31). Tools found in the central part of the site including the former "communal" area around 1000/1000 pit, suggest the occasional use of this space probably as a living area (Fig. 31). 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 and observed in the archaeological record are strong evidence for the continuous use of this location throughout the Late Holocene period. The comparison of the distribution 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) was mainly used during the earliest phase of the Late Holocene occupation. The 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 (Fig. 31, Tables 5, 25).

Summary. The set and distribution of the Middle Holocene tools reveal the full range of activities, their spatial organisation and the complex intra-site structure with evidence of regular cleanup of habitation areas. This behaviour of the Middle Holocene inhabitants at FAO does not support the hypothesis of settlement patterns characterised by the short-term occupation of locations within the island's landscape by highly mobile groups (Torrence, 2002a:773, Torrence *et al.*, 2000:237).

Late Holocene spatial and temporal changes in the distributional pattern of activities indicate that the site was not a large village or a small stable hamlet which was permanently occupied over a long period of time (Kirch, 1997:167; Torrence, 2003:298). The relocation 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 the dumping ground into an area for domestic activities all indicate some changes in settlement strategy over time. FAO was a well-situated site which was repeatedly settled and resettled by small groups of people. Evidence of the carrying out of multiple activities and the structural organisation of those activities suggests a relatively prolonged period of time having been spent by the inhabitants of the site during each stage of occupation. This pattern of Late Holocene occupation of FAO, in association with the evidence of marine resource exploitation and gardening (Lentfer & Torrence, 2007), is consistent with the model of relatively mobile Lapita sites proposed by some scholars (Gosden & Pavlides, 1994; Summerhayes, 2000:234).

FAO within the context of mobility in the Middle and Late Holocene

The factors underlying the need for mobility in prehistoric populations are complex and there are also various forms of mobility. One form of mobility is the colonisation of Pacific islands using watercraft commencing in the Late Pleistocene and continuing throughout prehistory (e.g., Allen, 2003; Anderson, 2000; Gosden & Pavlides, 1994; Kirch, 2000:9; Lape *et al.*, 2004, 2007; O'Connor & Chappell, 2003; O'Connor & Veth, 2000; Spriggs, 1997:27–31). The maritime behaviour of people who had developed the use of watercraft led to settlement strategies and subsistence practises based on the discovery and exploitation of suitable land and marine resources. The occupation of Garua Island in the Middle and Late Holocene occurred because people had achieved the ability to cross the waters which surrounded the island. The development of watercraft was also required for the maintenance of exchange systems and social relationships (Summerhayes, 2007; Torrence & Summerhayes, 1977) and for access to and use of marine resources as important components of the subsistence strategies of the island's inhabitants. 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 availability of resources caused either by environmental conditions (e.g., climatic phenomena 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).

Natural resources recovered after each Holocene volcanic event and environmental conditions were generally unchanged after regeneration on Garua Island (Boyd *et al.*, 2005; Lentfer & Torrence, 2007). The archaeological record, however, indicates two different behavioural patterns of inhabitants who occupied the island before and after the catastrophic eruption. On the basis of technological studies of obsidian artefacts and their distribution within the landscape, researchers have proposed that the behaviour of the inhabitants of the island during the Middle Holocene was associated with highly mobile ways of life, short-term occupation of sites, curated technology and gradual intensification in land-use (Fullagar, 1992; Kealhofer *et al.*, 1999; Torrence, 1992, 2002a; Torrence & Stevenson, 2002; Torrence *et al.*, 2000). Some major changes in technology and subsistence occurred immediately after the massive W-K2 volcanic eruption: stemmed tools disappeared, Lapita pottery arrived, a different form of subsistence pattern linked to the introduction of new plants and animals became established, 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 are indicative of a different social system appearing on the island after the WK-2 catastrophic volcanic eruption. This new system allowed small groups to practice a subsistence pattern of existence that had greater dependence on cultivation (Torrence *et al.*, 2000).

Recent results obtained through palaeoenvironmental studies by Boyd, Lentfer and Parr (Boyd *et al.*, 2005; Lentfer, 1995, 2003; Lentfer & Torrence, 2007; Parr, 2003; Parr *et al.*, 2001) provided new data which, to some extent, contradict the previous view of the Middle Holocene history of the island. According to these palaeoenvironmental 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 results of functional study of the obsidian assemblage at FAO are more consistent with the palaeoenvironmental data than with the proposed model of a highly mobile pattern of human behaviour during the Middle Holocene. Use-wear/residue examination and morphological observations of artefacts, in conjunction with their spatial distribution, clearly shows the expedient production and use of flakes and of a few small stemmed tools designed for a diverse set of activities. These activities were spatially organised and maintained at FAO during both the early and late stages of occupation. The full range of daily activities related to the procurement and processing of stable marine resources and the collecting, production and processing of land resources, including gardening products such as tubers, and these all indicate a low level of mobility which was probably partly associated with the practice of "swidden" gardening or "shifting cultivation" (Kirch, 1997:203) from the Middle Holocene period.

The set of Late Holocene tools and associated activities have many common features with the previous chronological period despite the evidence for change emphasised by scholars. The data from this study indicate that the set of domestic activities, subsistence practices, intra-site structure and spatial organisation of activities at FAO are similar in both chronological periods. This suggests that a low level of mobility was characteristic of the behaviour of the island's inhabitants during both middle and Late Holocene. The Middle Holocene pattern of re-occupation of the site is continued in the Late Holocene. The relocation and re-arrangement of activities, which is obvious in the Late Holocene deposits, is a significant indicator of the repeated use of FAO with some time gaps between occupation episodes. This pattern of Late Holocene re-occupation, in conjunction with the evidence of gardening around the site (Boyd *et al.*, 2005:388–389), is consistent with the model of shifting cultivation reconstructed for the Lapita economy in the Bismarck Archipelago (e.g., Kirch, 1997:203). The model suggests the repeated occupation, abandonment and reoccupation of a particular area over time, and is associated with the practise of gardening and with the re-location of the habitation area increasingly closer to the gardens (e.g., Hogbin, 1938:143; Parkinson, 1999:68, 341). This model offers a plausible explanation of the low level of mobility for both middle and Late Holocene inhabitants of Garua Island. However, to test this suggestion further, use-wear study of obsidian artefacts recovered from all pits at FAO, as well as from other contemporary sites on the island, is required.

Conclusion. The middle and Late Holocene environmental conditions on Garua Island, with its abundance of obsidian raw material, stable and rich marine resources and diverse and accessible terrestrial resources provided favourable conditions for a style of life involving relatively low mobility in both chronological periods of occupation. The data derived from the functional study of artefacts indicate the basic pattern of continuity in subsistence, domestic activities, site structure and settlement patterns over time notwithstanding some minor changes in the use of particular plant resources. It is apparent from the use-wear/residue results that the continuity in subsistence, settlement patterns and tool-use strategy does not directly correlate with the changes in technology which occurred during the Late Holocene (Torrence *et al*., 2000). This means that functional data, in their own right, do not provide enough essential information on whether the appearance of Lapita pottery is the result of a new population with different social system arriving on Garua Island or the return of some Middle Holocene inhabitants displaced by the W-K2 volcanic eruption who brought their cultural traditions from neighbouring areas.

Implications of research results

An integrated use-wear/residue study of 190 obsidian tools from the FAO site together with experimental data has significantly extended the previously reported range of functions documented for obsidian tools, particularly in terms of uses related to tropical resources. The use-wear/residue methodology employed in the study was encouraged by previous functional studies of stone artefacts in other parts of the world and particularly research on obsidian tools. Microscopic analysis of wear attributes including scarring, rounding, striations, abrasion, polish, and to a lesser extent, residues, was used to determine the mode of use, material processed and duration of use. Testing the relationships between wear features and residues and particular tasks was achieved through an extensive experimental program. 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 had not previously been incorporated into obsidian use-wear experiments. The replication experiments previously undertaken by Hurcombe (1992), Fullagar (1986) and Kamminga (1982) in conjunction with a wide range of new experiments produced results that greatly extend the current understanding of the general process of use-wear formation on obsidian.

Two major results contribute to the general study of functional analysis. The first includes the diagnostic set of wear attributes resulting from working (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 (greens which include leaves, stems and grasses), (6) non-woody plants (tubers), (7) soft elastic materials (skin and fish), and, (8) dense, hard materials (shell and clay). This classification of use-materials was used to interpret functional data obtained from the archaeological assemblage. The second result concerns the stages of formation of diagnostic wear for each category of identified use-material. Since experimental data indicate an obvious relationship between wear formation and duration of use, an opportunity is created to estimate the duration of use of artefacts at the site. These artefacts were found to have short-term, moderate and long-term periods of use. This provided the means for studying elements of technological behaviour such as the degree of curation versus the expedient tool use.

The detailed description of use-wear patterns on obsidian experimental tools, presented in this monograph, can be used as a working guide for future functional studies of lithic assemblages. In particular, the extensive photographic record of use-wear and residues observed on artefacts and experimental tools provides an important resource for future comparative studies of obsidian assemblages. This study should stimulate discussion and encourage further experimental use-wear studies.

It is important to emphasise that the experimental program in this project was designed, as far as was possible, to investigate wear formation using local obsidian and other resources from the area under investigation. This approach produces the best possible data for the comparison of use-wear generated by experiments and that found on tools within archaeological assemblages. This overall approach also facilitated an understanding of the broader context in which subsistence, domestic and social activities were carried out in the middle and Late Holocene periods on Garua Island and the wider region.

An important result of the research is to demonstrate that functional studies of obsidian artefacts make an important contribution by testing hypotheses about tool-use, mobility and subsistence patterns. 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 were worked by various modes of use, including scraping, sawing, whittling, carving, drilling, cutting, slicing, peeling and piercing. 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 found in Middle Holocene deposits at FAO. The study as whole therefore provides important data about the nature of the expedient tool use strategy that has been previously been discussed only in terms of the absence of retouched forms in assemblages from the wider region.

The data produced by this study provides important insights about obsidian tool-use that establish a starting point for the further investigation of intra-site structure and organisation of activities in the middle and Late Holocene on Garua Island and in the Bismarck Archipelago generally. When examined together, the use-wear/residue study of obsidian tools and their stratigraphic and spatial distribution, confirm continuity in subsistence, daily activities and site use during the Holocene. This continuity can be explained by the combination of a number of factors. The physical needs of human beings, the continued use of the same raw material for the manufacture of tools, similarities in ecological conditions and available food and non-food resources all generate similar tool use strategies and structures of associated activities over time.

Potential of functional analysis

Despite the contributions of functional analysis, it is also important to acknowledge its limitation in studying stone artefacts. Firstly, in order to reconstruct the full range of activities at a site, it is important to examine the total assemblage of artefacts recovered by excavation. However, use-wear/residue analysis is such a labour-intensive method, that it is usually difficult to study entire stone assemblages from sites. As described in Part 5, an appropriate sampling strategy is generally required to ensure that the studied tools represent the full range of activities on the site. In this case the number of tools analysed from the selected test pits did provide evidence of a wide spectrum of human activity. However, a large open area excavation of FAO could have provided opportunities for a greater understanding of the spatial organisation of activities at the site and therefore of the nature of the settlement. Of course, given that the site is about one hectare in area, it would be an enormous undertaking to excavate the whole site to a depth of over two metres.

Secondly, the presence of starch, plant tissue and other residues on tools played an important role in the analysis of tool function in this study. The preservation of residues on obsidian, however, can be somewhat problematic and depends on many factors, including post-depositional processes and post-excavation cleaning of artefacts (Fullagar, 2006b:191). It is important for this reason that as large a sample as possible is collected in the field with only the minimal amount of handling. Although the study did include a sufficient sample of tools collected in this way, the majority of the sample had been washed prior to analysis, and limited the opportunity of finding residues which might have been preserved on the tools.

Thirdly, since obsidian is a fragile raw material, its surface is easily altered by both physical and chemical processes. Some artefacts do not preserve identifiable use-wear features and residues because the surface has been too greatly altered. This limitation can reduce the opportunity of employing use-wear analysis in the study of archaeological collections. In the case of FAO, obsidian artefacts from the Middle Holocene deposit have more highly altered surfaces 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.

Despite these potential problems, the results of the functional study provide reliable information about 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.

Prospects for future research

This study demonstrates that appropriate methodologies involving a rigorous series of procedures and techniques are necessary to ensure that reliable results are obtained by the functional study of obsidian assemblages. An important component of functional studies is the creation and presentation of useful records of the analyses particularly in the form of highly magnified colour images of use-wear patterns and residues. Further research into these methodological aspects of use-wear analysis would be very useful.

The experimental program was designed to examine wear formation on obsidian tools by using mostly local resources. However, a wide variety of potentially worked materials and modes of use still remain to be studied. For instance, the comparison of sets of wear produced by different plants showed that the definition of the worked species, on the basis of use-wear alone, can only be made on a generalised 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 designed to help differentiate wear patterns into more specific groups relating to plant types would make a significant contribution to the functional interpretation of stone tools and associated human activities, particularly for the Pacific region, but also for tropical regions around the world.

The study of microscopic organic residues on experimental tools is another area that would benefit from further investigation. The detailed analysis of residues is of particular importance because it has the potential to assist the specific identification of the material worked. In this project, the classification of use-materials was developed mainly on the basis of wear characteristics. There is good potential for making functional identifications more specific through detailed analyses of the residue samples extracted from the artefacts.

Although the number of tools analysed from FAO is larger than many functional studies, compared to previous research projects, not all the artefacts excavated from FAO have been studied. Additional analyses could be useful for improving our understanding of site use. Furthermore, the project concerned obsidian tool use at only one specific site on Garua Island. A more coherent understanding and explanation of tool use strategies, settlement patterns and subsistence in the middle and Late Holocene, requires the further examination of larger obsidian assemblages from other contemporary sites on the island and throughout the Bismarck Archipelago in general. Such further studies would be particularly illuminating.

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Table 1. Experimental tools and resulting wear patterns.

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
Palms													
77	*Cocos nucifera* Coconut	sawing stem, spathe	flake	large	straight	2	wrapped	5	c,f	dense, parallel	intensive	well developed	film, tissue, needle-like
79	*Cocos nucifera* Coconut	sawing spathe	flake	large	convex	2	wrapped	15	c,f	dense, parallel	intensive	well developed	tissue, starch
80	*Cocos nucifera* Coconut	whittling/ sawing frond	flake	large	straight	2	wrapped	15	b,c,f	dense, parallel, diagonal	intensive	developed	film, tissue
164	*Cocos nucifera* Coconut	whittling/ midrib	flake	medium	convex	2	wrapped	23	d/c,m	dense, parallel, diagonal	intensive	developed, patchy	film, tissue, starch
87	*Cocos nucifera* Coconut	scraping nutshell	flake	medium	concave	2	hand	30	c,f,s	dense, perpendicular, parallel	intensive	well developed, patchy	film, tissue
160	*Cocos nucifera* Coconut	carving nutshell	flake	large	convex	2	hand	60	b,c,f	dense, diagonal flaked	light, patchy	light, patchy	film, tissue
253	coconut meat	cutting/ slicing	flake	large	convex	2	hand	30	b,d/c,f	isolated, parallel diagonal	very light, patchy	very light, patchy	film, tissue
6	coconut meat	scraping	stemmed, Kombewa	large	convex	1	wrapped	30	b,c,f	few, diagonal, isolated	very light, patchy	very light, patchy	film, tissue, starch
309	coconut meat	scraping/ slicing	flake	small	convex	2	hand	25	b,c,f	few, diagonal, isolated	light	very light, patchy	film, tissue
169	*Metroxylon* spp., sago palm	sawing midrib	flake, Kombewa	large	convex	1	wrapped	5	b,c	dense, parallel	medium	developed	tissue, starch
172	*Metroxylon* spp., sago palm	sawing frond	flake	large	irregular	3	hand	10	c,f,s	dense, parallel	medium	developed patchy	film, tissue

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
167	*Metroxylon* spp., sago palm	sawing frond	flake	large	concave	2	wrapped	15	c,f	dense, parallel	intensive	well developed	tissue
166	*Metroxylon* spp., sago palm	sawing frond	flake	large	convex	2	wrapped	30	b,c,f	dense, parallel	medium	well developed	film, tissue, starch, white
269	*Metroxylon* spp., sago palm	scraping pith	flake	large	irregular	3	hand	30	c,s	dense, perpendicular	intensive	well developed	tissue, needle-like
180	*Metroxylon* spp., sago palm	cutting frond	stemmed, Kombewa	large	convex	2	wood handle	60	b,c,f	dense, parallel	intensive	well developed	tissue, starch
246	*Nypa fruticans* nypa palm	cutting frond	flake	medium	irregular	2	wrapped	10	b,c,f	dense, parallel	intensive	developed, patchy	tissue
247	*Nypa fruticans* nypa palm	sawing frond	stemmed, Kombewa	medium	convex	2	wood handle	15	c,s	dense, parallel	intensive	well developed	tissue
188	*Caryota* sp. black palm	scraping bark	flake	medium	convex	2	wrapped	5	c,f,s	dense, perpendicular	intensive	well developed	film, tissue, starch
223	*Caryota* sp. black palm	scraping stem	flake	medium	convex	2	wrapped	15	c,f,s	rare, perpendicular, patchy	light, patchy	light, patchy	film, tissue
257	*Caryota* sp. black palm	scraping stem	flake	large	irregular	3	hand	45	b,c,s	dense, perpendicular, patchy	intensive, patchy	well developed, patchy	tissue
270	*Caryota* sp. black palm	scraping stem	flake	large	straight	2	hand	45	b,c,s	dense, slightly diagonal	intensive, patchy	well developed, patchy	tissue
187	*Caryota* sp. black palm	sawing stem	flake	medium	concave	2	wrapped	5	b,f,s	dense, parallel	intensive	developed, rough	film, tissue, starch
224	*Caryota* sp. black palm	sawing stem	flake	large	irregular	2	wrapped	15	b,c,f	dense, parallel	intensive, patchy	developed, patchy	tissue, starch
271	*Caryota* sp. black palm	sawing stem	flake	large	straight, irregular	2	hand	60	b,c,f	dense, parallel	intensive	well developed	tissue

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
184	*Caryota* sp. black palm	whittling stem	flake	large	concave	2	hand	5	b,d/c,f,	diagonal. isolated, patchy	light, patchy	light, patchy	tissue
225	*Caryota* sp. black palm	scraping/ whittling sawing stem	flake	large	straight, concave convex	2	wrapped	20	c,m	dense, parallel and isolated perpendicular	light to medium	light to medium	tissue, starch
218	*Caryota* sp. black palm	whittling/ sawing/ scraping stem	flake	large	concave, convex	3	wrapped	30	c,f,s	parallel, diagonal, crossed	intensive	well developed, patchy	tissue, starch
67	*Pandanus* spp. pandanus	piercing leaves	stemmed, flake	medium	convex	1	wood handle	15	d/c,f, snap	parallel, diagonal, crossed	very light	very light	tissue, starch
1	*Pandanus* spp. pandanus	cutting stem, flesh	stemmed, flake	medium	convex	1	wood handle, wrapped	15	b,c,f	diagonal, isolated	very light	very light	film, tissue, starch, needle-like
26	*Pandanus* spp. pandanus	cutting leaves	flake, Kombewa,	large	straight	2	hand	15	b,c,f	dense, parallel, diagonal	very light	very light	film, tissue, starch
2	*Pandanus* spp. pandanus	cutting stem, flesh	stemmed, Kombewa	medium	convex	1	wood handle, hand	30	b,c,f	diagonal, parallel, isolated	light	light	film, tissue, starch
176	*Pandanus* spp. pandanus	cutting leaves	stemmed, flake	medium	convex	1	wood handle, hand	95	b,c,f	dense, parallel, perpendicular, diagonal	light	light	film, tissue, starch, white
20	*Pandanus* spp. pandanus	cutting/ slicing leaves, stem	flake, Kombewa	medium	concave	2	hand	15	b,c,f	parallel, diagonal, crossed	light	light	film, tissue, starch, needle-like
219	*Calamus* spp. rattan, cane	sawing vine, stem	flake	medium	irregular	3	hand	5	b,c,f	dense, parallel	intensive	well developed	tissue

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
177	*Calamus* spp. rattan, cane	sawing vine, stem	flake	medium	irregular	2	hand	30	b,c,f	dense, parallel	intensive	well developed	tissue
159	*Calamus* spp. rattan, cane	cutting stem, skin	flake	medium	irregular	1	hand	5	b,c,f	dense, diagonal, parallel	medium	light	tissue, needle-like
120	*Calamus spp.* rattan, cane	cutting stem, skin	flake	medium	convex	2	hand	15	b,c,f	dense, parallel	medium	developed	tissue, starch
45	*Calamus* spp. rattan, cane	Scraping vine	flake	medium	straight	2	hand	8	b,c,f,s	dense, perpendicular, diagonal	intensive	well developed	tissue
283	non-identified species	cutting midrib (burin)	flake	medium	concave	2	hand	10	c,b,f,	dense, parallel, diagonal	medium	light	tissue
Softwood													
93	*Calophyllum* sp.	sawing/ whittling stem, branch	stemmed, Kombewa	large	irregular	3	wrapped	15	c,m	parallel, diagonal	intensive	well developed	tissue
70	*Octomeles sumatrana* erima	sawing stem, branch	flake, Kombewa	medium	straight	1	hand	5	c,m	parallel, diagonal	medium	developed	tissue
72	*Octomeles sumatrana* erima	sawing stem, branch	flake	medium	straight	2	wrapped	15	b,c,f,	dense, parallel	intensive	well developed	tissue, white
74	*Octomeles sumatrana* erima	sawing stem, branch	flake	large	convex	2	wrapped	30	b,c,f	parallel, isolated, many	medium	developed	tissue, white
65	*Octomeles sumatrana* erima	whittling stem, branch	flake	large	straight	2	wrapped	15	b,d/c,f	few, diagonal	very light	very light	some tissue
62	*Octomeles sumatrana* erima	whittling stem, branch	flake	large	convex	2	wrapped	30	b,d/c,f	diagonal, isolated	light	very light	tissue, white

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
165	*Octomeles sumatrana* erima	sawing/ carving/ gouging stem	core	medium	irregular	3	hand	15	c,f,s,	dense, diagonal	intensive	developed	tissue, starch, white
128	*Octomeles sumatrana* erima	scraping/ sawing stem, branch	stemmed, Kombewa	large	convex	3	wood handle, hand	60	c,m	diagonal, parallel	medium	developed	film, tissue
156	*Hibiscus tiliceus L.*	whittling stem, branch	flake, Kombewa	large	irregular	3	hand	5	b,c,f	dense, diagonal, parallel	medium	developed	film, tissue
44	*Hibiscus tiliceus L.*	whittling stem, branch	flake, Kombewa	large	straight	2	wrapped	15	b,d/c,f	diagonal, isolated	very light	very light	film, tissue
237	*Hibiscus tiliceus L.*	whittling stem, branch	flake	large	irregular	1	wrapped	30	b,c,f	diagonal, parallel	light	light	film, tissue, starch
157	*Hibiscus tiliceus L.*	whittling/ sawing stem	flake	large	concave	2	hand	10	b,d/c,f	diagonal, parallel, isolated	light	very light	film, tissue
234	*Hibiscus tiliceus L.*	carving stem, branch	flake	medium	straight	2	wrapped	25	b,c,f	diagonal, parallel	light	light	film, tissue, starch
95	*Hibiscus tiliceus L.*	carving stem, branch	flake	large	straight	2	hand	30	c,f,s	rare, diagonal, isolated	very light	very light, patchy	film, tissue
47	*Hibiscus tiliceus L.*	engraving stem, branch	flake	medium	irregular	2	wrapped	30	b,d/c,f	rare, diagonal, isolated	very light	none	film, tissue, white
235	*Hibiscus tiliceus L.*	whittling bark	stemmed, flake	large	irregular	1	wood and wrapped	20	b,c,f	diagonal, isolated, patchy	very light	very light	film, tissue
18	*Homalium foetidum* malas	sawing stem, branch	flake	large	convex	2	hand	5	b,c,f	dense, parallel	medium	developed	tissue
32	*Homalium foetidum* malas	sawing stem, branch	flake	large	straight	2	wrapped	15	b,c,f	dense, parallel	intensive	well developed	tissue, starch

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
41	*Homalium foetidum* malas	sawing stem, branch	flake	large	straight	3	wrapped	30	b,c,f	dense, parallel	intensive	well developed	tissue, starch, raphides
38	*Homalium foetidum* malas	carving stem, branch	flake	large	convex	2	wrapped	15	c,f, snap	dense, diagonal, parallel	intensive	developed	tissue, needle-like
239	*Toona ciliata* red cedar	carving stem	flake	large	irregular	3	hand	60	c,f,s	diagonal, parallel, crossed, isolated	medium to intensive	developed, patchy	film, tissue
240	*Toona ciliata* red cedar	carving stem	flake	medium	convex	1	hand	60	b,c,f	dense, diagonal, parallel	medium to intensive	developed,	film, tissue
282	*Ficus* sp. fig	whittling stem	flake	medium	straight	2	hand	10	b,c,f	diagonal, isolated	medium	light	film, tissue
13	Soft wood non-identified species	whittling stem, branch	flake	large	convex	1	wrapped	15	b,c,f	diagonal, isolated, patchy	extremely light	none	film, tissue, starch
268	Soft wood – non-identified species	whittling/ sawing stem	flake	medium	straight	2	hand	10	b,c,f	diagonal, parallel isolated,	light	light	tissue
316	Soft wood – non-identified species	drilling stem	retouched, like stem	small	irregular	3	hand	15	c,f,s	dense, perpendicular	intensive	well developed	tissue, starch
248	Soft wood – non-identified species	smoothing	flake	large	dorsal side with ridges	surface	hand	15	none	dense, parallel	intensive	well developed	tissue
115	Soft wood – non-identified species	sawing/ whittling stem, branch	stemmed, flake	large	convex	3	wrapped	30	b,c,f	diagonal, parallel, isolated, patchy	light to medium, patchy	developed, patchy	tissue, starch
297	Sandalwood	sawing stem, branch	flake	large	irregular	2	hand	45	b,c,f	dense, parallel	intensive	well developed	tissue
Hard wood													
134	*Casuarina* sp. horsetail oak	whittling bark	flake	large	convex	2	wrapped	30	m,c,	diagonal, parallel, isolated	medium	light to developed	film, tissue

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
82	*Pometia pinnata* ton	whittling stem	flake	large	straight	2	hand	5	b,c,f	diagonal, isolated, rare	very light, patchy	developed, patchy	tissue
83	*Pometia pinnata* ton	whittling stem	flake	large	irregular	2	wrapped	15	b,c,f	rare diagonal, isolated, single	very light, patchy	developed, patchy	tissue
60	*Pometia pinnata* ton	whittling stem	flake	large	irregular	2	hand	30	b,c,f	rare diagonal, single	very light, to light, patchy	developed, patchy	tissue, white
301	*Pometia pinnata* ton	scraping stem	flake	medium	concave	2	wrapped	30	c,f,s	dense, perpendicular	intensive	well developed	tissue
75	*Mangifera indica* bush mango	sawing stem, branch	flake	large	convex	2	hand	5	b,c,f	dense, parallel	intensive	well developed	tissue
71	*Mangifera indica* bush mango	sawing stem, branch	flake, Kombewa	large	convex	3	wrapped	15	b,c,f	dense, parallel	intensive	well developed	tissue
303	*Eucalyptus* sp. eucalyptus	sawing stem, (dry)	flake	medium	straight	2	hand	20	c,m	dense, parallel, diagonal	intensive	well developed	tissue
304	*Eucalyptus* sp. eucalyptus	sawing stem, (green)	flake	small	straight	3	hand	20	b,c,f	dense, parallel, diagonal	intensive	well developed	tissue
302	non-identified species	sawing stem, (dry)	flake	medium	convex	3	hand	20	c,m	dense, parallel, diagonal	intensive	well developed	tissue
300	"lipi"	scraping/ whittling sapwood	flake	large	concave	2	wrapped	30	b,c,f	dense, diagonal, flaked, patchy	medium	light	tissue
170	non-identified species	whittling/ cutting stem, branch	flake	large	concave	3	hand	30	b,c,f	diagonal, parallel, isolated, patchy	very light	light, patchy	tissue

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
Non-woody plants													
280	*Bambusa* spp. bamboo	sawing stem	flake	small	convex	1	hand	5	b,c,f	dense, parallel	intensive	well developed	tissue' needle-like
231	*Bambusa* spp. bamboo	sawing stem	flake	large	convex	3	wrapped	15	c,m	dense, parallel	intensive	well developed	tissue
295	*Bambusa* spp. bamboo	sawing stem	flake	large	straight	2	hand	45	b,c,f	dense, parallel	intensive	well developed	tissue
296	*Bambusa* spp. bamboo	sawing stem	stemmed, flake	small	straight	1	bamboo handle	50	b,c,f	dense, parallel	intensive	well developed	tissue
233	*Bambusa* spp. bamboo	whittling stem	flake	large	straight	2	wrapped	15	c,m	dense, diagonal parallel, patchy	medium, patchy	developed, patchy	tissue, needle-like
236	*Bambusa* spp. bamboo	carving stem	flake	large	irregular	2	wrapped	15	b,c,f	dense, parallel	intensive	well developed	tissue
258	*Bambusa* spp. bamboo	scraping stem	flake	large	concave	2	hand	45	c,s	dense, perpendicular, diagonal	intensive	well developed	tissue
141	*Saccharum* spp. sugar cane	cutting/ whittling grass	flake, Kombewa	medium	straight	1	wrapped	5	b,c,f	dense, parallel, isolated	light to medium	light to medium, patchy	tissue
140	*Saccharum* spp. sugar cane	cutting/ whittling grass	flake	large	irregular	2	wrapped	15	b,d/c,f	dense, parallel, some diagonal	intensive	well developed	film, tissue
139	*Saccharum* spp. sugar cane	cutting/ whittling grass	flake	large	irregular	1	wrapped	35	b,c,f	dense, parallel, diagonal	intensive	well developed	film, tissue
105	*Musa* spp. banana	cutting leaves	flake	small	convex	2	hand	5	b,d/c,f	rare, parallel, isolated	very light	none	film, tissue, white
97	*Musa* spp. Banana	cutting leaves, stem	flake	large	irregular	3	wrapped	15	b,c,f	parallel, isolated, few diagonal	light	very light	film, tissue, white

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
106	*Musa* spp. banana	cutting leaves, stem	flake, Kombewa	small	convex	1	hand	15	b,c,f	rare, diagonal	very light	none	film, tissue, white
112	*Musa* spp. banana	cutting leaves, stem	flake, Kombewa	medium	convex	2	wrapped	30	b,c,f	parallel, diagonal, isolated	light	light	film, tissue
100	*Musa* spp. banana	cutting leaves, stem	flake	large	convex	2	wrapped	30	b,c,f	rare, diagonal, few parallel	very light	extremely light	film, tissue, starch, white
178	*Musa* spp. banana	cutting leaves, stem	stemmed, flake	medium	convex	1	wood handle	45	b,c,f	rare, diagonal, parallel, isolated	very light, patchy	very light, patchy	film, tissue
278	*Musa* spp. banana	cutting stem	flake	medium	irregular	1	hand	10	b,d/c,f	rare, diagonal, isolated	very light,	very light, patchy	tissue, starch. needle-like
127	*Musa* spp. banana	Scraping midrib	stemmed, Kombewa	medium	irregular	1	hand	25	b,d/c,f	dense, diagonal, perpendicular	intensive	well developed	film, tissue
116	*Musa* spp. banana	Scraping midrib	flake	large	irregular	2	hand	15	b,c,f	diagonal, perpendicular	intensive	well developed	film, tissue, starch
118	*Asplenium nidus* fern, crow's nest	cutting leaves	flake	large	irregular	3	hand	5	b,d/c,f	relatively dense, diagonal, parallel isolated	light	light	film, tissue, white, white
135	*Asplenium nidus* fern, crow's nest	cutting leaves, stem	flake	medium	convex	1	hand	5	b,c,f	diagonal, patchy	very light to light, patchy	light to developed, patchy	film, tissue, starch, white
136	*Asplenium nidus* fern, crow's nest	cutting leaves, stem	flake	large	convex	2	hand	15	b,d/c,f	dense, diagonal, isolated, patchy	light	light to developed, patchy	film, tissue

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
281	*Asplenium nidus* fern, crow's nest	whittling stem	flake	small	irregular	1	hand	10	b,c,f	diagonal, crossed, isolated	very light	very light, patchy	tissue, starch
104	*Codiaeum variegatum* croton	cutting stem	flake	medium	convex	1	hand	5	b,c,f	diagonal, parallel, crossed, isolated	very light	very light, patchy	film, tissue
108	*Codiaeum variegatum* croton	cutting stem	flake	medium	straight	1	wrapped	15	b,c,f	diagonal, parallel, isolated	light	very light, patchy	film, tissue
107	*Codiaeum variegatum* croton	cutting stem	stemmed, Kombewa	large	convex	2	wrapped	30	b,c,f	diagonal, parallel, shallow	medium, patchy	developed, patchy	film, tissue
5	*Zingiber officinale* ginger	cutting stem	flake	small	irregular	1	hand	5	b,c,f	diagonal, isolated	very light	very light, patchy	film, tissue
12	*Zingiber officinale* ginger	cutting/ slicing stem	flake	medium	straight	2	wrapped	15	b,c,f	dense, parallel	medium	developed	film, tissue, starch, needle-like
217	*Hibiscus manihot* aibika	cutting stem	flake	medium	irregular	2	hand	15	b,d/c,f	parallel, isolated	very light	none	film, tissue, starch, white
36	*Colocasia esculenta* taro	Scraping/ slicing raw tubers	stemmed, Kombewa	large	convex	1	wood handle	5	b,c,f	diagonal, perpendicular, isolated	light to intensive	developed, patchy	film, tissue, starch, needle-like
277	*Colocasia esculenta* taro	slicing raw tubers	flake	large	convex	1	hand	10	b,d/c,f	diagonal, isolated	light	light	film, tissue, starch, needle-like
313	*Colocasia esculenta* taro	cutting raw tubers	flake	small	irregular	1	hand	25	b,c,f	rare, parallel	medium, patchy	developed, patchy	tissue, starch

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
267	*Colocasia esculenta* taro	scraping/ slicing raw tubers	flake	medium	convex	1	hand	10	b,c,f	diagonal, isolated	medium, patchy	light, patchy	tissue, starch
314	*Colocasia esculenta* taro	scraping/ slicing raw tubers	stemmed, Kombewa	medium	convex	3	hand	25	b,c,f	diagonal, isolated	light , patchy	light , patchy	tissue, starch
315	*Colocasia esculenta* taro	slicing roasted tubers	flake	small	straight	2	hand	10	b,d/c,f	diagonal, crossed, isolated	light , patchy	light , patchy	tissue, starch
151	*Colocasia esculenta* taro	scraping roasted tubers	flake	medium	straight	2	hand	15	c,s	diagonal, crossed, isolated	intensive, patchy	developed patchy	charred tissue, starch
149	*Colocasia esculenta* taro	scraping roasted tubers	flake	medium	straight	1	hand	30	b,c,s	perpendicular, diagonal, isolated	light	light , patchy	charred tissue, starch
148	*Colocasia esculenta* taro	scraping roasted tubers	flake	large	irregular	2	hand	30	b,c,f,s	perpendicular, diagonal, crossed, isolated	medium	developed patchy	charred tissue, starch
109	*Colocasia esculenta* taro	cutting taro stem	flake	medium	convex	2	hand	5	b,d/c,f	rare, diagonal, isolated	extremely light, patchy	none	film, tissue, starch, white
102	*Colocasia esculenta* taro	cutting taro leaves	flake	small	convex	1	hand	15	b,d/c,f	rare, diagonal, isolated	very light	none	film, tissue, starch
117	*Colocasia esculenta* taro	chopping taro stem	flake	medium	convex	1	hand	30	b,c,f	rare, diagonal, isolated	none	none	film, tissue, starch, white
310	*Dioscorea esculenta* yam	scraping/ slicing raw tubers	flake	medium	irregular	2	hand	25	b,c,f,s	perpendicular, diagonal	medium	developed patchy	Film, tissue, starch

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
311	*Dioscorea esculenta* yam	scraping/ slicing raw tubers	flake	small	straight	3	hand	10	b,c,f,	diagonal, isolated	light, patchy	light, patchy	tissue
279	*Ipomoea batatas* sweet potato	slicing raw tubers	flake	medium	straight	2	hand	10	b,d/c,f	diagonal, isolated	very light	very light	tissue, starch
312	*Ipomoea batatas* sweet potato	scraping/ slicing raw tubers	flake	small	concave	1	hand	25	c,m	diagonal, parallel, isolated	light, patchy	light, patchy	tissue
Soft elastic material													
76	Parrot fish, *Scaridae*	gutting/ cutting	flake, Kombewa	large	convex	2	wrapped	15	b,c,f	parallel, diagonal, isolated	light to medium, patchy	light to developed, patchy	greasy film, rainbow tissue
263	Salmon fish, *Oncorhynchus gorbuscha*	gutting/ cutting	Flake	medium	convex	2	hand	25	b,c,f	parallel, crossed, isolated	light to medium, patchy	light to developed, patchy	greasy film, rainbow tissue
306	Salmon fish, *Oncorhynchus gorbuscha*	gutting/ cutting	biface	large	convex	2	hand	30	b,d/c,f	diagonal, crossed, isolated	medium, patchy	light to developed, patchy	greasy film, rainbow tissue
305	Salmon fish, *Oncorhynchus gorbuscha*	gutting/ cutting	flake	medium	convex	2	hand	30	b,c,f	diagonal, crossed, isolated	medium, patchy	light to developed, patchy	greasy film, rainbow tissue
308	Wrasse fish, *Labridae*	gutting/ cutting	flake	large	irregular	2	hand	30	b,c,f	diagonal, crossed, isolated	medium, patchy	light to developed, patchy	tissue
307	Wrasse fish, *Labridae*	gutting/ cutting	flake	large	irregular	2	hand	30	b,c,f,s	diagonal, parallel, isolated	medium, patchy	light to developed, patchy	greasy film, rainbow tissue

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
264	Chicken skin	piercing	stemmed, flake	small	straight	1	hand	30	b,d/c,f, few	perpendicular, diagonal, isolated	light to medium	light to developed	greasy film, tissue, blood
265	Chicken skin	cutting	stemmed, flake	small	concave	1	hand	25	b,d/c,f, few	parallel, diagonal, isolated	light to medium	light to developed	greasy film, tissue, blood
266	Chicken skin	cutting/ piercing	flake	small	straight	1	hand	35	b,d/c,f, few	parallel, diagonal, isolated	light to medium	light to developed	greasy film, tissue, blood
55	Human skin	shaving	flake	medium	straight	1	hand	3	b,d/c,f, rare	diagonal, perpendicular, few	very light to light	very light, patchy	greasy film, hair, tissue, blood-like
52	Human skin	shaving	flake	medium	straight	2	hand	3	b,d/c,f, rare	diagonal, few	very light to light	very light, patchy	greasy film, hair, tissue, blood-like
46	Human skin	shaving	flake	large	irregular	2	hand	3	b,d/c,f, rare	diagonal, few	very light to light	very light, patchy	greasy film, hair, tissue, blood-like
319	Human skin	shaving	flake	small	irregular	1	hand	10	b,d/c,f, rare	diagonal, few	very light	extremely light, patchy	greasy film, hair, tissue, blood-like
Hard dense material													
254	Cockle shell, *Katylesia* spp.	sawing	flake	small	irregular	1	hand	5	b,c,f	diagonal, parallel	intensive	well developed	tissue, white

Experiment No.	Type of Worked Material	Mode of Use	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Mode of Hafting	Use Duration in Minutes	Scar Type	Striations, Orientation	Edge Rounding	Polish	Residue Type (before cleaning)
259	Cockle shell, *Katylesia* spp.	sawing	flake	large	irregular	2	hand	15	c,m	dense, diagonal, parallel, flaked, patchy	intensive	well developed, patchy	tissue, white
260	Cockle shell, *Katylesia* spp.	sawing	blade	large	straight	2	hand	2 hours	b,c,s	diagonal, parallel, patchy	intensive	well developed	tissue, white
261	Cockle shell, *Katylesia* spp.	scraping	flake	medium	straight	2	hand	10	b,c,s	perpendicular, dense	intensive	well developed	tissue, white
262	Cockle shell, *Katylesia* spp.	scraping	flake	medium	irregular	2	hand	25	b,c,s	perpendicular, dense	intensive	well developed	tissue, white
256	Cowrie shell, *Cypraeidae* spp.	sawing	blade	large	straight	2	hand	45	c,m	dense, diagonal, parallel, flaked	intensive	well developed	tissue, white
251	Clay	scraping	flake	medium	convex	1	hand	15	b,c,f	perpendicular, diagonal, crossed	intensive	well developed	white, yellow
252	Clay	scraping	flake	medium	irregular	1	hand	15	b,c,f	perpendicular, diagonal, crossed	intensive	well developed	white, yellow

Edge angle refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution.

Table 2. Materials and actions used in experiments.

	Botanical name	Common name	State	Used parts and actions	Number of experiments	Number of analysed experiments
Palms						
	Cocos nucifera	coconut palm	green	frond, spathe, leaf, shell, meat	20	8
				scraping	5	3
				sawing	6	2
				carving	3	1
				engraving	2	0
				whittling/sawing	3	2
				cutting/slicing	2	1
2	*Metroxylon* spp.	sago palm	green	frond, leaf, pith	10	6
				sawing	5	4
				cutting	2	1
				scraping	2	1
				sawing/whittling	1	1
3	*Nypa fruticans*	nypa palm	green	leaf, midrib	2	2
				cutting leaf,	1	1
				sawing midrib	1	1
4	*Caryota* sp.	black palm	green	stem, midrib of leaf, frond	19	10
				scraping	5	4
				sawing	7	3
				whittling	2	1
				chopping	1	0
				sawing/whittling	1	1
				sawing	1	1
				scraping/planing	2	0
5	*Calamus* spp.	rattan or cane	green	vine, stem	13	4
				cutting	6	2
				sawing	3	2
				sawing/whittling	3	0
				sawing/scraping	1	0
6	*Pandanus* spp.	pandanus	green	leaves, flesh	8	6
				cutting	5	5
				piercing	2	1
				cutting/scraping	1	0
7	Non-identified	palm	green	midrib	1	1
				sawing/scraping	1	1
Soft wood						
8	*Artocarpus altilus*	breadfruit	green	sap	4	0
9	*Calophyllum* sp.		green	stem, branches	3	1
				sawing/whittling	3	1
10	*Octomeles sumatrana*	Tok Pisin: "erima"	green	stem, branches	12	7
				sawing	3	3
				whittling	3	2
				carving	4	0
				scraping/sawing	1	1
				sawing/carving	1	1
11	*Hibiscus tiliaceuas* L.	cottonwood, hibiscus	green	stem, branches, bark	20	8
				whittling	6	4
				carving	2	2
				engraving	1	1
				cutting	3	0
				sawing	6	0

	Botanical name	Common name	State	Used parts and actions	Number of experiments	Number of analysed experiments
12	*Homalium foetidum*	Tok Pisin: "malas"	half dry and green	stem, branches sawing carving chopping engraving scraping/planing	8 3 1 1 2 1	5 3 1 1 0 0
13	*Toona ciliata* (syn. Cedrela toona)	red cedar	green	stem, branches carving	3 3	2 2
14	*Ficus* sp.	fig	green	branches whittling	1 1	1 1
15	Soft wood	non-identified	green	stem, branches whittling smoothing sawing carving whittling/sawing scraping/planing drilling	14 3 1 3 3 2 1 1	6 2 1 1 0 1 0 1
Hard wood						
16	*Casuarina* sp.	horsetail oak	green	stem, branches, bark whittling sawing scraping	4 1 2 1	1 1 0 0
17	*Pometia pinnata*	ton, Tok Pisin: "taun"	green	stem, branches whittling scraping	4 3 1	4 3 1
18	*Mangifera indica*	bush mango, Tok Pisin: "wil mango"	green	stem, branches sawing	3 3	2 2
19	*Eucalyptus* sp.	eucalypt	dry and green	stem, branches sawing	2 2	2 2
20	Non-identified	sandalwood	green	branches sawing	1 1	1 1
21	Non-identified	"lipi"	green	branches scraping/whittling	1 1	1 1
22	Non-identified		dry and green	stem, branches sawing sawing/whittling	2 1 1	2 1 1
Non-woody plants						
23	*Bambusa* spp.	bamboo	green tall grass	stem, leaf sawing whittling scraping carving cutting cutting/whittling	19 8 4 1 3 3 1	7 4 1 1 1 0 0
24	*Saccharum* spp.	sugar cane	green grass	grass cutting/whittling whittling/scraping/ sawing/whittling	6 3 1 2	3 3 0 0
25	*Musa* spp.	banana	green tall herb	leaves, stem, flesh cutting scraping cutting/slicing	14 7 5 2	9 7 2 0
26	*Asplenium nidus*	Crow's Nest Fern	green	stem, leaves cutting whittling splitting	5 3 1 1	4 3 1 0
27	*Codiaeum variegatum*	Tok Pisin: "croton"	green	stem, leaves cutting	5 5	3 3

	Botanical name	Common name	State	Used parts and actions	Number of experiments	Number of analysed experiments
28	*Zingiber officinale*	ginger	green herb	stem, leaves	7	2
				cutting	5	1
				cutting/slicing	2	1
29	*Hibiscus manihot*	Tok Pisin: "aibika"	green	stem, leaves	2	1
				cutting	2	1
30	*Colocasia esculenta*	taro	raw and cooked	tubers, stem, leaves	22	12
				scraping	5	4
				cutting	9	5
				slicing	1	2
				scraping/slicing	5	2
				cutting/slicing	2	0
31	*Dioscorea esculenta*	yam	raw and cooked	tubers	3	2
				scraping/slicing	3	2
32	*Ipomoea batata*	sweet potato	raw	tubers	2	2
				slicing	1	1
				scraping/slicing	1	1
Soft elastic material						
33	Fish: parrot, salmon, wrasses		raw	skin and scales	6	6
				gutting/cutting	6	6
34	Human skin			shaving	8	4
35	Chicken skin		raw	skin	3	3
				cutting	1	1
				piercing	1	1
				cutting/piercing	1	1
Hard dense material						
36	Shell: Cowrie *and cockle*			shell	6	6
				sawing	4	4
				scraping	2	2
37	Clay		half-dry	scraping	2	2
Surface preservation after 22 months						
40	Non-used flakes			buried within soil deposits		
41	Used flakes			buried within soil deposits		
	TOTAL				290	154

Table 3. Plant remains recovered from archaeological sites (1–5), modern plants (6) and their uses (7–13).

Plants	Arawe Islands	Mussau Islands	Watom Island	Garua Island, FAO	Present Data, New Britain	Tools/ weapons	Canoes/ rafts	Building house/ shelter	Cordage, barkcloth, textile	Food	Medicine	Ritual, ceremonial, decoration
Aleurites moluccana (candlenut)	●	●			●					●		●
Alstonia spathulata (swamp forest)			●		●		●	●			●	
Annonaceae				●	●					●		●
Bambusa spp. (bamboo)				●	●	●	●	●		●		●
Bruguiera		●			●					●		
Burckella obovate	●	●			●					●		●
Callophyllum inophullum	●				●		●	●			●	●
Canarium indicum	●	●			●		●	●		●	●	
Canarium spp.	●	●	●	●	●		●			●		●
Caryota rumphiana (fishtail palm)				●	●	●		●		●		
Casuarina equisetifolia	●	●			●	●		●			●	●
Cocos nucifera	●	●	●		●	●	●	●	●	●	●	●
Compositae				●	●	●						
Cordia subcordata	●	●			●							
Corynocarpus cribbeanus		●			●							
Cycas circinalis	●	●			●						●	●
Cyperaceae				●	●	●						
Dracontomelondao	●	●			●							●
Dioscorea (yam)				●	●					●		
Ficus spp. (Moraceae)				●	●	●	●	●	●	●	●	●
Heliconia sp.				●	●			●		●		
Heritiera littoralis (wet habitat)			●		●							
Imperata cyclindrica (Poaceae)				●	●			●			●	
Incarpus fagiferus (taitian chestnut)	●	●			●					●		
Metroxlyn sp. (sago palm)	**?**				●	●		●		●		
Morantaceae				●	●				●	●		
Musa spp. (bananas)				●	●		●	●	●	●	●	●
Nypa fruticans		●	**?**		●			●		●		
Pandanus sp. (screwpine)	●	●			●	●	●	●	●	●	●	●
Pangium edule	●	●			●							
Panicoideae				●	●							
Poacea				●	●					●	●	●
Pometia pinnata		●			●			●		●		
Spondias dulcis (vi apple)	●	●			●					●		●

Plants	Arawe Islands	Mussau Islands	Watom Island	Garua Island, FAO	Present Data, New Britain	Tools/ weapons	Canoes/ rafts	Building house/ shelter	Cordage, barkcloth, textile	Food	Medicine	Ritual, ceremonial, decoration
Streculia sp.	**?**				●			●	●	●		●
Terminalia catappa (indian almond)	●	●	●		●					●		
Syzygium				●	●	●			●	●	●	●
Zingiberaceae				●	●					●	●	●
Reference:	1	2	3	4	5	6	7	8	9	10	11	12

(1) Gosden *et al*., 1989; *(2)* Kirch, 1991, 1997: 203–212; *(3)* Specht, 2003; Spriggs, 1997:79; *(4)* Barton *et al*., 1998; Kealhofer, 1995; 2003:294–300; *(5–12)* Floyd, 1954; Powell, 1976:106–183; Lentfer, 1995.

Table 4. Radiocarbon dates from the FAO archaeological site (Torrence & Stevenson, 2000; Lentfer & Torrence, 2007; Petrie & Torrence, 2008).

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

Table 5. FAO site. Distribution of obsidian artefacts within test pits.

A. Middle Holocene – Layer 6							W-K2 catastrophic event	B. Late Holocene – Layer 8					
Test Pit	TOTAL	Spit 5	Spit 4	Spit 3	Spit 2	Spit 1		Spit 4	Spit 3	Spit 2	Spit 1	TOTAL	Test Pit
1000/1000	358	56	106	6	10	180		4	27	44	33	108	1000/1000
1001/1000	9				7	2			15	9	5	29	1001/1000
1000/999	38			2	36				3	6	7	16	1000/999
1001/999	0								22	4	3	29	1001/999
990/1000	72				24	48				24	13	37	990/1000
980/1000	70			7	8	55			23	16	20	59	980/1000
970/1000	285		27	92	61	105			199	54	32	285	970/1000
1010/1000	6					6					10	10	1010/1000
1000/1010	897		6	17	271	603			12	31	28	71	1000/1010
1000/1020	2					2				6	38	44	1000/1020
1000/990	28				8	20			4	17	26	47	1000/990
989/1020	6				6			14	28	9	10	61	989/1020
989/1010	40				5	35			4	55	78	137	989/1010
990/990	22				7	15		22	43	82	27	174	990/990
990/980	30				3	27				36	10	46	990/980
990/970	3					3			9	22	14	45	990/970
962/990	112				46	66					61	61	962/990
A	27			14	6	7						0	A
B	30				14	16				2	1	3	B
C	8					8			7	17	11	35	C
TOTAL	2043	56	139	138	512	1198		40	396	434	427	1297	TOTAL
%	100	2.7	6.8	6.8	25.1	58.6		3.1	30.5	33.5	32.9	100	%

Table 6. Type of artefacts and wear patterns from 970/1000 test pit, Layer 8 (the late Holocene).

M# 970	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
312	1	flake	medium	irregular a, b	2	absent	medium pitted	b,c,f	a, b – parallel, dense	medium, intensive, patchy	developed, well developed, patchy	a, b – sawing	siliceous, soft wood, palm, bamboo	d	short	tissue, starch	
2023	1	blade-like flake	medium	straight	3	present	medium	a – b,d/c,f b – b,d/c,f	a – parallel, b – diagonal, dense	a – intensive, b – medium	a,b – developed, patchy	a – sawing, b – whittling	siliceous, soft wood, palm, bamboo	d	short	tissue	
1933	2	flake	medium	a,b – concave	2	present	low pitted	b,c,f,s	perpendicular, diagonal, dense	a – intensive, b – medium	a – well developed, b – light	both edges – scraping	siliceous, soft wood, palm, bamboo	d	short	starch, tissue	
324	3	blade-like flake	medium	irregular	2	absent	low pitted	b,c,f,	diagonal, dense	medium	well developed, patchy	whittling	siliceous, soft wood, palm, bamboo	d	short, wrapped	white, starch	
328	3	blade-like flake	medium	a – straight, b – convex	2	absent	low pitted	b,c,f	a – diagonal, parallel, b – parallel, dense	medium, intensive, patchy	well developed, patchy	a – whittling/ sawing, b – cutting (burin, carving)	siliceous, soft wood, palm, bamboo	d	short, probably wrapped	tissue, white, starch	
331	3	flake	small	convex	1	absent	low pitted	b,d/c,f	diagonal, dense	slight to medium, patchy	well developed, patchy	whittling	siliceous, soft wood, palm, bamboo	d	short	starch	129
333	3	flake	small	convex	2	present	medium pitted	b,d/c,f	dense, parallel, slightly	intensive	well developed	sawing	siliceous, soft wood, palm,	d	short	starch	132

M# 970	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
									diagonal				bamboo				
336	3	flake	large	a,b,c,d – irregular	2	absent	low to medium pitted	b,c,f, burin spall	a – diagonal, b – parallel, c – diagonal, d – diagonal, parallel, dense	medium to intensive, patchy	well developed, patchy	a – whittling, b – sawing, c – whittling, d – both whittling/ sawing	siliceous, soft wood, palm, bamboo probably processing resinous plants like breadfruit, *Calophyllum*	d	moderate and intensive use in various actions for the same material wrapped, probably in palm leaves	starch, palm (P), 65% palm phytolith (K)	117, 135
1919	3	core	medium	irregular	3	present	low pitted	b,c,s	diagonal, dense	intensive, patchy	well developed	scraping	siliceous, soft wood, palm, bamboo	d	short	tissue	
1946	3	blade-like flake	medium	a,b – straight	2	absent	low pitted	a – b,c,f,s b – b,c,f	a – perpendicular, b – parallel, dense	intensive, patchy	well developed	carving: scraping/ cutting	siliceous, soft wood, palm, bamboo	d	short	starch	134
2028	3	flake, broken during use	medium	straight	2	absent	low pitted	b,c,f	diagonal, dense	intensive	well developed	whittling	siliceous, soft wood, palm, bamboo	d	short	tissue, starch	
2032	3	flake	small	straight	1	present	low pitted	b,c,f	diagonal, parallel, dense	medium, patchy	light, patchy	whittling	siliceous, soft wood, palm, Bamboo	d	short	tissue	
2034	3	flake	small	straight	1	absent	low pitted	b,c,s	perpendicular, dense	medium	light	scraping	siliceous, soft wood, palm,	d	short	tissue, starch	133

M# 970	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
													bamboo				
2036	3	flake	small	straight	1	present	low pitted	b,c,s	perpendicular, dense	medium	light	scraping	siliceous, soft wood, palm, bamboo	d	short	tissue, starch	
2037	3	flake	small	irregular	1	absent	low pitted	b,c,s	diagonal, dense	slight	light	scraping	siliceous, soft wood, palm, bamboo	d	short	tissue, starch	
2040	3	flake	medium	convex	3	present	low pitted	b,c,f,s	perpendicular, dense	medium	developed	scraping	siliceous, soft wood, palm, bamboo	d	short	none	
2041	3	flake	small	convex	2	absent	low pitted	b,c,f	diagonal, dense	intensive	well developed	whittling/ carving	siliceous, soft wood, palm, bamboo	p	short	tissue, starch	
Siliceous hard wood and hard palm																	
1922	3	flake	large	concave, a,b,c	3	absent	low pitted	b,c,f,s	a – parallel, dense b,c – perpendicular	slight, patchy	developed, patchy	a – sawing, b,c – scraping	siliceous, hard wood, palm	p	short	tissue, rare starch	150
1925	3	flake	large	a – irregular b – straight	a-2 b-3	absent	low pitted	a,b – b,c,f	a,b – parallel, dense	intensive, patchy	well developed, patchy	a,b – sawing	siliceous, hard wood, palm	d	moderate	tissue, starch	149
2027	3	flake	large	irregular	3	present	low pitted	b,c,f	diagonal, parallel, dense	intensive, patchy	well developed, patchy	whittling/ sawing by the same edge	siliceous hard wood, palm	d	short, probably wrapped	tissue, starch	
Non-siliceous soft wood																	
1923	1	flake	small	convex	3	present	low	c,f,s	perpen-	slight	very light	scraping	non-	p	short	tissue	

M# 970	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
							pitted		dicular, diagonal, Isolated				siliceous, soft wood				
1924	1	flake	large	a – concave, b – straight, c – straight	2	absent	heavy pitted	a – c,f,s, b – b,d/c,f c – b,c,f	a – perpendicular, diagonal, b – parallel, c – parallel, diagonal	a – intensive, b – slight, c – slight	a – developed, b,c – very light	carving: a – scraping, b – sawing, c – whittling/ cutting	non-siliceous, soft wood	d	short	tissue, starch	160
2022	1	flake	small	a – straight, b – concave	2	present	medium pitted	a – b,c,f b – b,c,s	a – diagonal, isolated, b – perpendicular, diagonal, isolated	a – intensive b – medium	a – developed, b – light	carving: whittling/ cutting, scraping	non-siliceous, soft wood	d	short	tissue	156,158
2024	1	flake	large	a – concave, b – straight	2	present	low pitted	a,b – b,d/c,f	a,b – diagonal, isolated	slight to medium patchy	light to developed, patchy	whittling	non-siliceous, soft wood	d	short	none	
2025	2	flake	medium	concave	2	absent	low pitted	b,d/c,f	diagonal, perpendicular, Isolated	slight, patchy	light, patchy	whittling	non-siliceous, soft wood	d	short	tissue, starch	154
2026	2	flake	small	irregular	2	absent	low pitted	b,c,f	diagonal, perpendicular, isolated	medium to intensive, patchy	developed, patchy	carving/ whittling	non-siliceous, soft wood	d	moderate	tissue	159
325	3	flake with retouc	large	straight	2	absent	heavy pitted	b,c,f	diagonal, isolated	intensive	developed, patchy	whittling	non-siliceous, soft wood	d	moderate, wrapped	starch (P), palm	

M# 970	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
		h														phytolith (K)	
326	3	flake	medium	straight	2	absent	low pitted	b,c,f	diagonal, isolated	slight	light	whittling	non-siliceous, soft wood	d	short	white, tissue, starch	124, 153
1936	2	flake	medium	straight	2	absent	medium pitted	b,c,f	diagonal, isolated,	medium	developed	whittling	non-siliceous, soft wood	d	short	none	
1938	3	flake	large	a – irregular, b – convex	2	absent	low pitted	b,c,f	a – diagonal, b – parallel, diagonal, isolated, moderate	slight to intensive, patchy	light to developed, patchy	a – whittling, b – whittling/ sawing	non-siliceous, soft wood	d	moderate	tissue	157,163
1945	3	flake	medium	irregular	2	absent	low pitted	b,c,f	diagonal, isolated, moderate	slight, patchy	very light, patchy	whittling	non-siliceous, soft wood	p	short	tissue	
2033	3	flake	small	concave	1	present	low pitted	b,c,f	parallel, crossed, isolated	slight	very light	whittling/ sawing	non-siliceous, soft wood	p	short	none	155
2038	3	flake	medium	straight	1	present	low pitted	b,d/c,f	diagonal, isolated	slight	light	whittling	non-siliceous, soft wood	d	short	tissue	
Non-siliceous hard wood																	
334	3	flake	medium	a – concave, b – irregular	2	absent	heavy pitted	a – b,c,f,s b – b,c,f	a – perpen-dicular b – parallel	slight to medium, patchy	light to developed, patchy	a – scraping, b – sawing	non-siliceous, hard wood	u	short	starch	125, 174
1942	3	flake	medium	straight	3	present	low pitted	b,c,f,s	diagonal, perpen-dicular,	slight to intensive, patchy	developed, patchy	scraping	non-siliceous, hard wood	d	short	tissue, starch	173

M# 970	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
									Isolated								
Non-woody plants (tubers)																	
1930	1	flake	large	convex	3	present	low pitted	b,c,f	diagonal, perpendicular, isolated	intensive	well developed, merging	scraping/ slicing	non-woody plants (tubers)	d	long-term	starch	182
310	1	flake	large	concave	3	absent	low pitted	b,c,f,s	diagonal, perpendicular, isolated	slight to medium, patchy	light, patchy	scraping/ slicing	non-woody plants (tubers)	d	long-term, probably wrapped, bamboo phytolith	starch (P), needle-like, *Dioscorea* (K)	186
317	1	blade-like flake	medium	a – convex, b – irregular	a, b-1	absent	low pitted	a,b – b,c,f	diagonal, perpendicular, parallel, isolated	intensive	developed, patchy, merging	scraping/ slicing, both edges	non-woody plants (tubers)	d	long-term, probably wrapped, arboreal phytolith	starch, probably tubers (P)	188
1921	2	flake with retouch edge rejuvination	large	a,b,c,d, irregular	c, d-2, a, b-3	absent	medium pitted	b,c,f,s	all edges diagonal, perpendicular, moderate, isolated	medium to intensive, patchy	light to developed, patchy	scraping/ slicing	non-woody plants (tubers)	d	long-term use with edge resharpening	starch, tissue	119A, 187
1926	3	flake	small	concave	3	absent	medium pitted	b,c,f,s	diagonal, isolated	intensive	developed, merging	scraping	non-woody plants (tubers)	p	short	tissue	
2030	3	flake	medium	a – convex, b – concave	a-2 b-3	absent	low pitted	b,c,f,s	both – diagonal, perpendicular, isolated	medium	developed, patchy	scraping	non-woody plants (tubers)	d	moderate	starch	
2039	3	flake	small	straight	1	present	low pitted	b,c,f	parallel, diagonal,	slight, patchy	light, patchy	slicing/ peeling	non-woody	d	short	starch	

M# 970	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
									isolated				plants (tubers)				
Non-woody plants (greens)																	
1929	1	flake	medium	a – convex, b – straight	2	absent	medium pitted	a,b – b.d/c,f	parallel, isolated	medium	light	cutting	non-woody plants (greens)	p	moderate	tissue, starch	190
313	1	flake	large	irregular	3	present	low pitted	b,c,f	diagonal, perpendicular, isolated	medium to intensive	developed, merging, patchy	scraping	non-woody plants (greens)	p	moderate, probably wrapped	starch, arboreal phytolith (K)	
470	2	flake	small	convex	1	absent	low pitted	b.d/c,f	diagonal, isolated	medium	light	cutting	non-woody plants (greens)	p	short	starch	192
1941	3	flake	medium	a,c – concave, b – straight	1	absent	low pitted	b.d/c,f	a – diagonal, b,c – parallel, isolated	medium	light	cutting/ slicing	non-woody plants (greens)	d	moderate	tissue	189
2029	3	flake	medium	convex	1	absent	low pitted	b,c,f	parallel, diagonal, isolated, moderate	medium to intensive	developed to well developed	cutting/ slicing	non-woody plants (greens)	d	moderate to long-term	tissue	193
2031	3	flake	small	irregular	1	present	low pitted	b,c,f	diagonal, dense	intensive, patchy	well developed, patchy	cutting/ splitting	non-woody plants (greens)	p	short to moderate	tissue	191
Soft elastic material (skin, fish)																	
469	2	pointed flake	small	irregular, snapped tip	1	absent	low pitted	b,c	parallel to side-edge, diagonal, Isolated	intensive	developed, merging	piercing	soft elastic material (skin)	d	long-term	rainbow residues	207
1934	2	flake	small	straight	2	absent	heavy	c,f,s	none	medium	none	none	possibly	u	none	none	

M# 970	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
							pitted						soft elastic material (skin)				
322	3	pointed flake	small	straight, snapped tip	1	present	low pitted	b,d/c	parallel to side-edge, diagonal, isolated	intensive	developed, merging	piercing	soft elastic material (skin)	d	moderate to long-term	none	205
1939	3	flake	medium	convex	2	present	low pitted	b,d/c,f	parallel, diagonal, isolated	medium	developed, merging	gutting/ cutting	soft elastic material (fish)	d	moderate	blood-like, white	208
1940	3	Kombewa flake	medium	irregular	2	absent	medium pitted	b,c,f	parallel, diagonal, isolated	medium	developed, merging	gutting/ cutting	soft elastic material (fish)	d	moderate	blood-like, white, rainbow, tissue	209
2035	3	flake broken during use	meium	straight	2	present	low pitted	b,c,f	diaonal, parallel, isolated	medium	developed, merging	gutting/ cutting	soft elastic material (fish)	d	moderate	white, rainbow	

Edge angle refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution. Source references abbreviated as follows: *(B)* Barton *et al.*, 1998), *(F)* Fullagar, pers. comm., *(K)* Kealhofer *et al.*,1998, *(P)* Parr, pers. comm.

Table 7. Type of artefacts and wear patterns from 1000/1000 test pit, Layer 8 (the late Holocene).

M# 1000/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
1916	2	flake	medium	irregular	2	present	low pitted	b,d/c,f	diagonal, parallel, isolated	medium	light	whittling	siliceous, soft wood, palm, bamboo	d	short	tissue, starch (P)	130
1917	2	flake	medium	straight	2	absent	medium pitted	b,c,f	parallel, isolated	intensive	well developed, patchy	sawing	siliceous, soft wood, palm, bamboo	d	short	tissue, starch (P)	131
125	3	flake	small	a,b – straight	1	absent	low pitted	b,c,f	a – perpendicular, b – parallel, dense	medium	developed, patchyt	a – scraping b – sawing	siliceous, soft wood, palm, bamboo	p	short	white	126
126	3	flake	small	a – irregular b - convex	1	absent	low pitted	b,c,f,s	diagonal, flaked, dense	intensive, patchy	well developed, patchy	a,b – scraping	siliceous, soft wood, palm, bamboo	d	short	white, starch (P), tissue (P) like Pandanus	127
1913	3	blade-like flake	medium	irregular	3	absent	low pitted	b,c,f,s	diagonal, dense	intensive, patchy	well developed, patchy	scraping/ whittling	siliceous, soft wood, palm, bamboo	d	short	tissue, starch	128
Non-siliceous soft wood																	
112	1	flake	large	a,b,c – concave	3	present	low pitted	b,c,s	diagonal, perpendicular, Isolated	slight to medium	very light to medium	a,b,c – scraping/ whittling	non-siliceous, soft wood	d	short	starch (B), tissue (P), white	

M# 1000/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
113	1	flake	medium	a,b – concave, c – straight	3	absent	low pitted	b,c,s	diagonal, perpendicular, isolated	intensive	developed	scraping	non-siliceous, soft wood	d	short	phytolith, palm (P), starch	
118	2	flake	medium	a,b – convex, c – concave	2	absent	low pitted	b,c,f	a,b – parallel, crossed c – diagonal, isolated	medium, intensive	developed, patchy	a,b – whittling/ sawing c – whittling (carving)	non-siliceous, soft wood	d	moderate	white, starch, probably *Canarium* (P)	162
1915	1	flake	large	irregular	3	present	medium pitted	b,c,f	diagonal, isolated	medium	light	whittling	non-siliceous, soft wood	p	short	tissue, starch	
2045	3	flake, broken during use	small	a – straight, b – convex	2	absent	low pitted	b,c,f,s	a – perpendicular, b – parallel, fern-like, isolated	medium, b – slight	developed, b – light	a – scraping, b – sawing	non-siliceous, soft wood	d	moderate	tissue, starch	161
Non-siliceous hard wood																	
114	1	flake	medium	a – concave, b,c – convex	2	absent	low pitted	b,c,f	diagonal, c – perpendicular, isolated	medium	developed, light, patchy	a,b – sawing, c – scraping	non-siliceous, hard wood	p	short	starch, white	175
1914	3	flake	medium	straight	1	absent	low pitted	b.c,f	diagonal, parallel, isolated	slight	light	cutting/ slicing	non-woody plants (tubers)	d	moderate	tissue, starch (P)	184
2046	3	flake	large	a – concave, b – convex	a-1, b-2	absent	low pitted	b,c,f,s	diagonal, perpendicular, crossed	intensive	well developed	a,b – scraping/ slicing	non-woody plants (tubers)	d	long-term, probably wrapped	starch	185

[Footnotes for Table7]. *Edge angle* refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution. Source references abbreviated as follows: *(B)* Barton *et al.*, 1998), *(F)* Fullagar, pers. comm., *(K)* Kealhofer *et al.*,1998, *(P)* Parr, pers. comm.

Table 8. Type of artefacts and wear patterns from 980/1000 test pit, Layer 8 (the late Holocene).

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
2107	1	flake	medium	straight	2	present	low pitted	b,c,f	diagonal, dense	medium	developed	whittling/ sawing	siliceous, soft wood, palm, bamboo	d	short	tissue, white	
2108	1	flake broken during use	small	straight	2	present	low pitted	b,c,f	diagonal, dense	intensive	well developed	whittling	siliceous, soft wood, palm, bamboo	d	short	tissue	
2110	2	flake broken during use	medium	straight	2	absent	low pitted	b,c,f	parallel, diagonal, dense	intensive	well developed	whittling/ sawing	siliceous, soft wood, palm, bamboo	p	short	tissue	
2111	2	flake	medium	a – convex, b – concave	2	absent	medium pitted	b,c,s	diagonal, perpen-dicular, parallel, dense	intensive	developed	scraping/ sawing	siliceous, soft wood, palm, bamboo	d	short	tissue	
2112	2	flake	medium	convex	3	present	low pitted	b,c,f	parallel, diagonal, dense, few flaked	intensive	light	whittling/ sawing	siliceous, soft wood, palm, bamboo	d	short	tissue	142
2113	2	flake	medium	irregular	2	present	medium pitted	b,c,f	parallel, dense	intensive	developed	sawing	siliceous, soft wood, palm, bamboo	d	short	tissue	

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
2116	3	flake	large	straight	2	present	heavy pitted	b,c,f	diagonal, parallel, isolated	slight	none	whittling/ sawing	siliceous, soft wood, palm, bamboo	u	short	tissue	145
Non-woody plants (tubers)																	
2115	3	flake	small	convex	2	absent	low pitted	b.c,f,s	diagonal, isolated	medium	well developed, patchy	scraping	non-woody plants (tubers)	d	moderate	starch, tissue	
Soft elastic material (skin, fish)																	
2109	1	pointed flake	medium	straight	2	absent	low pitted	b,d/c,f	diagonal, isolated	slight	light	cutting/ piercing	soft elastic material (skin)	d	moderate	blood-like	
Dense, hard material (shell, clay)																	
2114	3	flake, broken during use	large	a,b – irregular	3	absent	heavy pitted	b,c,f,s	parallel, dense	intensive	well developed	sawing	dense, hard material (shell)	p	moderate	white	223

Edge angle refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution. Source references abbreviated as follows: *(B)* Barton *et al.*, 1998), *(F)* Fullagar, pers. comm., *(K)* Kealhofer *et al.*,1998, *(P)* Parr, pers. comm.

Table 9. Type of artefacts and wear patterns from 990/1000 test pit, Layer 8 (the late Holocene).

M# 990/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
2144	1	flake	medium	convex	2	present	low pitted	b,c,f	parallel, diagonal, isolated	medium	developed, patchy	cutting/ whittling	siliceous, soft wood, palm, bamboo	d	short	starch	
2140	1	pointed flake	large	irregular	3	absent	low pitted	b,c,f,s	rotational, parallel, dense, flaked	intensive, patchy	developed, patchy	drilling	siliceous, soft wood, palm, bamboo	d	short	tissue, starch	136
Non-silicious soft wood																	
2141	2	flake	medium	irregular	1	present	low pitted	b,c,f	diagonal, isolated	intensive	developed, patchy	whittling	non-siliceous, soft wood	d	short	tissue	
2142	2	flake	small	straight	1	absent	low pitted	b,c,f	diagonal, isolated	slight	very light	whittling	non-siliceous, soft wood	p	short	tissue	
Soft elastic material (skin, fish)																	
2143	2	flake	small	straight	1	absent	low pitted	b,d/c,f	diagonal, isolated	slight to moderate	light to developed	cutting	soft elastic material (skin)	p	moderate	none	

Table 10. Type of artefacts and wear patterns from 1001/999 test pit, Layer 8 (the late Holocene).

M# 1001/999	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
2102	1	flake	large	irregular	2	present	low pitted	b,c,f	diagonal, dense	intensive	well developed	whittling	siliceous, soft wood, palm, bamboo	d	short	tissue	
2103	1	flake	medium	straight	3	absent	medium pitted	b,c,f,s	diagonal, perpendicular, dense	intensive	developed, patchy	scraping	siliceous, soft wood, palm, bamboo	d	short	tissue	
2106	2	flake	large	a – straight b – convex	a-2, b-3	absent	low pitted	a – b,c,f, b – b,c,f,s	a – diagonal, dense, b – perpendicular, diagonal	a – medium, b – intensive	a,b – developed	a – whittling b – scraping	siliceous, soft wood, palm, bamboo	d	short	tissue	
Non-woody plants (tubers)																	
2105	3	flake	small	a,c – concave, b – convex	2	absent	low pitted	b.c,f,s	diagonal, perpendicular,	intensive	developed	scraping, 3 edges	non-woody plants (tubers)	d	moderate	starch,	183
Soft elastic material (skin, fish)																	
2104	2	pointed flake	medium	straight	1	absent	low pitted	b,d/c,f	parallel, perpendicular, isolated	intensive	developed, merging	piercing	soft elastic material (skin)	d	long-term	red, blood-like	206

Table 11. Type of artefacts and wear patterns from 1000/999 test pit, Layer 8 (the late Holocene).

M# 1000/999	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
2101	3	flake	small	straight	2	present	low pitted	b,c,f,s	diagonal, perpendicular, dense	intensive	developed	scraping	siliceous, soft wood, palm, bamboo	d	short	starch	

Edge angle refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution. Source references abbreviated as follows: *(B)* Barton *et al.*, 1998), *(F)* Fullagar, pers. comm., *(K)* Kealhofer *et al.*,1998, *(P)* Parr, pers. comm.

Table 12. Type of artefacts and wear patterns from 970/1000 test pit, Layer 6 (the middle Holocene).

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
339	1	flake	large	straight	2	absent	medium to heavy pitted	b,c,f	diagonal, isolated	intensive, patchy	developed, patchy	whittling	siliceous, soft wood, palm, bamboo	d	moderate	tissue, starch, (K,P)	
1994	1	flake	large	a – irregular b – convex	2	present	heavy pitted	b,c,f	diagonal, dense	intensive, patchy	developed, patchy	whittling	siliceous, soft wood, palm, bamboo	d	short	tissue	144
1997	1	flake	medium	irregular	2	present	medium pitted	b,c,f	diagonal, dense	intensive, patchy	well developed, patchy	whittling	siliceous, soft wood, palm, bamboo	d	short	tissue	139
2007	1	blade-like flake	large	straight	2	absent	low to medium pitted	b,c,f,	parallel, diagonal, dense	intensive	well developed	cutting/ whittling	siliceous, soft wood, palm, bamboo	d	moderate	tissue, black residue	
356	2	flake	medium	irregular	2	absent	medium pitted	b,c,f	diagonal, dense	intensive, patchy	well developed, patchy	whittling	siliceous, soft wood, palm, bamboo	d	short,	tissue	
2051	2	flake	medium	irregular	2	absent	medium pitted	b,c,f	diagonal, dense	intensive, patchy	well developed, patchy	whittling	siliceous, soft wood, palm, bamboo	d	short	tissue	
1965	2	flake	large	concave	2	absent	medium	b,c,f,s	perpen-	intensive,	well	scraping	siliceous,	d	short	tissue	146

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
							pitted		dicular, parallel, dense	patchy	developed, patchy		soft wood, palm, bamboo				
1966	2	flake	large	a – convex, b – irregular, c – convex	2	present	heavy pitted	b,c,f,s	a – diagonal, parallel, b – diagonal, parallel c – diagonal	medium to intensive, patchy	well developed, patchy	a – scraping/ sawing, b – whittling/ sawing, c – whittling	siliceous, soft wood, palm, bamboo	d	short	tissue, white residues	
2010	3	flake, broken tip	small	straight	1	absent	medium pitted	b,d/c,f	parallel, perpen-dicular, dense	intensive	well developed	scraping/ cutting	siliceous, soft wood, palm, Bamboo	d	short	tissue, white	147
2011	3	flake	small	straight	1	present	low pitted	b,c,f	diagonal, dense	medium	developed	whittling	siliceous, soft wood, palm, bamboo	d	short	tissue	
2012	3	blade-like flake	medium	convex	1	present	medium pitted	b,c,f	parallel diagonal, dense	intensive, patchy	developed, patchy	whittling/ sawing	siliceous, soft wood, palm, bamboo	d	short	tissue	
2013	3	flake	small	irregular	1	present	medium to heavy pitted	b,c,f	parallel diagonal, dense	intensive, patchy	well developed, patchy	carving	siliceous, soft wood, palm, bamboo	d	short	tissue	148
2016	4	flake	large	convex	3	absent	medium pitted	b,c,f	parallel, diagonal,	intensive	well developed	whittling/ sawing	siliceous, soft	d	short	tissue, starch	140

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
									dense				wood, palm, bamboo				
Siliceous hard wood and hard palm																	
1979	1	flake	large	irregular	3	absent	low pitted	b,c,f,s	perpendicular, dense	intensive, patchy	well developed, patchy	scraping	siliceous, hard wood, palm	d	short	tissue, starch	151
1989	3	flake, broken during use	large	straight	3	present	medium to heavy pitted	b,c,f,s	perpendicular, dense	intensive, patchy	developed, patchy	scraping	siliceous, hard wood, palm	d	moderate	tissue	
367	3	stemmed tool, flake	large	a – straight, b – concave	3	absent	medium to heavy pitted	a – b,c,f b – b,c,f,s	a – diagonal, b – diagonal, perpendicular, dense	intensive, patchy	well developed, patchy	a – whittling b – scraping	siliceous, hard wood, palm	d	moderate, wood hafted	tissue, starch (P)	118
1955	3	flake	medium	concave	3	present	heavy pitted	b,c,f,s	perpendicular, parallel dense	intensive, patchy	well developed, patchy	scraping/sawing	siliceous, hard wood, palm	d	short	tissue	
1976	4	flake	large	a – irregular, b – concave	3	present	medium to heavy pitted	a – b,c,f b – b,c,f,s	a – parallel, diagonal, dense, b – perpendicular, dense	intensive, patchy	well developed, patchy	a – whittling/sawing b – scraping	siliceous, hard wood, palm	d	short	tissue	152
1978	4	flake	large	concave	3	present	heavy pitted	b,c,f,s	parallel, dense	intensive, patchy	developed, patchy	sawing	siliceous, hard wood, palm	d	short	tissue	

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Non-siliceous soft wood																	
1949	2	blade-like flake	large	irregular	2	present	heavy pitted	b,c,f,	parallel isolated	medium	light	sawing	non-siliceous, soft wood	d	short	tissue	
1951	2	flake, broken during use	medium	convex	1	absent	medium pitted	b,c,f	diagonal, dense	intensive, patchy	developed, patchy	Scraping/ sawing	non-siliceous, soft wood	d	short	tissue	170
1952	2	flake, broken during use	small	a,b – straight	2	absent	low to medium pitted	a – b,c,s b – b,c,f	diagonal, perpen-dicular, b – parallel, isolated	slight	light, patchy	a – scraping, b – sawing	non-siliceous, soft wood	d	short	tissue	
1967	2	flake	large	straight	2	absent	medium pitted	b,c,f	diagonal, isolated	slight	light	whittling	non-siliceous, soft wood	d	short	tissue	164
1981	3	flake	large	straight	3	absent	heavy pitted	b,c,f,s	rare diagonal	intensive, patchy	developed, patchy	scraping	non-siliceous, soft wood	p	short	none	
2014	3	flake	large	convex	3	absent	medium to heavy pitted	b,c,f,s	perpen-dicular, isolated	intensive, patchy	well developed, patchy	scraping	non-siliceous, soft wood	d	short	tissue, black residues	168
2015	3	flake	large	a – convex b – concave	a-2 b-1	absent	medium to heavy pitted	b,d/c,f	a – parallel, b – diagonal, isolated	slight	light	a – sawing, b – whittling	non-siliceous, soft wood	d	short	tissue	171

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
363	3	flake	large	convex	2	present	medium pitted	b,c,f,s	diagonal, isolated	slight	very light	scraping	non-siliceous, soft wood	p	short	white	166
366	3	flake	medium	straight	2	absent	medium pitted	b,d/c,f	diagonal, isolated,	slight	light	whittling	non-siliceous, soft wood	d	short	tissue	
1957	3	flake	large	concave	2	absent	medium to heavy pitted	b,c,f	diagonal, isolated	medium	developed, patchy	carving/ cutting like burin	non-siliceous, soft wood	d	moderate	tissue	172
1958	3	flake	medium	irregular	2	present	medium pitted	b,c,s	diagonal, isolated	slight	light	scraping	non-siliceous, soft wood	p	short	tissue	169
1962	3	flake	medium	irregular	1	absent	low pitted	b,c,s	diagonal, isolated	slight	light	scraping	non-siliceous, soft wood	p	short	tissue, white residues	167
1973	4	flake	medium	convex	3	present	medium pitted	b,c,f	diagonal, isolated	intensive, patchy	developed, patchy	whittling	non-siliceous, soft wood	d	short	tissue, starch	120B
2017	4	flake	medium	straight	2	present	heavy pitted	b,d/c,f	diagonal, isolated	slight	very light	whittling	non-siliceous, soft wood	p	short	tissue	165
Non-siliceous hard wood																	
354	2	flake	large	straight	3	present	heavy pitted	b,c,f,s	diagonal, parallel, isolated	slight patchy	very light, patchy	scraping, sawing	non-siliceous, hard wood	p	short	tissue, starch	178

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
1972	4	flake	large	straight	3	present	heavy pitted	b,c,f,s	parallel, diagonal, isolated	medium	developed	cutting (splitting as burin)/ whittling	non-siliceous, hard wood	p	short	tissue	181
1980	1	flake broken during use	medium	convex	3	present	medium pitted	b,c,f,s	diagonal, isolated	intensive, patchy	well developed, patchy	whittling/ sawing	non-siliceous, hard wood	d	short	tissue	180
1983	3	flake	large	irregular	2	present	heavy pitted	b,c,f,s	diagonal, isolated	slight, patchy	very light, patchy	scraping	non-siliceous, hard wood	p	short	tissue, starch	177
Non-woody plants (tubers)																	
1996	1	flake broken during use	medium	convex	2	absent	low pitted	b,c,f,s	perpendicular, diagonal, isolated	intensive	developed	scraping	non-woody plants (tubers)	p	moderate	tissue	195
2008	1	flake	large	straight	2	absent	heavy pitted	b,d/c, f,s	perpendicular isolated	intensive, patchy	developed, patchy	scraping	non-woody plants (tubers)	p	moderate	tissue, starch	
1953	2	flake	large	convex	2	absent	medium pitted	b,c,f	diagonal, isolated	medium to intensive	developed	cutting/ slicing	non-woody plants (tubers)	d	moderate	tissue	200
359	3	stemmed tool, Kombewa	medium	convex	1	absent	heavy pitted	b,c,f	diagonal, isolated	intensive, patchy	developed, patchy	scraping/ slicing	non-woody plants (tubers)	d	moderate, wood hafted	tissue, starch	123, 194
361	3	flake	medium	straight	2	present	low pitted	b,d/c,f	diagonal, parallel, isolated	medium	light	cutting/ slicing	non-woody plants (tubers)	d	moderate	tissue, starch (P)	199

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
364	3	flake	medium	straight	2	absent	medium pitted	b,c,f,s	diagonal, perpendicular, isolated	medium	light to developed, patchy	scraping	non-woody plants (tubers)	d	moderate, probably wrapped	tissue, starch (P), phytolith (K), white	121, 198
2018	4	flake	medium	concave	3	present	heavy pitted	b,c,f,s	diagonal, perpendicular, isolated	medium	developed	scraping/ slicing	non-woody plants (tubers)	d	moderate	starch, tissue	197
2020	4	flake	large	irregular	2	absent	medium pitted	b.c.f	diagonal, parallel, isolated	medium	light	scraping/ slicing	non-woody plants (tubers)	d	moderate	starch, tissue	196
Non-woody plants (greens)																	
1969	1	flake	medium	straight	1	absent	heavy pitted	b,c,f	diagonal, parallel, isolated	slight to medium, patchy	light to developed, patchy	cutting/ slicing	non-woody plants (greens)	d	moderate	tissue, starch	202
1987	1	flake	medium	straight	3	present	low pitted	b,c,f,s	perpendicular, diagonal, isolated	medium	light to developed	cutting/ slicing	non-woody plants (greens)	d	moderate	white	203
358	3	flake	medium	straight	1	absent	low to medium pitted	b.d/c,f	diagonal, parallel, crossed, isolated	slight	light	cutting	non-woody plants (greens)	d	moderate	tissue, starch – Pandanus	201
2019	4	flake broken during use	medium	straight	1	absent	medium to heavy pitted	b.c,f	parallel, diagonal, isolated	medium	light	cutting/ slicing	non-woody plants (greens)	d	moderate	tissue	
2021	3	flake	medium	straight	1	absent	medium pitted	b,c,f	diagonal, isolated	slight	light	cutting/ slicing	non-woody plants (greens)	d	short	none	

M# 970/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Soft elastic material (skin, fish)																	
351	2	flake	large	straight	2	present	low pitted	b,c,f	diagonal/ parallel, isolated	medium	light to developed, patchy	gutting/ cutting	soft elastic material (fish)	d	moderate	rainbow residues	219
1954	2	flake	large	convex	2	present	low pitted	b,c,f	diagonal, parallel, isolated	medium	light to developed, patchy	gutting/ cutting	soft elastic material (fish)	d	moderate	animal tissue, rainbow, black	
2009	2	pointed flake	small	straight	1	present	low pitted	b,d/c,f	diagonal, parallel, isolated	slight	light	piercing	soft elastic material (skin)	d	moderate	charred plant mixed as pigment for tattooing (F, pers com)	210
Dense, hard material (shell, clay)																	
1968	3	flake	large	straight	3	absent	medium pitted	b,c,f,s	perpendicular, diagonal, dense	intensive	well developed	scraping	dense, hard material (shell)	d	short	white, coloured	224
1982	3	flake	large	convex	3	present	low pitted	b,c,f,s	diagonal, dense	very intensive	well developed	scraping	dense, hard material (clay)	p	short	white, yellow	225

Edge angle refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution. Source references abbreviated as follows: *(B)* Barton *et al.*, 1998), *(F)* Fullagar, pers. comm., *(K)* Kealhofer *et al.*,1998, *(P)* Parr, pers. comm.

Table 13. Type of artefacts and wear patterns from 1000/1000 test pit, Layer 6 (the middle Holocene).

M# 1000/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
128	1	flake	medium	convex	2	absent	heavy pitted	b,c,f	diagonal, parallel, dense, both seen on the same edge	slight to medium, patchy	developed, patchy	whittling/ sawing	siliceous, soft wood, palm, bamboo	d	short	starch	122, 137
1906	1	flake	large	straight	3	absent	heavy pitted	b,c,f	parallel, dense	intensive	light	sawing	siliceous, soft wood, palm, bamboo	d	short	starch (P)	138
Non-siliceous soft wood																	
130	1	flake	large	convex	3	present	low pitted	b,d/c,f,	diagonal, isolated	slight	very light, patchy	whittling	non-siliceous, soft wood	d	short	starch (P)	
1909	1	blade-like flake	large	irregular, pointed	3	absent	medium to heavy pitted	b,c,f,s	diagonal, perpendicular to the tip, isolated	intensive, patchy	developed, patchy	cutting, splitting (burin)	non-siliceous, soft wood	d	short,	tissue, starch	
2044	1	flake	small	straight	2	absent	low pitted	b,c,f	parallel, isolated	slight	very light	sawing	non-siliceous, soft wood	p	short	starch	
380	4	flake	large	concave	2	absent	medium pitted	b,d/c,f	diagonal, isolated	slight	very light, patchy	whittling	non-siliceous, softwood	p	short	tissue	

M# 1000/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
1998	4	flake	large	concave	2	absent	medium pitted	b,d/c,f	diagonal, isolated	slight	very light, patchy	whittling	non-siliceous, soft wood	p	short	tissue	
Non-siliceous hard wood																	
1905	1	flake	large	a,c – straight b,d – convex	a,c, d – 3, b – 2	absent	medium pitted	a,c – b,c,f,s, b,d – b,c,f	a,c – diagonal, perpendicular, b,d – diagonal, isolated	intensive, patchy	developed, patchy	a,c – scraping, b,d – scraping/ whittling	non-siliceous, hard wood	d	short	tissue starch (P)	179
Non-woody plants (tubers)																	
129	1	flake broken during use	medium	irregular	1	absent	low pitted	b,c,f	diagonal, isolated	medium, patchy	developed, patchy	cutting/ slicing	non-woody plants (tubers)	d	moderate	starch (B)	
1908	1	flake	medium	concave	2	absent	heavy pitted	b,c,f,s	diagonal, isolated	intensive	developed	scraping	non-woody plants (tubers)	p	moderate	starch	
1911	1	flake	medium	straight	2	absent	heavy pitted	b,c,f,s	diagonal, isolated	slight	very light	scraping	non-woody plants (tubers)	p	short	starch (P)	
1912	1	flake	medium	irregular	2	absent	medium pitted	b,c,f,s	perpendicular, diagonal Isolated	intensive	developed	scraping/ slicing	non-woody plants (tubers)	d	moderate	starch	
2042	1	flake	medium	irregular	1	present	medium pitted	b,c,f,s	diagonal, parallel, isolated	intensive	well developed, patchy	scraping/ slicing	non-woody plants (tubers)	d	moderate	tissue	

M# 1000/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Non-woody plants (greens)																	
131	1	flake, broken during use	small	straight	2	absent	low pitted	b,d/c,f,	diagonal, isolated	slight to medium, patchy	developed, patchy	cutting/ slicing	non-woody plants (greens)	d	moderate	tissue, starch (B), white	
133	1	flake	medium	convex	2	present	medium pitted	b,d/c,f	diagonal, isolated	slight	none	cutting/ slicing	non-woody plants (greens)	p	short	starch (B)	
Soft elastic material (skin, fish)																	
132	1	pointed flake, broken tip	medium	straight	1	absent	heavy pitted	b,d/c,f	perpendicular to the tip, isolated	slight	very light	piercing	soft elastic material (skin)	d	moderate	animal tissue (B,F)	
1782	1	stemmed tool, broken tip	small	straight	1	present	medium pitted	b,d/c,f	diagonal	medium	developed, patchy	cutting/ piercing	soft elastic material (skin)	p	moderate, wood handle	starch on hafting part, dark-red, rainbow	212
1907	1	pointed flake	medium	straight	2	absent	medium pitted	b,d/c,f	perpendicular to the tip, isolated	medium to intensive	developed, patchy	piercing	soft elastic material (skin)	d	moderate, wrapped	starch, resin	211
135	1	flake	large	irregular	1	absent	medium pitted	b,c,f	parallel, diagonal, isolated	medium	light	gutting/ cutting	soft elastic material (fish)	d	moderate	animal tissue, rainbow residues (P)	218
1903	1	flake	medium	concave, pointed	1	absent	heavy pitted	b,d/c,f	parallel, diagonal, isolated	medium, patchy	developed, patchy	gutting/ cutting	soft elastic material (fish)	p	short	rainbow, red, black	

M# 1000/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
1910	1	flake	large	irregular	1	absent	low to medium pitted	b,c,f	diagonal, parallel, isolated	medium, patchy	developed, patchy	gutting/ cutting	soft elastic material (fish)	d	moderate	rainbow, possible blood (P)	120A, 222
2043	1	flake	medium	a – convex, b – concave	2	absent	medium pitted	b,c,f	parallel, isolated	medium	light	gutting/ cutting	soft elastic material (fish)	d	moderate	rainbow residues	220

Edge angle refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution. Source references abbreviated as follows: *(B)* Barton *et al.,* 1998), *(F)* Fullagar, pers. comm., *(K)* Kealhofer *et al.,*1998, *(P)* Parr, pers. comm.

Table 14. Type of artefacts and wear patterns from 980/1000 test pit, Layer 6 (the middle Holocene).

M# 980/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
2118	1	flake	large	a,b – concave, c – straight	2	present	heavy pitted	b,c,f	a,c – parallel, b – diagonal, dense	intensive	well developed	a,c – sawing, b – whittling	siliceous, soft wood, palm, bamboo	d	moderate	tissue	141
2121	1	flake	large	convex	3	present	heavy pitted	b,c,f	diagonal, parallel, dense	medium	light	whittling/ sawing	siliceous, soft wood, palm, bamboo	d	short	tissue	143
Non-siliceous soft wood																	
2120	1	flake	large	convex	2	present	heavy pitted	b,c,f,	diagonal, isolated	slight	none	whittling	non-siliceous, soft wood	p	short	none	
2123	1	flake	large	convex	3	present	low pitted	b,c,f,s	diagonal, isolated	slight, patchy	light, patchy	scraping	non-siliceous, soft wood	d	short,	tissue	
Non-siliceous hard wood																	
2124	1	flake	large	a – straight b – concave	3	present	medium to heavy pitted	b,c,f,s	diagonal, perpen-dicular, dense	intensive, patchy	developed, patchy	a – whittling, b – Scraping	non-siliceous, hard wood	d	short	starch tissue	
Non-woody plants (tubers)																	
2117	1	flake	medium	straight	2	present	low pitted	b,c,f	diagonal, isolated	medium, to intensive, patchy	developed, patchy	scraping	non-woody plants (tubers)	d	short	tissue	
2119	1	flake	large	convex	2	absent	medium pitted	b,c,f	diagonal, isolated	intensive	developed, patchy	slicing	non-woody plants (tubers)	d	moderate	tissue, starch	

M# 980/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Soft elastic material (skin, fish)																	
2122	1	flake	large	convex	1	present	medium pitted	b,d/c,f	diagonal, parallel, isolated	medium, to intensive, patchy	light to developed, patchy	gutting/ cutting	soft elastic material (fish)	d	moderate	blood-like	221
2127	2	pointed flake	medium	straight	1	absent	medium pitted	b,c,f	parallel, diagonal, rotative, isolated	slight	light to very light	piercing/ cutting	soft elastic material (skin)	d	short	rainbow, red film	
2126	2	blade-like flake	medium	straight	1	absent	low pitted	b,d/c,f	parallel, diagonal, isolated	slight to medium, patchy	light, patchy	cutting/ piercing	soft elastic material (skin)	p	short	none	215
2128	2	pointed flake	small	straight	1	present	medium pitted	b,d/c,f	perpendicular to the tip, parallel, isolated	slight to medium	light	cutting/ piercing	soft elastic material (skin)	d	short	rainbow, red film	213

Edge angle refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution. Source references abbreviated as follows: *(B)* Barton *et al.*, 1998), *(F)* Fullagar, pers. comm., *(K)* Kealhofer *et al.*,1998, *(P)* Parr, pers. comm.

Table 15. Type of artefacts and wear patterns from 990/1000 test pit, Layer 6 (the middle Holocene).

M# 990/1000	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Siliceous soft wood, palm, bamboo																	
2130	1	flake broken during use	medium	straight	2	absent	medium pitted	b,c,f	parallel, perpen-dicular, dense	intensive, patchy	well developed, patchy	whittling/ sawing,	siliceous, soft wood, palm, bamboo	d	short	tissue	
2132	1	blade-like flake	large	irregular	2	present	medium to heavy pitted	b,c,f,s	perpen-dicular, diagonal, dense	intensive, patchy	well developed, patchy	scraping/ whittling	siliceous, soft wood, palm, bamboo	d	moderate	tissue, starch	
Siliceous hard wood and hard palm																	
2137	1	flake	large	concave	3	absent	heavy pitted	b,c,f	parallel, dense	intensive, patchy	well developed, patchy	sawing	siliceous, hard wood, palm	d	short	white	
2131	2	flake broken during use	large	a,b – convex	3	absent	heavy pitted	b,c,f	parallel, dense	intensive, patchy	well developed, patchy	sawing	siliceous, hard wood, palm	d	short	starch	
2138	2	flake broken during Use	large	a,b – convex	a-2, b-3	absent	heavy pitted	b,c,f	parallel, dense	intensive, patchy	well developed, patchy	sawing	siliceous, hard wood, palm	d	short	tissue	
Non-siliceous soft wood																	
2136	1	flake	large	a,c – concave, b – straight	a,c-2, b-3	absent	low pitted	a,b,c – b,c,f,s	a,c – diagonal, b – perpen-dicular, Isolated	medium, patchy	light, patchy	a,c – whittling b – scraping	non-siliceous soft wood	d	short	tissue	

Non-siliceous hard wood																	
2139	1	flake broken during use	medium	straight	3	absent	medium to heavy pitted	b,c,f,s	diagonal, isolated, flaked	slight, patchy	light, patchy	scraping	non-siliceous hard wood	p	short	none	176
Non-woody plants (greens)																	
2133	1	blade-like flake	large	convex	2	present	low to medium pitted	b,c,f	parallel, isolated	slight	light	cutting/ slicing	non-woody plants (greens)	d	moderate	starch	204
Soft elastic material (skin, fish)																	
1871	1	stemm-ed tool	small	straight	1	absent	medium to heavy pitted	b,d/c,f	parallel	medium	developed	cutting	soft elastic material (skin)	d	moderate	none	
2129	1	pointed flake	medium	straight	1	absent	medium to heavy pitted	b,d/c,f	diagonal, parallel, isolated	medium	developed	cutting/ piercing	soft elastic material (skin)	p	moderate	red residues	214
2134	1	pointed flake	medium	straight	1	absent	medium pitted	b,d/c,f	parallel, diagonal, isolated, a few only	light	very light	scraping/ cutting (shaving)	soft elastic material (skin)	p	short	blood-like, tissue	216
2135	1	flake	small	a – straight b – convex	1	absent	low pitted	b,c,f	diagonal	medium	developed	cutting (shaving)	soft elastic material (skin)	p	moderate	dark red residues	217

Table 16. Type of artefacts and wear patterns from 1000/999 test pit, Layer 6 (the middle Holocene).

M# 1000/999	Spit	Tool Type	Size of Tool	Shape of Edge	Edge Angle	Cortex	Surface Preservation	Scar Type	Striation Orientation	Edge Rounding	Polish	Mode of Use	Contact Material	Confidence	Use-duration, Hafting Pattern	Residue Type	Reference to Plates
Non-woody plants (greens)																	
2100	2	flake	medium	straight	1	absent	medium pitted	b,d/c,f	parallel, diagonal, isolated	medium	developed	cutting	non-woody plants (greens)	p	short	none	

Edge angle refers to the following categories: *(1)* less than 15°; *(2)* between 15° and 55°; and *(3)* more than 55°. *Scar type* refers to the presence of distinct termination types of use-wear scars as follows: *(f)* feather; *(b)* bending; *(s)* step; *(m)* mixed types; *(c)* continuous distribution; and, *(d/c)* discontinuous distribution. Source references abbreviated as follows: *(B)* Barton *et al.*, 1998), *(F)* Fullagar, pers. comm., *(K)* Kealhofer *et al.*,1998, *(P)* Parr, pers. comm.

Table 17. Distribution of late Holocene tools within test pits.

970/1000				1000/1000				980/1000				990/1000				1001/999				1000/999			
Item No.	M# 970/1000	Spit	Plate No.	Item No.	M# 1000/1000	Spit	Plate No.	Item No.	M# 980/1000	Spit	Plate No.	Item No.	M# 990/1000	Spit	Plate No.	Item No.	M# 1001/1000	Spit	Plate No.	Item No.	M# 1000/999	Spit	Plate No.
Siliceous soft wood, palm, bamboo																							
1	312	1		1	125	3	126	1	2107	1		1	2144	1		1	2102	1		1	2101	3	
2	324	3		2	126	3	127	2	2108	1		2	2140	2	136	2	2106	3					
3	328	3		3	1913	3	128	3	2110	2						3	2103	2					
4	331	3	129	4	1916	2		4	2111	2													
5	333	3	132	5	1917	2		5	2112	2	142												
6	336	3	135					6	2113	2													
7	1919	3						7	2116	3	145												
8	1933	2																					
9	1946	3	134																				
10	2023	1																					
11	2028	3																					
12	2032	3																					
13	2034	3	133																				
14	2036	3																					
15	2037	3																					
16	2040	3																					
17	2041	3																					
Siliceous hard wood and palm																							
18	1922	3	150																				
19	1925	3	149																				
20	2027	3																					
Non-siliceous soft wood																							
21	325	3																					
22	326	3	153																				
23	1923	1																					
24	1924	1	160																				
25	1936	2		7	112	1						3	2141										
26	1938	3	163	8	113	1						4	2142										

970/1000				1000/1000				980/1000				990/1000				1001/999				1000/999			
Item No.	M# 970/1000	Spit	Plate No.	Item No.	M# 1000/1000	Spit	Plate No.	Item No.	M# 980/1000	Spit	Plate No.	Item No.	M# 990/1000	Spit	Plate No.	Item No.	M# 1001/1000	Spit	Plate No.	Item No.	M# 1000/999	Spit	Plate No.
27	1945	3		9	118	2	162																
28	2022	1	158	10	1915	1																	
29	2024	1		11	2045	3	161																
30	2025	2	154																				
31	2026	2	159																				
32	2033	3	155																				
33	2038	3																					
Non-siliceous hard wood																							
34	334	3	198	6	114	1	175																
35	1942	3	199																				
Non-woody plants (tubers)																							
36	310	1	186	12	1914	3	184	8	2115	3						4	2105	3	183				
37	317	1	188	13	2046	3	185																
38	1921	2	187																				
39	1926	3																					
40	1930	1	182																				
41	2030	3																					
42	2039	3																					
Non-woody plants (greens)																							
43	313	1																					
44	470	2	192																				
45	2029	3	193																				
46	2031	3	191																				
47	1929	1	190																				
48	1941	3	189																				
Soft elastic material (skin, fish)																							
49	322	3	205					9	2109	1		5	2143	1		5	2104	2	206				
50	469	2	207																				
51	1939	3	205																				
52	1940	3	209																				
53	2035	3																					
Dense, hard material (shell, clay)																							

970/1000				1000/1000				980/1000				990/1000				1001/999				1000/999			
Item No.	M# 970/1000	Spit	Plate No.	Item No.	M# 1000/1000	Spit	Plate No.	Item No.	M# 980/1000	Spit	Plate No.	Item No.	M# 990/1000	Spit	Plate No.	Item No.	M# 1001/1000	Spit	Plate No.	Item No.	M# 1000/999	Spit	Plate No.
								10	2114	3	223												
Without use-wear																							
54	1934	2																					
Total: 54 tools				Total: 13 tools				Total: 10 tools				Total: 5 tools				Total: 5 tools				Total: 1 tool			

Table 18. Distribution of middle Holocene tools within test pits.

970/1000					1000/1000					980/1000					990/1000					1000/999			
Item No.	M# 970/1000	Spit	Plate No.		Item No.	M# 1000/1000	Spit	Plate No.		Item No.	M# 980/1000	Spit	Plate No.		Item No.	M# 990/1000	Spit	Plate No.		Item No.	M# 1000/999	Spit	Plate No.
Siliceous soft wood, palm, bamboo																							
1	339	1			1	128	1	137		1	2118	1	141		1	2130	1						
2	356	2			2	1906	1	138		2	2121	1	143		2	2132	1						
3	2051	2																					
4	1965	2	146																				
5	1966	2																					
6	1994	1	144																				
7	1997	1	139																				
8	2007	1																					
9	2010	3	147																				
10	2011	3																					
11	2012	3																					
12	2013	3	148																				
13	2016	4	140																				
Siliceous hard wood and palm																							
14	367	3	118												3	2131	2						
15	1955	3													4	2137	1						
16	1976	4	152												5	2138	2						
17	1978	4																					
18	1979	1																					
19	1989	1																					
Non-siliceous soft wood																							
20	363	3	166		3	130	1			3	2120	1			6	2136	1						
21	366	3			4	380	4			4	2123	1											
22	1949	2			5	1909	1																
23	1951	2	170		6	1998	4																
24	1952	2			7	2044	1																
25	1957	3	172																				
26	1958	3	169																				
27	1962	3	167																				

970/1000				1000/1000				980/1000				990/1000				1000/999			
Item No.	M# 970/1000	Spit	Plate No.	Item No.	M# 1000/1000	Spit	Plate No.	Item No.	M# 980/1000	Spit	Plate No.	Item No.	M# 990/1000	Spit	Plate No.	Item No.	M# 1000/999	Spit	Plate No.
28	1967	2	164																
29	1973	4	120																
30	1981	3																	
31	2014	3	168																
32	2015	3	171																
33	2017	4	165																
Non-siliceous hard wood																			
34	354	2	178	8	1905	1	179	5	2124	1		7	2139	1	176				
35	1972	4	181																
36	1980	1	180																
37	1983	3	177																
Non-woody plants (tubers)																			
38	359	3	194	9	129	1		6	2117	1									
39	361	3	199	10	1908	1		7	2119	1									
40	364	3	198	11	1911	1													
41	1953	2	223	12	1912	1													
42	1996	1	220	13	2042	1													
43	2008	1																	
44	2018	4	197																
45	2020	4	196																
Non-woody plants (greens)																			
46	358	3	201	14	131	1						8	2133	1	204	1	2100	2	
47	1969	1	202	15	133	1													
48	1987	1	203																
49	2019	4																	
50	2021	4																	
Soft elastic material (skin, fish)																			
51	351	2	219	16	132	1		8	2122	1	221	9	2129	1	214				
52	1954	2		17	135	1	218	9	2126	2	215	10	2134	1	216				
53	2009	2	210	18	1782	1	212	10	2127	2		11	2135	1	217				
				19	1903	1		11	2128	2	213	12	1871	1					
				20	1907	1	211												

970/1000					1000/1000					980/1000					990/1000					1000/999			
Item No.	M# 970/1000	Spit	Plate No.		Item No.	M# 1000/1000	Spit	Plate No.		Item No.	M# 980/1000	Spit	Plate No.		Item No.	M# 990/1000	Spit	Plate No.		Item No.	M# 1000/999	Spit	Plate No.
					21	1910	1	222															
					22	2043	1	220															
Dense, hard material (shell, clay)																							
54	1968	2	224																				
55	1982	3	225																				
Without use-wear																							
										12	2125	1											
Total: 55 tools					Total: 22 tools					Total: 12 tools					Total: 12 tools					Total: 1 tool			

Table 19. Late Holocene tools: relationship between material worked and the mode of use.

	Contact material and mode of use	Pit 970/1000	Pit 1000/1000	Pit 980/1000	Pit 990/1000	Pit 1001/999	Pit 1000/999	Number of tools used and (%) by contact material		Number of tools used and (%) by mode of use	
1	Siliceous soft wood, palm, bamboo	17	5	7	2	3	1	35	39.8	35	39.8
	scraping	6	1			1	1			9	10.2
	whittling	4	1	1		1				7	8.0
	sawing	2	1	1						4	4.5
	carving	3								3	3.4
	drilling				1					1	1.1
	scraping/sawing		1	1						2	2.3
	scraping/whittling		1			1				2	2.3
	whittling/sawing	2		4						6	6.8
	cutting/whittling				1					1	1.1
2	Siliceous hard wood and hard palm	3						3	3.4	3	3.4
	sawing	1								1	1.1
	scraping/sawing	1								1	1.1
	whittling/sawing	1								1	1.1
3	Non-siliceous soft wood	13	5		2			20	22.7	20	22.7
	scraping	1	1							2	2.3
	whittling	7	1		2					10	11.4
	carving	3	1							4	4.5
	scraping/sawing		1							1	1.1
	scraping/whittling		1							1	1.1
	whittling/ sawing	2								2	2.3
4	Non-siliceous hard wood	2	1					3	3.4	3	3.4
	scraping	1								1	1.1
	scraping/sawing	1	1							2	2.3
5	Non-woody plants	13	2	1				17	19.3	17	19.3
	A. Tubers:	7	2	1		1		11	12.5	11	12.5
	scraping	2		1		1				4	4.5
	scraping/slicing	4	1							5	5.7
	cutting/slicing		1							1	1.1
	cutting/peeling	1								1	1.1
	B. Greens, grasses										

	Contact material and mode of use	Pit 970/1000	Pit 1000/1000	Pit 980/1000	Pit 990/1000	Pit 1001/999	Pit 1000/999	Number of tools used and (%) by contact material		Number of tools used and (%) by mode of use	
	and leaves:	6						6	6.8	6	6.8
	scraping	1								1	1.1
	scraping/slicing	2								2	2.3
	cutting/slicing	2								2	2.3
	cutting/splitting	1								1	1.1
6	Soft elastic material	5		1	1	1		8	9.1	8	9.1
	A. Skin:	2		1	1	1		5	5.7	5	5.7
	piercing	2				1				3	3.4
	cutting				1						1.1
	piercing/cutting			1							1.1
	B. Fish:	3						3	3.4	3	3.4
	gutting/cutting	3								3	3.4
7	Dense hard material			1				1	1.1	1	1.1
	A. Shell							1	1.1	1	1.1
	sawing			1						1	1.1
	B. Clay										
8	No use-wear	1						1	1.1		
	Total number of tools	54	13	10	5	5	1	88		88	
	Total percentage of tools	61.4	14.8	11.4	5.7	5.7	1.1		100.0		100.0

Table 20. Middle Holocene tools: relationship between material worked and the mode of use.

	Contact material and mode of use	Pit 970/1000	Pit 1000/1000	Pit 980/1000	Pit 990/1000	Pit 1000/999	Number of tools used and (%) by contact material		Number of tools used and (%) by mode of use	
1	Siliceous soft wood, palm, bamboo	13	2	2	2		19	18.8	19	18.8
	scraping	1							1	1.0
	whittling	7							7	6.9
	sawing		1						1	1.0
	carving	1							1	1.0
	scraping/whittling				1				1	1.0
	whittling/sawing	2							6	5.9
	cutting/scraping	1							1	1.0
	whittling/sawing/scraping	1							1	1.0
2	Siliceous hard wood and hard palm	6			3		9	8.8	9	8.8
	scraping	2							2	1.9
	sawing	1			3				4	3.9
	scraping/sawing	2							2	1.9
	whittling//sawing/scraping	1							1	1.0
3	Non-siliceous soft wood	14	5	2	1		22	21.6	22	21.6
	scraping	4		1					5	4.9
	whittling	5	3	1					9	8.8
	sawing	1	1						2	1.9
	carving	1	1						2	1.9
	scraping/sawing	1							1	1.0
	scraping/whittling	1	1						2	1.9
	whittling/sawing	1							1	1.0
4	Non-siliceous hard wood	4	1	1	1		7	6.9	7	6.9
	scraping	2			1				3	2.9
	scraping/whittling		1	1					2	1.9
	whittling/sawing	1							1	1.0
	cutting/whittling (burin)	1							1	1.0
5	Non-woody plants	13	7	2	1	1	24	23.5	24	23.5
	A. Tubers:	8	5	2			15	14.7	15	14.7
	scraping	2	3	1					6	5.9
	slicing			1					1	1.0
	scraping/slicing	4	1						5	4.9
	cutting/slicing	2	1						3	2.9

	Contact material and mode of use	Pit 970/1000	Pit 1000/1000	Pit 980/1000	Pit 990/1000	Pit 1000/999	Number of tools used and (%) by contact material		Number of tools used and (%) by mode of use	
	B. Greens, grasses and leaves:	5	2		1	1	9	8.8	9	8.8
	cutting	1			1	1			3	2.9
	cutting/slicing	3	2						5	4.9
	scraping/slicing	1							1	1.0
6	Soft elastic material	3	7	4	3		18	17.6	18	17.6
	A. Skin:	1	3	3	4		11	10.7	11	10.7
	piercing		2						2	1.9
	cutting			1	1				2	1.9
	shaving				2				2	1.9
	piercing/cutting	1	1	2	1				5	4.9
	B. Fish:	2	4	1			7	6.9	7	6.9
	gutting/cutting	2	4	1					7	6.9
7	Dense hard material	2					2	1.9	2	1.9
	A. Shell	1					1	1.0	1	1.0
	scraping	1							1	1.0
	B. Clay	1					1	1.0	1	1.0
	scraping	1							1	1.0
8	No use-wear			1			1	1.0	1	1.0
	Total number of tools	55	22	12	12	1	102		102	
	Total percentage of tools	53.9	21.6	11.8	11.8	1.0		100.0		100.0

Table 21. Late Holocene tools: morphological features and the material worked.

Type and morphological features of artefacts	Worked Material												
	Siliceous soft wood, palm, bamboo	Siliceous hard wood, Palm	Non-siliceous soft wood	Non-siliceous hard wood	Tubers	Greens	Skin	Fish	Shell	Clay	Non-identifiable	Total (N)	Total (%)
Type of artefact													
flake	26	3	18	3	9	6	5	1			1	72	81.8
flake – broken during use	3		1					1	1			6	6.8
Kombewa flake								1				1	1.1
retouched flake			1	1								2	2.3
blade-like flake	5			1								6	6.8
core	1											1	1.1
TOTAL	35	3	20	3	11	6	5	3	1		1	88	100.0
Size													
large	5	3	6	3	4	1			1			23	26.1
medium	18		8		3	3	2	3				37	42.0
small	12		6		4	2	3				1	28	31.8
TOTAL	35	3	20	3	11	6	5	3	1		1	88	100.0
Shape and number of working edges													
straight	12		5	1	2		4	1			1	26	29.5
irregular	8	1	4			2	1	1				17	19.3
convex	6		1		2	2		1				12	13.6
concave		1	2		2							5	5.7
2 edges	8	1	6	1	4	1			1			22	25.0
3 edges			1			1						2	2.3
4 edges	1		1	1	1							4	4.5
TOTAL	35	3	20	3	11	6	5	3	1		1	88	100.0
Edge angle													
less than 15° – 1	6		4		3	4	3					20	22.7
16° to 55° – 2	22	1	12	2	5	1	2	3			1	49	55.7
over 56° – 3	7	2	4	1	3	1			1			19	21.6
TOTAL	35	3	20	3	11	6	5	3	1		1	88	100.0

Type and morphological features of artefacts	Worked Material												
	Siliceous soft wood, palm, bamboo	Siliceous hard wood, Palm	Non-siliceous soft wood	Non-siliceous hard wood	Tubers	Greens	Skin	Fish	Shell	Clay	Non-identifi-able	Total (N)	Total (%)
Cortex													
"Yes" – present	12	1	8	1	2	2	1	2				29	33
Use-duration													
Short-term	33	2	15	3	2	1						56	63.6
Moderate	2	1	5		4	5	3	3	1			24	27.3
Long-term					5		2					7	8.0
Not identifiable												1	1.1
TOTAL	35	3	20	3	11	6	5	3	1		1	88	100.0

Table 22. Middle Holocene tools: morphological features and the material worked.

Type and morphological features of artefacts	Worked Material												
	Siliceous soft wood, palm, bamboo	Siliceous hard wood, Palm	Non-siliceous soft wood	Non-siliceous hard wood	Tubers	Greens	Skin	Fish	Shell	Clay	Non-identifi-able	Total (N)	Total (%)
Type of artefact													
flake	14	6	18	5	13	6	7	7	1	1		78	76.4
flake – broken during use	2	2	2	2	1	2	1					12	11.8
blade-like flake	3		2			1	1					7	6.9
stemmed tools		1			1		2				1	5	4.9
TOTAL	19	9	22	7	15	9	11	7	1	1	1	102	100.0
Size													
large	10	7	14	5	4	1		5	1	1	1	49	48.0
medium	6	2	6	2	11	7	7	2				43	42.2
small	3		2			1	4					10	9.8
TOTAL	19	9	22	7	15	9	11	7	1	1	1	102	100.0
Shape and number of working edges													
straight	6	1	5	3	5	7	10	1	1			39	38.2
irregular	5	2	4	1	4			2				18	17.6
convex	4		7	1	4	2		2		1		21	20.6
concave	1	3	3		2			1				10	9.8
2 edges	2	3	2	1			1	1				10	9.8
3 edges	1		1									2	2.0
4 edges				1								1	1.0
broken edge											1	1	1.0
TOTAL	19	9	22	7	15	9	11	7	1	1	1	102	100.0
Edge angle													
less than 15° – 1	4		2		3	5	10	3				27	26.5
16° to 55° – 2	12	1	14	1	11	3	1	4				47	46.1
over 56° – 3	3	8	6	6	1	1			1	1		27	26.5
broken edge											1	1	1.0
TOTAL	19	9	22	7	15	9	11	7	1	1	1	102	100.0
Cortex													

Type and morphological features of artefacts	Worked Material												
	Siliceous soft wood, palm, bamboo	Siliceous hard wood, Palm	Non-siliceous soft wood	Non-siliceous hard wood	Tubers	Greens	Skin	Fish	Shell	Clay	Non-identifi-able	Total (N)	Total (%)
"Yes" – present	9	4	8	5	4	3	3	3		1		40	39.2
Use-duration													
Short-term	15	7	21	7	2	2	4	1	1	1		61	59.8
Moderate	4	2	1		13	7	7	6				40	39.2
Not identifiable											1	1	
TOTAL	19	9	22	7	15	9	11	7	1	1	1	102	100.0

Table 23. Number of tools used on different categories of worked material in both middle and late Holocene.

Contact materials	Late Holocene									Middle Holocene						
	970/1000	1000/1000	980/1000	990/1000	1001/999	1000/999	total tools (N)	Percent - age (%)		970/1000	1000/1000	980/1000	990/1000	1000/999	total tools (N)	Percent - age (%)
Woody plants	35	11	7	4	3	1	61	69.3	W-K 2	37	8	5	7		57	55.9
Silicious soft wood, palm and bamboo	17	5	7	2	3	1	35	39.8		13	2	2	2		19	18.8
Silicious hard wood and hard palm	3						3	3.4		6			3		9	8.8
Non-siliceous soft wood	13	5		2			20	22.7		14	5	2	1		22	21.6
Non-siliceous hard wood	2	1					3	3.4		4	1	1	1		7	6.9
Non-woody plants	13	2	1		1		17	19.3		13	7	2			24	23.5
Tubers	7	2	1		1		11	12.5		8	5	2			15	14.7
Greens, grasses and leaves	6						6	6.8		5	2		1	1	9	8.8
Soft elastic material	5	1		1	1	1	8	9.1		3	7	4	4		18	17.6
Skin	2			1	1	1	5	5.7		1	3	3	4		11	10.8
Fish	3						3	3.4		2	4	1			7	6.9
Dense hard material		1					1	1.1		2					2	2.0
Shell		1					1	1.1		1					1	1.0
Clay										1					1	1.0
Non-identifiable	1						1	1.1				1			1	1.0
Total number of tools	54	13	10	5	5	1	88			55	22	12	12	1	102	
Total – percentage (%)	61.4	14.7	11.4	5.7	5.7	1.1		100		53.9	21.6	11.8	11.8	1.0		100

Table 24. Distribution of tools used in subsistence and craft activities in the middle and late Holocene.

Activities, materials and mode of use	The Late Holocene		The Middle Holocene	
	Total tools (N=87)	Percentage (%)	Total tools (N=101)	Percentage (%)
Subsistence activities	14	16.0	22	21.8
Non-woody plants (tubers)	11	12.6	15	14.9
scraping	4		6	
slicing			1	
scraping/slicing	5		5	
cutting/slicing	1		3	
slicing/peeling	1			
Soft elastic material (fish)	3	3.4	7	6.9
cutting/gutting	3		7	
Domestic Activities	73	84.0	79	78.2
Siliceous soft wood, palm and bamboo	35	40.2	19	18.8
scraping	9		1	
whittling	7		7	
sawing	4		1	
carving	3		1	
drilling	1			
scraping/sawing	2			
scraping/whittling	2		1	
whittling/sawing	6		6	
cutting/whittling	1			
scraping/cutting			1	
whittling/scraping/sawing			1	
Siliceous hard wood and palm	3	3.4	9	8.9
scraping			2	
sawing	1		4	
scraping/sawing	1		2	
whittling/sawing	1		1	
Non-siliceous soft wood	20	23.0	22	21.8
scraping	2		5	
whittling	10		9	
sawing			2	
carving	4		2	
scraping/sawing	1		1	
scraping/whittling	1		2	
whittling/sawing	2		1	
Non-siliceous hard wood	3	3.4	7	6.9
scraping	1		3	
scraping/sawing	2			
scraping/whittling			2	
whittling/sawing			1	
cutting/whittling (burin)			1	
Non-woody plants (greens, grasses and leaves)	6	7.0	9	8.9
scraping	1		3	
cutting	2		5	

Activities, materials and mode of use	The Late Holocene		The Middle Holocene	
	Total tools (N=87)	Percentage (%)	Total tools (N=101)	Percentage (%)
cutting/slicing	2		1	
scraping/slicing	1			
Soft elastic material (skin)	5	5.8	11	10.9
piercing	3		2	
cutting	1		2	
shaving			2	
piercing/cutting	1		5	
Dense hard material (shell)	1		1	1.0
scraping				
sawing				
Dense hard material (clay)			1	1.0
scraping			1	
Total:	87	100	101	100

Table 25. Middle and late Holocene distribution of identified tools within artefact assemblages from test pits.

Test pit and type of material worked by identified tools (middle Holocene)	Spit 1		Spit 2		Spit 3		Spit 4		Spit 5		Total	
	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools
1000/1000	180	20	10	0	6	0	106	2	56	0	358	22
1001/1000	2	0	7	0							9	0
1000/999			36	1	2	0					38	1
990/1000	48	10	24	2							72	12
980/1000	55	9	8	3	7						70	12
970/1000	105	11	61	14	92	20	27	10			285	55
Total:	390	50	146	20	107	20	133	12	56		832	102

Test pit and type of material worked by identified tools (late Holocene)	Spit 1		Spit 2		Spit 3		Spit 4		Total	
	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools	Total number of artefacts	Number of tools
1000/1000	33	4	44	3	27	6	4	0	108	13
1001/1000	5	0	9	0	15	0	0	0	29	0
1000/999	7	0	6	0	3	1	0	0	16	1
1001/999	3	1	4	2	22	2	0	0	29	5
990/1000	13	1	24	4	0	0	0	0	37	5
980/1000	20	3	16	4	23	3	0	0	59	10
970/1000	32	11	54	8	199	35	0	0	285	54
Total:	113	20	157	21	289	47	4	0	563	88