Stone artefact manufacture at Natunuku, Votua, Kulu and Ugaga, Fiji

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Introduction

Pacific flaked-stone assemblages after ca. 3000 years ago are often portrayed as simple, expedient, homogeneous and typologically depauperate. Recent technological analyses, however, are beginning to reveal significant variation in the types of reduction strategies employed in different regions and sites, as well as in the degree to which raw materials of various origins were reduced, conserved and curated (Halsey 1995; Sheppard 1992, 1993; Swete Kelly 2001). These studies have largely been concerned with identifying the mechanisms and quantities in which raw materials (but typically obsidian) were distributed across the Pacific at different times. Yet there is a growing concern that flaked-stone assemblages of all kinds, and not simply those derived from long-distance exchange, should be better described and integrated into current research questions in Pacific prehistory. Such questions include the tempo and economic basis of Lapita expansion, changing mobility, settlement and subsistence patterns, Lapita and post-Lapita innovation, and the continuity and nature of local and regional interaction. Although Allen and Bell (1988) called for greater reporting of basic information on aspects of Pacific assemblage variability nearly 20 years ago, there is still an alarming lack of data on such basic issues as the types, origins and proportions of raw materials found in assemblages, the form in which they were procured and imported, the various reduction techniques employed, the types and abundance of technological categories represented, their size and form, the function of stone tools, and the impact of various taphonomic processes on assemblage size and composition.

At present, only a few, small stone artefact assemblages have been recovered from a handful of well-dated sites in Fiji. In addition, little is known of the origins, form or abundance of many of the raw materials that make up these assemblages. There are also very few past studies of stone artefacts to draw on, and most of these are typological in nature, concentrating on the minority of morphologically regular artefacts in an assemblage (e.g. adzes and retouched flakes) rather than whole assemblages. Early studies have identified the presence of various reduction techniques as well as some commonly used raw materials, but overall, our understanding of the nature and organisation of lithic technology in Fiji is still rudimentary.

We therefore aim to address four basic questions in this paper:

1. What was the nature of stone procurement on different islands?
2. What was the range of reduction strategies and manufacturing activities undertaken at each site?
3. Are there differences in reduction intensity between sites?
4. Might assemblage variability reflect levels of mobility or economic and social differentiation between sites?

Our analysis is essentially a base-line technological study on which future studies of Fijian stone artefacts may build. It is primarily descriptive, rather than analytical, and the few hypotheses we propose are based on simple data rather than extensive inter-site comparisons.

Previous work

Previous stone-artefact studies in Fiji reflect past approaches to stone-artefact analysis world-wide, with attention given primarily to the construction of typologies and the range of possible tool functions, rather than the range of reduction strategies and material remains produced. Before 1979, no systematic descriptions of Fijian flaked-stone-artefact assemblages were undertaken. Gifford (1949, 1951) was the first to mention stone artefacts in Fijian sites, but only formal types such as adzes, hammerstones and whetstones were mentioned. Sixteen years later, Birks and Birks (1967) reported the presence of stone artefacts in their excavations at the Sigatoka Dune site and the Yanuca site on southwest Viti Levu. Their description focused on raw-material types and imputed tool functions, but no assemblage data was provided (Birks and Birks 1967:18). In a later study, Birks (1973) reported flakes of chalcedony found at the Sigatoka site, but again, no detail about the artefacts was provided. In 1975 and 1976, Best (1977, 1984) began excavating open sites and rock shelters on Lakeba and recovered hundreds of flakes.

Charles Hunt's (1979) study provided the first basic description of stone artefacts from Fiji. He recovered numerous chert flakes and cores from a ring-ditch site near the Samabula River. He described the flakes as amorphous with few signs of use, but described truncated triangular cross-sectioned blades and thick, narrow flakes resembling drill points. Cores were described as 'pyramidal', with large square platforms and more than four flake scars. Terry Hunt (1980) later analysed an assemblage from the site of Yanuca on southwest Viti Levu. The assemblage consisted of 41 flaked pieces, some of which exhibited use-wear and retouch. Raw materials used in the manufacture of the assemblage varied and reflected the local geology of the area. A selection of adzes was also analysed, building on Birks and Birks (1968) earlier description of these artefacts.

Best's (1984) dissertation on sites on Lakeba provides the first detailed description of a Fijian flaked-stone industry, as well as some details on the range of raw materials and manufacturing strategies employed. Best noted the presence of rotated and unrotated cores, as well

as bipolar cores and flakes made from a range of raw materials. He developed a typology that divided utilised, retouched and unretouched flakes of various shapes and sizes into the categories of 'drills', 'shallow pointed flakes', 'heavy duty flakes', 'oval ended flakes', and 'blades and concave scrapers'. Artefacts were made from chert and a chalcedony-like silicified coral found outcropping on Vanuabalavu, with the latter material dominating the assemblages of Lapita age. Exotic obsidian was rarely found, and was most abundant after the Lapita period. Best (1984) also classified adzes on the basis of cross section and performed chemical sourcing analysis, although no source workshops were identified in his study.

Finally, Hunt et al. (1999) have recently mentioned flake assemblages recovered from excavations in the Yasawa Islands, including small cores and other artefacts made from basalt, chert, and quartzite. These showed no signs of retouch or use-wear.

In summary, there is little data available with which to formulate general statements about the organisation of flaked-stone technology in Fiji. Our own analysis therefore attempts to provide a more thorough technological description for the four assemblages recovered from the recent excavations at Natunuku, Kulu, Ugaga and Votua.

Technological analysis

The following analysis presents information on a variety of aspects of lithic technology for each site. The analysis is based on macroscopic inspection of artefacts and the recording of up to 39 morphological and technological variables for flakes, 18 for cores and 13 for adzes, as well as microscopic inspection of artefacts for traces of use-wear. The excavation strategy and chronology for each of the sites analysed in this chapter are reported in earlier chapters and are not repeated here. Because sites were argued in earlier chapters to either exhibit marked disturbance or represent single-phase occupations, we present assemblage data as single units rather than spatial or temporal components.

Assemblage size and density

Table 67 presents data on the size and contents of each of the excavated assemblages. From this table, we see that Votua is the largest assemblage in both size and density, and is more than twice the size of any other site reported here. Natunuku is the next largest assemblage, followed by Kulu and Ugaga. With only five artefacts, Ugaga is too small to provide a reliable basis for statements about reduction technology and is therefore omitted from much of the following discussion and analysis.

Assemblage richness

In keeping with the notion that rare artefacts tend only to appear as sample size increases (Hiscock 2001), a clear relationship exists between sample size and the number of technological categories present for Natunuku, Kulu and Ugaga (Figure 144). Votua, on the other hand, represents a clear outlier in that it is the largest of the excavated assemblages and yet has very low assemblage diversity. This situation could reflect real differences in the diversity of economic and manufacturing activities undertaken at Votua compared with the other sites.

Raw material procurement

Table 68 provides information on the proportions of different raw materials found at each site. Chalcedony dominates the Kulu and Natunuku assemblages, whereas chert is most abundant at Votua. Volcanic stone makes up the majority of the five artefacts found at Ugaga. It is worth considering first whether the proportions of raw materials found in each assemblage might reflect the relative availability of different raw materials in the vicinity of each site.

Table 67. Assemblage breakdown for each of the excavated assemblages.

Site	Kulu	Ugaga	Natunuku	Votua
Flaked and ground adze	1	3	3	
Flaked adze blank		1		
Adze rejuvenation flake	4		1	4
Biface				1
Unidirect. bipolar core	1		5	
Multi-direct. bipolar core	5		3	
Bipolar flake	3		11	3
Bipolar drill	1		1	
Bipolar retouched flake			1	
Multi-platform core				1
Core fragment				
Drill	4		5	
Flake	26		45	100
Flaked piece	9	1	25	153
'Pot lid' flake	1			
Flaked quartz crystal			1	
Hammerstone				2
Retouched flake			5	9
Retouched flake piece			2	
Total	55	5	106	274
Number of categories	10	3	13	8
% Bipolar	18.2	0	19.8	1.1
Total weight (g)	162	1946.4	586.3	2053.7
Artefacts/m ³ deposit	19	3	31	88

Figure 144. Relationship between assemblage size and richness for Fijian assemblages.

At present, little is known about the availability of stone suited to artefact manufacture in the Fiji Islands. However, examination of the geological and archaeological literature helps identify a number of potential sources of chert, chalcedony and other materials, such as novaculite, flinty tuff and mudstone, on some of the larger islands.

From this literature, it appears that chalcedony is abundant at various locations across Viti Levu (Figure 145), and is probably available less than 50 km inland from Natunuku in at least two locations (Bartholomew 1960:14; Band 1968:12; Harvey 1958 cited in Hunt 1979:37). From the available descriptions, this material occurs in a variety of sizes, up to large boulders and blocks, the larger sizes probably better suited to the manufacture of stone artefacts. Jasper and a variety of other chert types, and fine-grained siliceous rocks such as mudstones and tuff also appear to be obtainable within ca. 80 km of Natunuku (Bartholomew 1960:14; Houtz 1963:4), although it is possible that undiscovered sources of these and other materials exist closer to the site.

Votua is apparently the closest of any site to a stone source (Best 1984). Jasper outcrops in large blocks, up to 1 m in diameter, on Vanuabalavu, only 23 km northeast of Mago Island, and no doubt accounts for much of the chert in the Votua assemblage (see Chapter 6). Chalcedony

Table 68. Percentages of raw material types used at each site.

Site	Chalcedony	Chert	Quartz crystal	?Quartz	Volcanic
Kulu	65	18	–	–	16.8
Ugaga		20			80
Natunuku	75	10	1.9	0.9	11
Votua	10	84	–	–	5.8

Figure 145. Location of archaeological sites and reported stone sources in Fiji.

and silicified coral heads were also found adjacent to the jasper source on Vanuabalavu by Best (1984).

As no sources of non-volcanic flakeable stone are mentioned in the geological reports for Beqa Island, it is possible that chalcedony and chert had to be imported to Kulu and Ugaga from sources on Viti Levu, as far away as 40–80 km.

A wide variety of flakeable non-volcanic rocks are also available on Vanua Levu (including chalcedony, jasper and novaculite) and probably on other islands in the Fijian Group (Ibbotson 1969:6). In addition to siliceous materials, there is an abundance of different types of volcanic rocks on most islands in Fiji. Some are likely suited to flaking and/or adze manufacture. Best (1984) identified several sources of basalt, tuff and andesite in the Lau Group, some of which were certainly used in adze manufacture. It remains for future surveys and sourcing studies to determine the exact location and nature of other volcanic and siliceous stone sources, and to discover rare and recognisable raw-material types that might allow investigation of inter-island transport.

From this review of the literature, the only known sources of flakeable stone close to the coast and easily accessed by people reliant on ocean transport are the jasper sources in the Nadi riverbed and around Savusavu Bay, as well as the silicified coral and jasper sources on Vanuabalavu. Overland travel would have been necessary to access the larger chalcedony blocks in the interior of the islands. At the minimum, people would have had to travel 13 km inland to access these sources of chalcedony, chert, tuff and mudstone; however, some of the larger sources of chalcedony are as far as 36 km inland. Future physical and elemental characterisation of these sources should help determine the relative quality and importance of each source in the past. As a side note, inspection of a small collection in the Fiji Museum of chert and chalcedony flakes from the Natunuku site revealed large pieces of chalcedony, one of which still had an oyster shell adhering to its surface. Whether this results from post-depositional exposure within the littoral zone, or indicates the existence of a local source of chalcedony right on the coast requires investigation.

Returning to the data presented in Table 68, it appears that the proportions of raw materials present in the Natunuku and Votua assemblages probably reflect the relative availability and quality of raw materials in the local area. The inhabitants of Natunuku made greatest use of chalcedony sources that perhaps outcrop no further than 50 km away (in a straight line) from the site, while at Votua, greatest use was made of jasper which was probably obtained as large nodules from nearby Vanuabalavu. Kulu mainly contains chalcedony, but as sources on the island are unrecorded, we assume this material had to be imported from sources 40–80 km away on Viti Levu or other islands.

Further clues about the form in which stone was procured and its likely origins can be obtained from examining the size ranges and type of cortex on stone artefacts of each raw-material type. This information is presented in Table 69 and indicates that artefacts made from volcanic materials at Natunuku are the largest, followed by chert and then chalcedony. At Kulu and Votua, the maximum size of chert and volcanic artefacts is the same. However, a sample of large cores collected from the surface of the Votua site, which has probably eroded from the same single occupation layer as the excavated material, enlarges the maximum size of chert and chalcedony artefacts considerably. These consist of a jasper core measuring 200 mm in diameter and a chalcedony core measuring 83 mm in diameter (as indicated in brackets in Table 69).

Given the size of the assemblages, it is possible that the mean and maximum lengths of artefacts are partially attributable to the small sample size. Regression analyses confirm that the max-

Table 69. Mean and maximum length (mm) and dominant cortex type for each raw material type.

Material	Kulu	Natunuku	Votua
Chalcedony			
Mean	13 ± 6	17 ± 7	16 ± 5
Max.	26	36	27 (83)
Cortex	Irregular	Irregular	Irregular
Chert			
Mean	20 ± 11	29 ± 17	21 ± 10
Max.	44	66	82 (200)
Cortex	Irregular	Irregular	Irregular
Volcanic			
Mean	17 ± 12	30 ± 16	36 ± 24
Max.	44	71	82
Cortex	None	Angular	Irregular
Dominant cortex			
Angular	0%	31%	21%
Irregular	100%	62%	71%
Rounded	0%	8%	8%

imum lengths of artefacts increase with sample size for chert and chalcedony (chert: $R^2=0.99$, $p=0.06$; chalcedony: $R^2=0.99$, $p=0.04$), but not for volcanic artefacts ($R^2=0.74$, $p=0.34$). However, the results do not rule out the possibility that size also reflects real differences in the form in which materials were procured or the degree to which they were subsequently reduced. Cortex type may provide further clues as to the form and geological setting in which materials were obtained, whereas the effects of reduction intensity on artefact size are explored below.

Examining the dominant type of cortex found on artefacts as indicated in Table 69, it appears that most raw materials preserve irregular cortex, except for the volcanic stone found at Natunuku. In fact, 79% of all chalcedony and 71% of all chert artefacts preserve irregular cortex. This type of cortex is more suggestive of procurement from primary outcrops, rather than beaches or watercourses, where cortex would tend to be rounded from water-transport (although conglomerates might also contain rounded cobbles). Some chalcedony artefacts from Natunuku also have a thick crystalline cortex suggestive of volcanic origins, although silicified coral is also present in all sites.

In summary, the scarcity of intact and relatively unreduced nodules at sites renders the determination of exact patterns of raw-material procurement very difficult. The type of cortex found on artefacts from all sites, however, suggests the use of primary outcrops rather than secondary sources of water-transported cobbles. The size of these cobbles is very difficult to determine. The mean and maximum size of artefacts does appear to be related to sample size, with the largest artefacts only appearing in the biggest assemblage. However, it is conceivable that these differences in mean and maximum size also relate to distance from a stone source and hence the degree to which raw material was reduced. In the next section, we examine evidence for the types and intensity of reduction found at each site.

Core reduction

An indication of the reduction strategies employed at the Fijian sites can be ascertained from the technological characteristics of cores and flakes. As shown in Table 67, bipolar reduction dominates both the Natunuku and Kulu assemblages, as indicated by cores and flakes exhibiting opposed crushed platforms, wedging initiations and flat or sinuous compression fracture planes (Cotterell and Kamminga 1987:689) (Figure 146). Cores from these sites are also extremely small, with numerous flake scars. In contrast, both the excavated and collected cores from Votua are predominantly worked by freehand percussion, and are much larger than those found at Kulu and Natunuku.

The common assertion that bipolar working represents a later stage in the reduction of cores than freehand percussion can be tested by plotting the weight of cores against maximum face length (Figure 147). Although the sample size is small, a good separation exists between core types, suggesting that real stages in the core-reduction process existed. From this graph, then, it appears that cores were initially worked on a single platform. They were subsequently rotated once platform angles became too great or step and hinge terminations began to appear on each face. Finally, reduction switched to a bipolar technique once cores hit inertia thresholds and flakes could no longer be struck while cores were held in the hand (Hiscock 1982). The bipolar cores shown in the bottom left-hand corner of Figure 147 are nearing the absolute limits of reduction, and could barely have been held between thumb and finger. It is possible that some other method of stabilisation was at this point used to hold these tiny cores in place while blows were delivered from above. Overall, the greater abundance of bipolar cores at Kulu and Natunuku suggests that later stages of core reduction were carried out at both these sites than at Votua.

Changes to core size, geometry and the nature of force input that result from the use of different reduction strategies also have implications for the size and morphology of flakes. Table 70 presents data on the mean characteristics of flake scars found on cores at each stage

Figure 146. Bipolar cores and drill points from Kulu and Natunuku.

Figure 147. Relationship between core face length and weight at each stage of reduction.

Table 70. Mean dimensions and characteristics by core type.

Core type	Single platform	Rotated	Bipolar
Dominant material	Chert/jasper	Chalcedony	Chalcedony
Number	1	3	13
Platform area	6650	796	0
%Cortex	80	17	5
Number of rotations	0	5	1
Longest face	140	58	19
Feather/Non-feather	2	5	6
Number of parallel scars	0	0	2
Elongation of final scar	0.8	1.9	3.2

of reduction, and helps describe the changing nature of flakes throughout this process. For instance, the gradual decortication of cores should result in flakes with little or no cortex at later stages of reduction. The shrinking size of core platforms should similarly be reflected in a decrease in the size of flake platforms as knappers try to conserve what is left of the core. As more mass is struck from a core, the maximum face length also decreases, and so too should the length of flakes. As feather terminations are produced more regularly at later stages of core reduction, flakes should also possess fewer non-feather terminations. Finally, as parallel ridges (or arises) are set up, and flaking is increasingly aligned along a single plane (as, for example, in bipolar reduction), flakes should become more elongated and parallel sided.

Flake characteristics and reduction

Examining the nature of flakes found at each site, those from Kulu and Natunuku are indeed more characteristic of later stages of reduction than those found at Votua. Table 71 presents this data and shows that flakes from Kulu and Natunuku are shorter, have smaller platforms and less cortex, are more elongate and parallel sided, and have fewer aberrant terminations than those found at Votua.

The data for platform attributes also supports the trend for later stages of core reduction at Kulu and Natunuku. Table 72 gives the percentages of platform types found on flakes at each site. Crushed and focalised platforms are most common at Kulu and Natunuku. Crushing typically results from bipolar percussion or the delivery of excessive force to a small platform. Focalisation results from placing blows close to the edge of the platform, and may be indicative of greater precision in the placement of blows, the conservation of raw material, or the working of small cores. Platforms formed by cortex and single and multiple scars that are indicative of the reduction of single platform and rotated cores are most abundant at Votua.

Table 71. Mean characteristics of flakes.

Site	Kulu	Natunuku	Votua
Length	16	18	21
Mean platform area	6	16	27
%Cortex	3	7	16
%Bipolar crushing	18.2	19.8	1
%Parallel and elongate	4	8	1
Number of arises	1.3	1.1	0
Feather/Non-feather	2.5	1.9	1.7

Table 72. Percentages of flake platform types by site.

Site	Crushed	Focalised	Multiple	Single	Cortical
Kulu	56.7	6.3	16.0	26.7	
Natunuku	50.9	5.7	9.4	32.1	1.9
Votua	17.0	1.1	17.0	53.2	11.7

Retouching

If we turn to flake retouching, we find that Kulu and Natunuku artefacts again show signs of greater reduction than those from Votua. Table 73 presents data on the mean extent of retouch found on flakes using three measures of retouch intensity. These indices provide a measure of the coverage, lateral extent and steepness of retouch on flakes. The Index of Invasiveness (Clarkson 2002), for example, measures retouch coverage over both the dorsal and ventral surfaces of an artefact. A result of 0 indicates no retouch and a result of 1 indicates the artefacts are completely covered in retouch over both faces. The perimeter of retouch, on the other hand, simply calculates the percentage of the flake margin that has been retouched. The last measure, or Kuhn's (1990) geometric index of reduction, calculates edge attrition as the ratio of the height of retouch to the maximum thickness of the flake. Again, a score of 0 indicates no retouch, while a score of

1 indicates that retouch height has equalled (or exceeded) flake thickness. All three measures indicate that retouch is greatest at Kulu, followed by Natunuku and Votua. These measures also indicate that retouching in Fijian sites tends to be flatter and more invasive than steep-edged and marginal.

Table 73. Degree of retouch exhibited at each site.

Site	Index of invasiveness	%Perimeter of retouch	Kuhn Index
Kulu	0.4	65	.11
Natunuku	0.2	57	.02
Votua	0.1	43	.01

Manufacturing products and tool use

Drill points

Drill points are a poorly defined implement class technologically and functionally, yet the term is widely employed in Pacific archaeology (but see Smith et al. 1996; Allen et al. 1997). For this analysis, we define drill points as flakes exhibiting steep bi-directional flaking and/or crushing on their margins, tapering to a point (Figure 146). The tip itself must show signs of damage or working. Ten drill points were identified in the analysis, at various stages of reduction. From this sample, there are indications of the nature of drill-point manufacture and discard thresholds. At present, there is no demonstrated link between these particular implements and the function their name implies. It is relevant, though, that their morphology closely resembles drill points of known function from other parts of the Pacific (Kamminga 1982; Smith et al. 1996:197; Allen et al. 1997) and the world (Grace 1989), that there are numerous examples of drilled shell artefacts in the Fijian Islands, and that use-wear studies conducted on other Fijian drill points have revealed torsion fractures and striations consistent with use as drills, as well as calcium-carbonate residues likely derived from working shell (D. Davenport, pers. comm., ANU).

All of the drill points examined were made from a high-quality chalcedony free of cortex or internal flaws. It seems that a diverse range of flake blanks were employed in the manufacture of these artefacts. A large proportion of drill points was probably made on bipolar flakes, however, as most were broken or had distal ends badly damaged by use, it was often difficult to be sure. One drill point clearly at an early stage of reduction was also clearly made from a non-bipolar flake, and showed two distinct pointed tips initiated at opposite ends of the margin (Figure 146, No. 317). Another drill point was made from a burin spall, as indicated by the presence of truncated retouch scars running along the dorsal ridge of the flake (Figure 146, No. 375).

Most identified drill points were actually broken tip fragments that probably snapped off during use. Only one intact drill point appears to have been worked down to a very small slug. This artefact is only 12 mm long, suggesting that hafting enabled a very long use-life for some of these tools. Only one drill point appeared to have a distinct haft element, as indicated by an abrupt change in the width of the flake and the invasiveness of retouch (Figure 146, No. 72).

Thus, while drill points were clearly made from high-quality raw materials, and probably served a specialised purpose, they were selected from a wide range of flake types and varied considerably (at least initially) in size and shape. This last observation is supported by very high coefficients of variation (CV) for the width (CV=104) and thickness (CV=29) of drill points. Unfortunately, there are too few complete drill points to examine variation in length.

Adzes

Nine adzes and adze-blanks were found at the four Fiji sites, and these were highly variable in size and shape, as shown in Figure 148. In order to understand the sequence of adze manufacture and rejuvenation and the effects that reduction intensity might have had on adze variability, it is possible to explore the relationship between the extent of flaking and grinding found on adzes and changes to their shape.

If adzes were gradually flaked, ground and resharpened over their use-life, we should expect a strong positive correlation between the amount of flaking an adze has received and the proportion of its surface covered by grinding (see also Ulm et al. 2005). To explore this proposition, we conducted a regression analysis on the relationship between the Index of Invasiveness and the percentage of surface grinding found on each adze. This test returns a strong and significant *negative* relationship between the amount of visible retouch and the percentage of surface grinding on an adze ($R^2 = -0.865$, $p = 0.002$). This suggests adzes were entirely covered with flake scars before grinding, and grinding gradually removed these scars as it extended to cover the entire surface. When flake scar and grinding coverage are calculated for Best's (1984) 15 illustrated Lakeba adzes, and the data added to our own sample, the results become even more significant ($R^2 = -0.705$, $p < 0.0005$), as shown in Figure 149. We have excluded Best's adzes with high-backed, triangular cross sections (the so-called Samoan-type adzes) as these appear to have been manufactured from a very different type of blank to the other adzes in the collection. As Best only illustrated one side and one edge of each adze, we have assumed symmetry in the amount of flaking and grinding on the opposite surface. This has no doubt introduced error into our analysis, but we feel this is unlikely to be excessive, given the excellent results.

In Figure 150, we again pool Best's adze data with the present study to plot the percentage

Figure 148. Adzes and adze flakes from Fijian assemblages.

Figure 149. Relationship between the amount of retouch visible on adzes and the percentage of surface grinding for A) adzes from the excavated collection, and B) Best's (1984) illustrated adzes combined with those from the present study.

of surface grinding against the number of grinding facets found on each adze. It is clear that as more of the surface area is covered in grinding the number of grinding facets also increases ($R^2=0.582$, $p=0.001$).

Finally, Figure 151 shows that mean elongation decreases as the percentage of surface grinding increases, indicating that the blade tends to be successively worked back towards the butt end of the adze as it is resharpened (note that these results mirror the description by Smith et al. 1999 of Shag River Mouth adze rejuvenation). We do not explore size as a factor of reduction intensity as it is highly likely that different-sized adzes were manufactured for different purposes. Nevertheless, we are confident that the same changes to shape and surface morphology should hold for adzes of all sizes.

Figure 150. Relationship between the number of grinding facets on adzes and the percentage of ground surface area.

Figure 151. Relationship between adze elongation and the percentage of the ground surface area.

The preceding three tests allow us to form a basic model of Fijian adze manufacture and rejuvenation. Adzes were initially roughed out as ovate bifaces (Figure 152, No. 1). These were then steeply flaked around the perimeter to give a thick rectangular block tapering to a sharp edge at one end. Flake scars would tend to cover the entire blank at this stage. Grinding then initially adds an even edge to the adze, but also gradually increases in area and results in a growing number of facets as the adze continues to be shaped and resharpened. This process gradually removes old flake scars from the surface. With successive resharpening, whether involving regrinding or more drastic edge renewal (involving the removal of flakes that preserve grinding on their dorsal surfaces, e.g. top row of Figure 152), the edge is steadily worked back towards the butt, reducing length and elongation over its use-life.

If this model of adze reduction is correct, and the mean area of grinding and the mean number of facets are examined for each site, it appears that adzes from the Beqa sites are more heavily worked (mean surface grinding=75%, mean facets=6) than those found at Natunuku (mean surface grinding=53%, mean facets=3).

Use-wear analysis

Use-wear studies observe the degree of modification on an artefact's edge due to use. These can include edge rounding, striations, polish, abrasion and edge fractures (Kamminga 1982:4–17). Use-wear analysis is undertaken to determine the function to which the tool has been put. Ethnographic and ethnoarchaeological studies (White 1967:406; Gould et al. 1971:149; White et al. 1977; Shackley and Kerr 1985:95) have discovered that debitage and unmodified primary flakes are used for a wide range of purposes. In addition to these ethnoarchaeological studies, analyses of lithic assemblages from the Pacific have revealed that as well as complete flakes, broken flakes and flaked pieces were also used as tools (Sheppard 1993:133). These factors

Figure 152. Adze blank and rejuvenation flakes.

should be taken into consideration when analysis is undertaken and the lithic assemblages studied in their entirety. In keeping with these findings, the entire assemblages from all three sites were examined for traces of use-wear.

From microscopic analysis of the lithics recovered from the excavations, it is evident that only a small percentage of each assemblage carried any signs of use-wear. This consisted of edge fracturing (step fractures caused by friction) and edge rounding. Both forms of wear typically occurred together on these specimens, and are best attributed to the action of scraping. No attempt was made to identify the types of contact materials worked. Most flakes were large enough to have been hand held, and no signs of hafting were discovered, even on the proximal ends of drill points which were closely examined for this type of wear. The occurrence of use-wear at the three main sites is listed below.

Kulu

Use-wear occurs on six items, one flake made from chalcedony (C9:40–50 cm) and one bipolar flake (C11:130–140 cm) constructed from quartz, and four drill points. This represents 11% of the total assemblage. Use-wear consists of rounding and fractures on distal and lateral margins on the flakes, and damage to the distal points of the drill points.

Natunuku

Use-wear occurs on eight flakes (two bipolar) and six drill points, totalling 13% of the assemblage. Use-wear consists of tiny fractures and smoothing on the margins and distal ends of the drills. For unretouched flakes, the lateral margins most commonly exhibited wear, although two flakes did possess wear on the distal margin. One flake had wear on both the lateral and distal margins, while another showed wear on the dorsal ridge.

Votua

From *Votua*, 12 artefacts had use-wear (all flakes), making up 4% of the assemblage. This damage consisted of step fractures, striations and rounding, most commonly on the lateral margins, with only one flake displaying damage on the distal margin.

Manufacturing activities

Table 74 summarises evidence for the total range of technological activities conducted at each site. *Kulu* and *Natunuku* display the widest range of technological activities, despite smaller assemblage sizes. They also possess the highest frequencies of retouching, adze manufacture/use, and drill-point manufacture/use. The relative scarcity of retouching, adzes and drill points, in addition to the presence of large volcanic hammerstones and the absence of use-wear on artefacts, suggests a different set of manufacturing/use activities at *Votua* (Tables 74 and 75). These activities appear to be focused more on procurement and early-stage reduction than at *Kulu* or *Natunuku*. Overall, assemblage differences are attributable to the degree to which raw materials were reduced, as well as the range of manufacturing activities at each site. While

Table 74. Percentages for various manufacturing activities conducted at each site.

Site	%Retouched	%Adze products	% Drill points	% Hammerstones	% Use-wear
Kulu	14	9	9		11
Natunuku	12	4	6		13
Votua	4	1		1	4

Table 75. Summary of the abundance of technological activities and artefact types found at Fijian sites.

Nature/Activity	Kulu	Ugaga	Natunuku	Votua
Assemblage size	Small	Very small	Medium	Large
Richness	Normal	Normal	Normal	Low
Siliceous stone availability	Poor	Poor	Fair	Good
Reduction intensity	High	None	Medium	Low
Drill points	High	None	Medium	None
Flakes with use-wear	Low	None	High	None
Adzes	Low	High	Medium	None
Adze rejuvenation	High	None	Low	Low
Adze manufacture	None	None	Low	Very low
Adze reduction	High	None	None	Low

the range of manufacturing activities (and hence the range of technological classes) at three sites (Natunuku, Kulu and Ugaga) appears largely related to sample size, Votua stands out as technologically impoverished, consistent with primary core reduction as the single dominant technological activity at the site.

Discussion and conclusion

At the outset of this analysis, four basic questions were formulated:

1. What was the nature of stone procurement on different islands?
2. What was the range of reduction strategies and manufacturing activities undertaken at each site?
3. Are there differences in reduction intensity between sites?
4. Might assemblage variability reflect levels of mobility or economic and social differentiation between sites?

Technological analysis of the Fijian assemblages has provided partial answers to some of these questions, and these may be summarised as follows.

The nature of the stone-procurement strategies at each of the Fijian sites appears to reflect the availability of raw materials in the surrounding landscape, with the closest raw materials tending to dominate assemblages. In all cases, however, raw materials had to be imported over considerable distances, sometimes involving water-crossings of more than 40 km. A range of reduction strategies was employed at each site, with all sites exhibiting evidence for the use of both freehand percussion and bipolar reduction techniques. Bipolar reduction dominates the Natunuku and Kulu assemblages, with cores tending to be worked to a very small size and flakes tending to be more characteristic of later stages of reduction. In contrast, the Votua assemblage displays far greater use of freehand percussion, with cores and flakes exhibiting characteristics of earlier stages of reduction. Kulu and Natunuku also display the widest range of technological activities, despite their smaller assemblage sizes, and possess the highest frequencies of retouch, adze and drill-point manufacture/use. Votua, on the other hand, suggests a more limited set of manufacturing/use activities, focused more on procurement and early-stage reduction.

Our last question moved the focus from questions of a direct technological nature to one

of cultural significance – might assemblage variability reflect levels of mobility or economic and social differentiation between sites? At present, this question cannot be answered satisfactorily, although a number tentative suggestions are made below.

As outlined, assemblage variability is greatest at the sites of Natunuku and Kulu, where both assemblages exhibit dominant bipolar reduction and a reliance on chalcedony. Occupants of Natunuku accessed the raw materials at the range of up to 50 km inland, while at Kulu the nearest source is perhaps no closer than 40–80 km away on Viti Levu. The extreme degree of bipolar working at Kulu would appear to reflect the scarcity of lithic resources on the island, with a water-crossing necessary to access them. The fact that the same strategies were undertaken at Natunuku suggests that the distance of 50 km inland was also enough to require that raw materials were conserved and curated. Considering the maritime nature of Fijian society, the 40 km sea-crossing would be no more arduous or less frequently travelled than a distance of 50 km over land. Both sites seem to demonstrate, however, that travel to and from these sources was not frequent.

The assemblage at Votua is markedly different from the others, with freehand percussion dominating the assemblage, resulting in larger cores and flakes, with more cortex and fewer retouched artefacts. The distance between Mago and Vanuabalavu Island, where the source of the jasper that makes up the bulk of the Votua assemblage is located, is only 23 km, and the casual use of this resource suggests frequent contact between these two islands. Further work on the Fijian islands would serve to provide further baseline data to tackle these interesting questions of social relations, inter-island visitation and resource use.

The greater range of activities, technique variations and the degree of reduction exhibited at each of the sites analysed in this paper indicates a level of technological differentiation not previously documented for Fijian sites of Lapita age. Whether such differences are related to varying levels of residential mobility, the range or intensity of economic activities, the location of sites on islands of vastly different size, or differential access to raw materials, remains an open question at this stage. Addressing these questions in more detail requires attention to multiple lines of evidence, such as site sizes, the diversity and quantity of non-stone artefacts, evidence of inter-island contacts, and the range of subsistence opportunities offered in each location, as well as the taphonomic processes at work at each individual site. At this stage, only tentative conclusions can be reached regarding the wider implications of assemblage variation in Fiji, and as such, the questions raised in this paper remain an imperative for future research in the area.

Appendix: Inventory of artefacts made in shell, coral, bone and stone

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Table 76. Artefacts made in shell and other materials found in EPF and Karobo excavations (with permission of the Fiji Museum).

Number	Type of Artefact	Material	Location	Quantity	Comments
Natunuku					
1	Bead	Shell-?species	Trench 3, Square B6, 50–60 cm	1	Diameter 8.8 mm, 4.2 mm thickness, hole diameter 4.0 mm. Drilled biconically.
2	Bead	Shell-?species	Trench 3, Square B6, 40–50 cm	1	Bivalve shell. Diameter 8.6 mm, 1.7 mm thickness, inner diameter 2.5 mm.
3	Bead	Bone-fish	Trench 3, Square B6, Layer 1 30–40 cm	2+7 frags	Fish vertebrae – probably shark or other cartilaginous fish. Diameter 16.0 mm, 3.5 mm perforation.
4	Bead	Bone-fish	Trench 3, Square A3, Layer 2 (light brown)	1	Fish vertebrae – probably shark or other cartilaginous fish. Diameter 12.0 mm, internal perforation 1.7 mm.
5	Bead	Shell- <i>Conus</i> sp.	Trench 3, Square B5, 0–10 cm	1	Two perforations, one on spire, one on side. Diameter of largest hole 10.95 mm, 19.3 mm length.
6	Bead-long unit	Shell- <i>Tridacna</i> sp.	Test Pit 2, 10–20 cm	1	<i>Tridacna</i> . Biconical perforations. Flat polished back. Length 28.8 mm, width 11.9 mm, height 6 mm.
7	Bead-long unit	Shell- <i>Tridacna</i> sp.	Trench 3, Square B6, Layer 1, 50–60 cm	1	Burnt <i>Tridacna</i> . Biconical perforations with one end broken. Length 18.8 mm, width 15.3 mm, height 7.4 mm.
8	Bead-long unit	Shell- <i>Tridacna</i> sp.	Test Pit 1, 0–10 cm	1	Unfinished (beginning of a perforation). Length 24.0 mm, width 13.9 mm, height 9.8 mm.
9	Ring-armband	Shell- <i>Conus</i> sp.	Test pit 1–2, 0–10 cm	1	Thickness (height) uneven, ranging from 5.9 mm to 4.1 mm, width 16.4 mm. Finished and broken. Rectangular cross section.
10	Ring-armband	Shell- <i>Conus</i> sp.	From brown-black surface soil on west side of ditch between depression and shore	1	Width 6.4 mm, height 5.7 mm, internal diameter 55 mm. Finished and broken. Semi-circular cross section.
11	Ring-armband	Shell- <i>Conus</i> sp.	Trench 3, Square A4, 0–10 cm	1	Width 8.4 mm, height 5.2 mm, internal diameter 65 mm. Finished and broken. Semi-circular cross section.
12	Ring-armband	Shell- <i>Conus</i> sp.	Trench 3, Square A6, 40–50 cm	1	Width 9.7 mm, height 6.3 mm, internal diameter 55 mm. Finished and broken. Semi-circular cross section.
13	Ring	Shell- <i>Conus</i> sp.	Trench 3, Square A6, 40–50 cm	1	Finished and broken. Constructed from outer perimeter of a ground <i>Conus</i> spire. Width 4.0 mm, height 2.0 mm.
14	Ring	Shell- <i>Conus</i> sp.	Test Pit 1–2, 20–30 cm	1	Complete ring. Constructed from ground <i>Conus</i> spire. Diameter 17.5 mm, height 2.8 mm, hole diameter 8.6 mm.
15	Ring	Shell- <i>Trochus</i> sp.	Test Pit 1, 0–10 cm	1	Preform fragment.
16	Armband unit	Shell- <i>Conus</i> sp.	Test Pit 2, 10–20 cm	1	Rectangular unit. Four perforations – one at each corner. Polished. Perforations not biconical. One edge snapped off. Two others ground down and one flat. Finished and broken.
17	Armband unit	Shell-?species	Trench 3, Square A3, 0–10 cm	1	Rectangular unit. Two perforations. One at each end.

Continued on next page

Table 76 continued

Number	Type of Artefact	Material	Location	Quantity	Comments
18	Miscellaneous-Spire	Shell- <i>Conus</i> sp.	Trench 3, Square A4, 0–10 cm	1	Natural shape of spire has been smoothed. Ground flat on underside. Diameter 26.4 mm, diameter of perforation 4.9 mm.
19	Miscellaneous	Shell- <i>Spondylus</i> sp.	Test Pit 2, 10–20 cm	1	Fragment shaped to a rough drill shape, not finished. Length 25.2 mm, width 19.1 mm.
Navatu					
20	Ring-armband	Shell- <i>Trochus</i> sp.	Square 17A, Trench B, 20–40 cm	1	Circular fragment from base of <i>Trochus</i> shell flaked into shape. Unfinished ring blank. Diameter of shell 65 mm.
Malaqereqere					
21	Ring-armband	Shell- <i>Trochus</i> sp.	Square A2, 0–10 cm	1	Finished and broken. Constructed from outer perimeter of a ground spire. Diameter of original shell 5 mm, height 3.2 mm.
22	Ring-armband	Shell- <i>Trochus</i> sp.	Square A2, 10–20 cm	1	Incomplete. Base of shell starting to be shaped into ring.
Ugaga					
23	Ring-armband	Shell-?species.	Square A14, 10–20 cm	1	Finished and broken. Height 17.9 mm, width 18.9 mm. Triangular cross section.
24	Ring-armband	Shell- <i>Conus</i> sp.	Square D13, 40–60 cm	1	Finished and broken. Width 9.7 mm, height 5.6 mm. Rectangular cross section.
25	Miscellaneous	Shell-?species.	Square D13, 10–20 cm	1	Rectangular fragment. Width 23.1 mm, length 19.8 mm, height 4 mm. Smoothed and shaped on edge, engraved on inner side with triangular geometric pattern.
26	Miscellaneous	Shell-pearl shell	Square C12, 20–30 cm	1	Cut and smoothed on all edges. Rectangular in shape with drilled hole commenced on inside surface. Diameter of hole 7.2 mm, length 35.5 mm, width 25.3 mm, height 6.7 mm.
27	Miscellaneous	Shell- <i>Conus</i> sp.	Square P10, 10–20 cm	1	Rectangular cut section of shell. At start of working process. Length 40.6 mm, width 18.6 mm.
28	Miscellaneous	Shell- <i>Tridacna</i> sp.	Square J5, 40 cm	1	Large bivalve shell worked by removal of edge. Length 120.5 mm, width 154.0 mm.
Votua					
29	Ring-armband	Shell- <i>Conus</i> sp.	Area 1, surface	1	Finished and broken. Width 6.6 mm, height 3.5 mm. Semi-circular cross section.
30	Ring-armband	Shell- <i>Conus</i> sp.	Area 1, 20–30 cm	1	Finished and broken. Width 9.2 mm, height 3.6 mm. Rectangular cross section.
31	Ring-armband	Shell- <i>Conus</i> sp.	Area 2, Square 1, 50–60 cm	1	Finished and broken. Width 6.8 mm, height 5.1 mm. Semi-circular cross section.
32	Ring-armband	Shell- <i>Conus</i> sp.	Area 2, Square 1, 10–20 cm	1	Finished and broken. Width 12.7 mm, height 8.1 mm. Rectangular cross section.
33	Ring-armband	Shell- <i>Conus</i> sp.	Area 2, Square 2, 40–50 cm	1	Finished and broken. Width 2.7 mm, height 3.2 mm. Rectangular cross section.
34	Ring-armband	Shell- <i>Conus</i> sp.	Area 2, Square 1, 40–50 cm	1	Finished and broken. Width 6.7 mm, height 5.3 mm. Semi-circular cross section.
35	Armband unit	Shell-Shell- <i>Conus</i> sp. sp.	Area 2, Square 3, 50–60 cm	1	Curved rectangular segment. Four holes drilled at corners. Length 40.5 mm, width 16.5 mm, height 2.9 mm. Rectangular cross section. Complete.

Continued on next page

Table 76 *continued*

Number	Type of Artefact	Material	Location	Quantity	Comments
36	Armband unit	Shell- <i>Conus</i> sp.	Area 2, Square 2, 50–60 cm	1	Curved rectangular segment. Two drilled holes, one at each end. Length 30.8 mm, width 11.4 mm, height 2.7 mm. Rectangular cross section. Complete.
37	Armband unit	Shell- <i>Conus</i> sp.	Area 2, Square 2, 0–10 cm	1	Broken curved rectangular segment. Two corner holes along intact edge. Length 27.4 mm, width 20.4 mm, height 3.3 mm. Rectangular cross section.
38	Beads	Shell-?species	Area 2, Square 1, 40–50 cm	1	Circular shaped fragment of shell with central perforation, smoothed on all edges. Diameter 6.3 mm, central hole diameter 3.1 mm. Complete.
39	Beads	Shell-?species	Area 2, Square 4, 40–50 cm	1	Circular shaped fragment of shell with central perforation, smoothed on all edges. Diameter 13.6 mm, central hole diameter 3.5 mm. Complete.
40	Miscellaneous	Shell- <i>Tridacna</i> sp.	Area 2, Square 1, 0–10 cm	1	Adze preform. Length 119.0 mm, width 26.0 mm, height 32.6 mm. Flaked along length.
41	Miscellaneous	Sea urchin spine	Area 2, Square 1, 50–60 cm	1	Broken sea urchin spine shaped at end to form point. Length 37 mm.
42	Miscellaneous	Shell-pearl shell	Area 2, Square 1, 40–50 cm	1	Fish-hook blank, roughed out section in L shape. Length 15.2 mm, width 14.7 mm.
43	Miscellaneous	Shell-pearl shell	Area 2, Square 2, 50–60 cm	2	Flaked shell, possibly blanks at first stage of working.
Karobo					
44	Miscellaneous	Shell- <i>Trochus</i> sp.	Square Q3, Layer 1/2	1+6	Spire with hole drilled in one side, Diameter of hole 13.9 mm and lowest ring segment removed, opposite to hole. First stage reduction to make ring. Six other fragments.
Votua					
45	Abrader	Coral	Area 2, Square 2, 20–30 cm	1	Grooved coral cobble. Length 122.8 mm, width 83.3 mm, depth 52.0 mm. Three grooves on ground surface (6.7–8.2 mm wide, depth 3.5–5.5 mm). Two shallow grooves running across main grooves. One groove on side of cobble.
46	Abrader	Coral	Area 2, Square 3, 40–50 cm	1	Grooved coral. Length 63.6 mm, width 57.8 mm, depth 50.2 mm. Four grooves on surface and two sides. Width of grooves 8.3–9.7 mm, depth 6.2–7.3 mm.
47	Abrader	Coral	Area 2, Square 4, 10–50 cm	1	Grooved coral. Length 49.5 mm, width 42.4 mm, depth 39.2 mm. Two grooves, one on top and one on side. Width of grooves 11.6–11.8 mm, depth 7.9–8.2 mm.
48	Abrader	Coral	Area 2, Square 3, 50–60 cm	1	Grooved coral. Length 60 mm, width 48.2 mm, depth 30.3 mm. Two grooves on surface. Width is 10.5–10.9 mm, depth 9.1 mm.
49	Ornament/gaming piece?	Quartz/calcite?	Area 2, Square 1, 10–20 cm.	1	Stone disk. Ground on surfaces and circumference. Diameter 33.9 mm, depth 9.5 mm.
Ugaga					
50	File/abrader	Sandstone	P10, 40–50 cm	1	Stone file made in laminated material. Top and bottom surface ground flat, sides rounded. Length 146.5 mm, width 42.0 mm, depth 33.8 mm.

Continued on next page

Table 76 *continued*

Number	Type of Artefact	Material	Location	Quantity	Comments
51	Abrader	Coral	M8, 30–40 cm		Grooved coral. Length 109.8 mm, width 80.2 mm, depth 39.9 mm. Two grooves on surface, one on opposite face and one on side. Width is 13.1–13.4 mm, depth 7.4–9.2 mm.
Karobo					
52	Stone pot anvil	Volcanic conglomerate	Square A2, 1.5 m depth	1	Material with pyroxene/amphiboles. Length 62 mm, width 46 mm, depth 32.5 mm. Surface is incised by lines creating a checker-board pattern of squares ca. 5–6 mm in size.
53	Stone pot anvil	Volcanic conglomerate	Square A2, 1.5 m depth	1	Material with pyroxene/amphiboles. Length 62 mm, width 43 mm, depth 17.5 mm. Surface is incised by lines creating a checker-board pattern of squares ca. 5–6 mm in size.

Figure 153. Natunuku shell and bone artefacts.

Figure 154. Ugaga shell artefacts.

Figure 155. Votua shell artefacts and a worked sea urchin spine (41).

Figure 156. Worked *Trochus* shell from Karobo, Navatu, Malaqereqere and Natunuku.

Figure 157. A quartz/calcite stone disk from the Votua Lapita site.

Figure 158. Sandstone file from Ugaga Island.

Figure 159. Grooved coral artefacts from Ugaga (51) and Votua (46 and 45).

Figure 160. Top, grooved stone artefacts from Karobo made in a pyroclastic rock/tuff (Sq. A2, Layer 5, 1.5 m depth) used to mark pots with cross-hatch relief. Bottom, sherd with cross-hatch relief on right and impression in modelling compound taken from grooved stone (52) on left.

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