Expedient Shell Scrapers in the Kingdom of Tonga

by

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in the Department of Archaeology Faculty of Environment

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Abstract

Shell has played a significant role as a raw material for tool manufacture in the South Pacific. Archaeological research on Lapita (2850-2650 cal. BP) sites in the Kingdom of Tonga recovered an assemblage of *Anadara antiquata* valves with what appears to be deliberate edge modification. These were collected, but at the time of collection, the origin of the shells was unknown. No other researcher had determined if these shells had been modified anthropogenically or whether the modification was the result of natural taphonomic processes.

This study investigates whether or not the recovered valves represent a type of expedient shell tool, and if so, how they can be differentiated from naturally fragmented *Anadara antiquata*. The techniques used to assist in making these determinations include morphological analysis, a variety of experimental analyses, and a low power starch analysis.

Taken together, the results of these analyses provide a robust case for the consideration of the valves as scraping tools, and further, they provide guidelines for identification of such artifacts in the field.

**Keywords:** Shell, Scraper, Bivalve, Experimental Archaeology, Tonga, Polynesia, Lapita, Archaeomalacology, Experimental, *Anadara antiquata*
Dedication

This thesis is dedicated to my parents - Thank you for your endless support.
Acknowledgements

I have experienced an outpouring of support during the formulation and completion of this thesis. First, I would like to thank Dr. David Burley, my senior supervisor, for taking a chance on me, and continuing to support me at every turn throughout the last two and a half years. Dr. Dana Lepofsky deserves thanks for participating as my committee member, and for all the assistance she provided as the instructor for my cohort’s Research Methods course. Travis Freeland and Katie Leblanc have been powerful mentors and friends, and have always been quick to offer insight and kind words. I am grateful to Laura Walker, Merrill Farmer, and Chris Papaianni for the assistance they provided navigating the department as both an undergraduate and now as a graduate student.

Thanks go to the Department of Archaeology as well, for the financial assistance during the completion of this thesis.

Finally, to my mom and dad, to my brother and sister, and to the folks at Princess House: Thank you. You’ve been amazing.
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Chapter 1. Introduction

Shell has long played an important role in human prehistory as a raw material, but nowhere are its properties and potential realized as they are in Oceania. Pacific Islanders employed shell in the production of adzes (Szabó 2005: 10), net weights (Connaughton et al. 2010), razors (Bloomfield 2002: 121), tattooing needles (Szabó 2005: 4), gaming pieces (Connaughton et al. 2010) and fishhooks (Burley and Shutler 2007). The importance of shell in the colonization of the Remote Oceania cannot be overstated, though shell artifacts with limited modification are often overlooked. Shell valuables receive a certain attention (Szabó 2005), as do fishhooks and Tridacna adzes (Burley and Shutler 2007), but only recently has academic work intensified on the more domestic uses of shell. Ethnographers, for example, have identified shell as the primary raw material in the production of vegetable scrapers, paring knives, coconut-grater heads, and bark-cloth scrapers (Spennemann 1989: 45). These artifacts often require little modification and can be difficult to differentiate from naturally broken shell in archaeological assemblages. My thesis focuses one of these difficult to identify artifact types – Anadara shell scrapers recovered from archaeological sites in the Kingdom of Tonga.

Beginning in 1990, David Burley initiated a research program focusing on initial Lapita colonizing settlement in Tonga (Burley 1999). This ultimately resulted in excavations at 12 sites throughout the archipelago and the recovery of large numbers of ceramics and other types of artifacts. During these excavations, he noted many Anadara antiquata valves where the ventral edge had been fractured across the length of their margins. This fracture pattern suggested intentional modification as a scraping tool, but Burley was unable to verify such an interpretation since others working in Oceania had not identified these potentially modified shells as part of the non-ceramic artifact assemblage.
Burley’s suspected scrapers are characterized by a continuous, even, and uniform working edge on the ventral margin of the *Anadara* shell. The amount of wear and the profile of wear vary somewhat, but in general, these shells appear to represent a single identifiable tool type. Burley collected over 100 specimens of potential *Anadara* scrapers during his excavations, and has noted that many others were uncollected due to his mental template of what these tools should look like (Burley, pers. comm. 2014). Other researchers working in the same region have reported few, if any, of these items (Dye 1983, Kirch 1988, McKern 1929, Poulsen 1967, Spennemann 1989). Kirch (1988: 206) and Spennemann (1993:40) identify shell scrapers, but refer only to those produced from tiger cowrie (*Cypraea tigris*). This thesis aims to more fully analyse edge modified *Anadara* valves to assess their use as tools, to identify variability in the sample, and to define specific attributes allowing for their identification in future excavations across Remote Oceania.

**Research Objectives**

The objectives of my research are 1) to test the hypothesis that *Anadara antiquata* valves with edge modification are scraping tools, 2) to identify the defining characteristics of this artifact type for recognition in archaeological contexts, and 3) to determine potential uses of this tool based on residue analysis and experimental analyses.

My first objective, to determine whether these artefacts are scraping tools, is essential. Archaeologists do not formally recognize the tool type at present, and as such, it must first be proven to be a tool type, and not the result of natural taphonomic factors. This objective largely is undertaken through research into the shell's properties as a raw material. What force is required to break these shells? In what way do they break when the appropriate pressure is applied? What natural taphonomic factors are present in their environment? My goal is to demonstrate quantifiably that *Anadara antiquata* shell scrapers cannot be produced in any way other than by direct human intention.

My second objective serves to define the artifact type. The morphology of each potential scraper is recorded in a series of measurements relating to the location, size,
and profile of the edge modification wear. This provides future field excavators with a means to differentiate shell scrapers from damaged or naturally worn shells.

The final objective is addressed through experiments on the functionality of these potential scrapers, as well as an attempt to identify starch residues on the working edge of the valves. Recovery of starch through Lugol's Test further demonstrates the veracity of my interpretation for my first objective, and provides insight into what the valves were used for.

**Progression of Thesis**

This introduction has served as a brief orientation to the topics addressed in this thesis and the goals of the thesis. Chapter 2 begins with the placement of my research into the context of Polynesian archaeomalacological literature. This includes a brief orientation to Tonga's archaeological past, but focuses on issues of shell tool research, residue analysis, experimental analysis, morphological analysis, and ethnographic records of shell use. The next three chapters each represent an individual analytical component of the research, with methodology and results provided for each chapter. Chapter 3 explains the experimental studies, including the tests on functionality, and their results, while Chapter 4 presents the various methods and terminology used through the course of the morphological analysis as well as the results of that analyses. Chapter 5 presents the methods and results of the starch analysis. Finally, Chapter 6 concludes the thesis, providing a synthesis of the results of each individual analytical component and reiterates original contributions made through its course.
Chapter 2. Background

Introduction

This chapter aims to provide a context for my assessment of modified valves as shell scrapers in the Kingdom of Tonga. I do this first through discussion of Tongan geography, Tongan archaeology, and a review of the sites from which my data derives. This then leads to a broad discussion of existing archaeomalacological research relevant to my later analysis of *Anadara antiquata* scrapers. Finally, I provide a background to my experimental and starch analyses, the biology of *Anadara antiquata*, and relevant ethnographic material relating to the use of shell scrapers.

Geography of Tonga

The Kingdom of Tonga includes 169 islands oriented on a southwest-northeast axis across a distance of over 600 km (Figure 1). These islands form clusters including the Tongatapu group in the south, the Ha’apai group in the center and the Vava’u group in the north. The archipelago is comprised of two geologically distinct north-south oriented chains. The western chain consists of volcanic islands, while the eastern chain consists of uplifted coral limestone islands and sand cays (Burley 1998a).
The western volcanic islands are without fringing reefs and are difficult to access in high surf. These are the primary sources of basalt and andesite tool stone in Tongan prehistory, but with the exception of Niuatoputapu, these islands were isolated with only small residential populations (Burley 1998a). In contrast, the eastern islands have fringing and barrier reefs protecting their beaches, allowing for the landing of sea craft, and providing habitat for a wide variety of marine life, including molluscs. The shallow, sandy lagoon environments where *Anadara antiquata* thrive are abundant off the coasts of Tongatapu, less abundant in the Ha’apai group, and relatively rare in Vava’u. The eastern chain is also where the vast majority of settlement initially occurred. With suitable stone being limited, many daily implements were fashioned from shell.
Tongan Culture-History

The shell artifacts examined in this study derive from the earliest archaeological deposits in the Kingdom of Tonga. Recent research, using Uranium-Thorium dating techniques, places first arrival of oceanic voyagers in Tonga between 2830–2846 cal. BP (Burley et al. 2012). These colonists were an Austronesian-speaking group collectively referred to as “Lapita”, and are identified in the archaeological record by their distinctive dentate-stamped ceramics (Kirch 1997). Non-ceramic Lapita artifacts in Tonga generally consist of stone and shell adzes and a variety of other shell tools such as scrapers and knives. Shell valuables such as armbands, circlets, rings and beads are also commonly recovered. Pearl shell fishhooks, often used as culture-historical markers in other parts of Polynesia, are rare, suggesting an inshore fishery focusing on reef species (Burley 1998a: 356). The current understanding of the Lapita subsistence economy identifies a reliance on a combination of marine resources and a suite of domesticated food plants (Kirch 1997). The settlements are generally established first on small, offshore islands, before being incorporated onto larger islands (Burley 1998a; Kirch 1997). The end of the Lapita period is identified by the disappearance of dentate-stamped ceramics, a process that was apparently quite rapid in Tonga (Burley 2014). This dramatic transition occurs throughout Oceania and its cause remains an unresolved question in South Pacific archaeology. Kirch (1997) speculates that it may be the result of increasing island independence and specialization of their individual cultures to the variable island ecosystems.

The immediate post-Lapita period is known as Polynesian Plainware. The period sees a restriction in vessel form and changes in ceramic manufacture to a more utilitarian focus (Burley 1998a). This period is also characterized by population growth and the development of dry-land agriculture (Burley 1998a; Kirch and Green 2001). These changes cumulatively provided the foundation for the emergence of Polynesian culture that eventually spreads as far as Hawaii in the north, Rapa Nui in the east, and Aotearoa in the south. The end of the Polynesian Plainware period is marked by a cessation of ceramic manufacture around 1550 BP. The reasons for this second dramatic shift also remain a mystery.
This Aceramic or "Formative" period is poorly understood. Sudden disappearance of ceramics has left archaeologists with limited archaeological data to define this period. There is an assumption of continued population growth throughout this phase (Burley 1998a). As population grew, so did political complexity. It is from this context that the Classical Tongan Chiefdom emerges, beginning around 1000-750 BP.

The Classical Tongan chiefdom is characterized by a highly complex social hierarchy, large trade networks, and monumental stone features still visible on the landscape (Burley 1998a). This period lasts until European contact. Remnants of it are still visible in modern Tonga, such as its monarchy.

**Archaeological Sites and Specimens Used in this Study**

The research of Burley and his team (e.g., Burley et al. 2010) into the Lapita settlement of Tonga ultimately addresses the question of Polynesian origins. Specific research concerns are varied, but subsistence economy and interpretation of foodways are among them. Most early midden sites in Tonga incorporate *Anadara antiquata* shells as a component of food refuse. On Tongatapu, they are a dominant species with large beds occurring in Fanga 'Uta lagoon. In 1995, Burley began collecting *Anadara* shell where a portion of the ventral margin appeared to have been intentionally removed to create an abrupt angle for scraping. The length of area where the ventral margin had been removed varied, as did the location of the removal on the ventral margin, as well as the depth, and form of the area that been removed. The shapes varied from concave to convex, with some featuring deep removals of shell material that appeared to have created a "scoop" type characteristic. The key characteristic that all valves featured was a continuous flat edge somewhere on the ventral margin (e.g. Figure 2). At that time, he was uncertain whether this breakage could occur naturally but the robusticity of the *Anadara valves* seemed to preclude a natural origin. He continued to collect samples through all later excavations, although acknowledges a degree of selectivity in his process (Burley, pers. comm. 2014).
Since 1992 Burley’s team has excavated three sites on Tongatapu, six in Ha’apai and four in Vava’u. He has recovered potential *Anadara antiquata* shell scrapers from each of these. My sample has been assembled from five of these sites: Mele Havea and Vaipuna in Ha’apai, Nukuleka on Tongatapu, and Otea and Falevai in Vava’u (Figure 3, Table 1). For each site selected in this study, every potential scraper that was recovered was analyzed. This is not to say these are the only sites that featured potential scrapers, but rather, these sites provide a geographically diverse sample of a size deemed appropriate for the scale of my research.

Nukuleka is located on the large island of Tongatapu. Nukuleka refers to a village located on a sheltered peninsula on the eastern side of the Fanga ‘Uta/Fanga Kakau lagoon system. Nukuleka has been the subject of numerous field projects. Identified first by Poulsen (1967), and later re-examined by Burley in 2001 and 2007 (Burley et al. 2001; Burley et al. 2010). Mounting evidence continues to point to Nukuleka as a founder settlement within the Tongan archipelago (Burley et al. 2010). Nukuleka featured 79 potential shell scrapers, the largest component of any site yet excavated in the archipelago. This site was the most recently excavated, which may have played a role in the collection strategy regarding the potential *Anadara* scrapers. The shells at Nukuleka come predominantly from the Lapita component.

Mele Havea is located on the island of Ha’afeva in the Ha’apai group. The site consists of both Polynesian Plainware and Lapita components. The site is approximately
150m from the beach, and 900m² in dimension (Burley 1998b). A variety of shell valuables, adzes, and abraders were recovered during the field project, as well as seven suspected shell scrapers (Burley 1998b).

Vaipuna is also located in the Ha’apai group. This site is on the island of ‘Uiha in the southeast corner of ‘Uiha village. It is located approximately 400m from the present shore, and features a large Lapita component, complete with decorated sherds and shell valuables including bracelets, rings, and pendants (Burley 1998b). At the time of first settlement, the site was located on a coral sand back-beach (Burley 1998b). As sea levels fell in the post-Lapita era, site occupants moved their settlements shoreward, resulting in the present village of ‘Uiha (Burley pers. comm. 2014). Burley recovered eleven potential shell scrapers from this site.

Otea, on the island of Kapa in the Vava’u island group, is located on a back-beach near a collecting reef. The site is approximately 800m² in size, of which 16m² was excavated. Recovered artifacts included nine potential shell scrapers, amongst a suite of 155 non-ceramic artifacts, which also included six Anadara antiquata net weights (Burley 2003). Occupation at Otea spans both Plainware and Lapita phases (Burley and Connaughton 2007).

Falevai is the final site in this study. Falevai is also located in the Vava’u group and also located on Kapa Island. Falevai is approximately 600m² in size, of which Burley (2007) excavated 13m². During the excavation, over 10,000 ceramics were recovered, as well as 70 non-ceramics. Falevai yielded four potential shell scrapers.
Figure 3: Island specific maps for the sites used within this study
Table 1: Data for archaeological sites used within this study

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Island Group</th>
<th>No. of Potential Scrapers Analysed</th>
<th>Area Excavated</th>
<th>Non-Ceramic Artifacts (N)</th>
<th>Ceramics (N)</th>
<th>Estimated Site Size</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falevai</td>
<td>Vava'u</td>
<td>4</td>
<td>13m²</td>
<td>70</td>
<td>10195</td>
<td>600m²</td>
<td>Burley 2007</td>
</tr>
<tr>
<td>Otea</td>
<td>Vava'u</td>
<td>9</td>
<td>16m²</td>
<td>155</td>
<td>18414</td>
<td>800m²</td>
<td>Burley 2007</td>
</tr>
<tr>
<td>Vaipuna</td>
<td>Ha'apai</td>
<td>11</td>
<td>17.5m²</td>
<td>309</td>
<td>22660</td>
<td>400m²</td>
<td>Burley 1998b</td>
</tr>
<tr>
<td>Mele</td>
<td>Ha'apai</td>
<td>7</td>
<td>11m²</td>
<td>309</td>
<td>13348</td>
<td>900m²</td>
<td>Burley 1998b</td>
</tr>
<tr>
<td>Nukuleka</td>
<td>Tongatapu</td>
<td>79</td>
<td>37m²</td>
<td>699</td>
<td>47527</td>
<td>200000m²</td>
<td>Burley et al. 2010</td>
</tr>
</tbody>
</table>

A Global Archaeomalacology of Bivalve Scrapers

Outside of the South Pacific, there is a large volume of research dedicated to the study of shell as a tool material. Toth and Woods (1989) performed experiments regarding the use of oysters (*Crassostrea Virginica*) and mussels (*Mytilus spp.*) for animal butchery. Their research found that, without modification, the oyster and mussel valves performed poorly as butchering tools. However, retouching the edges of these valves improved their usefulness greatly. The authors note that early experimental attempts at flaking the shell yielded crushed and blunt working surfaces. The production of sharp edges required practice, with specific positioning and percussion flaking of the specimens. Of particular note, the authors concluded that shells must be flaked from the inside (Toth and Woods 1989: 252). They also expressed a preference for the more robust oyster shell during the butchery procedure, as the mussel was too brittle and tended to break unpredictably.

Expedient bivalve scrapers were identified in Stiner's (1993) research on shell tool use in the Mousterian period in Italy. Stiner identified unifacially flaked *Callista chione* among the recovered shell. She stated, "because of the natural curvature of the
shell, it is only feasible to produce such retouch by striking or pressing inward from the surface of the shell,” (Stiner 1993: 118). This illustrated another example of shell taphonomy being directly related to shell microstructure, a biological characteristic that is dependant on species. Furthermore, Stiner suggested that the best evidence for consideration of the shells as tools is that some shells featured unifacial flaking along their entire margin, while other shells of the same species, in the same context, featured only mild battering along the margin. Given that the contexts are the same, this implied that that battering should the maximum damage visible on the valves unless they are being intentionally modified. Stiner referred to the difference between the battered and intentionally modified valves as “stark” (1993: 118).

Lima et al. (1986) attempted a typological breakdown of various species of fractured bivalves from a site in Brazil. In this case, the researchers were faced with a wide variety of fracture types and locations on the bivalves. They came up with nominal level distinctions for the various forms of breakage. Their typology’s usefulness, unfortunately, does not extend beyond their sample. This is a common problem in shell research - the raw material is so variable that broad generalizations cannot be made, and researchers must resort to performing species-by-species level analyses (Szabó 2013).

O’Day and Keegan (2001) performed a similar analysis to Lima et al. based on logic, taphonomic processes, and repetition of modified forms in the Caribbean. This research considered Queen conch (Strombus gigas) shell as a potential raw material in the production of expedient shell tools. Much like the present thesis research, this work attempted to better illustrate an indigenous toolkit by identifying intent in potentially modified shells. The authors argued that the weight of their shell (2kg) versus meat weight (150g) were critical factors in limiting transport of the shell (O’Day and Keegan 2001: 281). They presented ethnographic evidence that Queen conch meat extraction generally occurs at the beach so as to not have to carry the heavy shell home. Specifically, they also noted the regional occurrence of suspicious breakage, with forms being recovered from across the Caribbean. The implication of these results is that shells were being transported for their value as raw material, rather than as a by-product
of food gathering. Use-wear studies were carried out to identify expedient shell tools occurring within their assemblages.

**Archaeomalacology in the South Pacific**

Formal shell tools make up an important portion of material culture in the South Pacific, with artifact types including *Tridacna* adzes, *Conus* beads, pendants and plaques, and fishhooks, among others (Szabó 2005). Like characteristic ceramics for the Lapita period, these formal tools occur in assemblages across Near Oceania and into Remote Oceania (Barton and White 1993; Kirch 1988; Spennemann 1989). Despite their presence in such a wide variety of contexts, and continuous use against a background of change, the research on formal shell tools is relatively sparse (Szabó 2005; 2010). Informal tools, which may also make up a large portion of the material record, have been largely unidentified in the South Pacific until recently (e.g. Allen and Ussher 2013; Szabó 2013).

Identifying human intent when examining broken shells is difficult. Spennemann's (1989; 1993) experimental work in Tonga focused to a degree on this issue. When broken shell is everywhere, how does one prove that a certain shell has been broken to serve a function, while other shells are broken by natural taphonomic processes? Spennemann (1989) examined ark shell (*Anadara antiquata*) net sinkers and *Conus* shell vegetable peelers (Spennemann 1993). In both cases, Spennemann looked to ethnographic evidence first to support the use of these shells as tools. In the case of ark shell net sinkers, these included specimens where the umbo was broken off, allowing the shell to be easily attached to the edge of a throw net. His experiments, however, suggested that the breakage could be produced by natural taphonomic factors. This work was an early and significant step, but remains incomplete. His experiments included treading on the shells, but he offered no description of other variables used in the experiment. What weight was applied? What footwear was being worn, if any? What was under the shell during the experiment? These factors each play a role, making his study impossible to replicate and test. One experiment regarding ark shell ambiguously involves "chucking" the shells (Spennemann 1989). One conclusion drawn is that, because the ark shells could have their umbos knocked off with a hammer-stone, throwing it into a pile of shells could knock off the umbo as well. The physics striking a
valve with a stone and tossing one onto a midden pile are very different, and as such, should not be applied as though they are the same. Spennemann concluded that one should use great caution in identifying non-formal worked shell (Spennemann 1989: 45). This conclusion was taken into serious consideration in the design of my research.

Connaughton et al. (2010) ran into the issue of quantifying human intent in their paper on Taupita, a game played in Tonga using ark shells. The goal of their work was to readdress a suspected tool-type, the ark shell net-weight (Spennemann 1989) in the light of new ethnographic evidence. Specifically, ark shells with removed umbos had traditionally been referred to as net-sinkers, as Spennemann noted, but Connaughton et al. (2010) had noticed local Tongans playing a game that produced morphologically similar specimens. During the course of an excavation project, the researchers witnessed local excavators playing a game, called “Taupita”, that involved smashing the umbos off shells with other shells. Connaughton et al. (2010) used measures of statistical similarity and ethnographic evidence to demonstrate the plausibility that the archaeological shells, previously identified as net-weight sinkers, were associated with gaming in the ancient past. They also noted, however, that this association does not negate the interpretation of Ark shell net weights, as they are a documented ethnographic artifact (Connaughton et al. 2010).

Identifying human intent in worked shell is even more contentious in relatively old specimens. Szabó et al. (2007) brought this to light in their work on expedient shell tools at Golo Cave, in Java. The researchers identified four different phases, cumulatively covering approximately 30,000 years of occupation. In the earliest parts of this occupation, there was ample evidence of shell working. Turbo mamoratus operculae were flaked along the margin to produce steeply angled scraping instruments. Szabó et al. (2007) relied on fracture mechanics to demonstrate the production of these tools from robust material, going so far as to identify unidirectionality in the flaking process. This research also paid due attention to the microbiology of the shells, noting that a prismatic microstructure allows the shell to be flaked successfully in this manner.
**Starch Analysis**

In recent years starch analysis has become a principal means of linking artifacts to food processing. The starchy organs of plants generally do not preserve in the archaeological record, but the traces they leave on tools can be identified as far back as the Middle Stone Age (Mercader et al. 2008: 298; Szabó 2007; Torrence and Barton 2006). The reason that starch can only be recovered in residue form is related to absorption of the starch into the porous substrate, which would protect it from degradation (Mercader et al. 2008: 297).

After the starch has adhered to a use-surface, it can be recovered through a variety of techniques depending on the resources available to the researcher. Species level distinctions of starch granules require polarized light microscopy at a minimum (Allen and Ussher 2013). Polarized light microscopy refers to the principle of turning normal light, which is characterized by randomly oriented vibrations, into polarized light, which is characterized by unidirectionally oriented vibrations. This unidirectional light allows the researcher to see "extinction" or "maltese" crosses on potential starch granules. The extinction cross is caused by obstruction of the unidirectional light as it travels through the specimen. This characteristic is unique to starch, and further, it is morphologically unique at the species level. This technique has been utilized by Barton (2007), Mercader (2008), and Allen and Ussher (2013).

"Lugol's Test" is a simple test for detecting the presence of starch (non-specific), This test produces a chemical reaction in starch granules that changes the colour of the starch granule from transparent or cloudy white to dark-purple or black. The test requires large conglomerates of starch granules to be visible, and has the added bonus of being able to identify starch after the starch has been gelatinized. Identification of gelatinized starch is difficult to accomplish with polarized light microscopy, as the extinction crosses generally disappear when the granules are exposed to heat, such as in the process of cooking. Lugol’s tests have been used by Loy (1994), and Barton (2007) to identify starch residue in various capacities.
Ark Shell Biology and Mechanics

Given that this thesis focuses on tools produced from Anadara antiquata (ark shell), it is essential to highlight the biological and mechanical attributes of the species because of the variability of such factors between species. Bivalves are a remarkably diverse group of organisms, occupying a variety of habitats all over the world. Anadara antiquata are known by a variety of different names, including Anadara scapha, Anadara suggesta, Anomalocardia transersalis, Arca antiquata, and Arca scapha (Rosenburg and Huber 2012). The shells can be found throughout the Indian and Pacific Oceans, but are notably absent from Hawai`i (Rosenburg and Huber 2012). They are found in shallow, sandy lagoon environments (Broom 1985), allowing for easy collection by shellfish gatherers. Specimens tend to grow larger where the species is less concentrated (Broom 1985). Spennemann (1987: 83) identified several areas on the shores of Tongatapu, Tonga that were especially favourable to the growth of Anadara antiquata, including the reef-flats northeast of the island, the reef-flats attached to the northwest tip, and at the entrance of the lagoon in the center of the island. The cumulative yield of these areas would have provided Tongatapu residents with ample amounts of Anadara antiquata for food and for use as a raw material.

In terms of mechanics, Zuschin and Stanton (2001) have demonstrated that shells of the Anadara genus are extremely robust. They performed “Point-Load” experiments on the shells, where shells were subjected to compaction from a single point while laying flat on a hard surface. They also performed compaction experiments where the shells were compacted in a tube filled with sand. The experiments found that Anadara has great structural integrity; at 3mm thick, one would have to apply, on average, 700 Newtons (approximately 160 pounds force) to crush the shell (Zuschin and Stanton 2001: 164). This robusticity is a combined result of the arched shape of the shell, as well as the thickness and the microstructure. Zuschin and Stanton also noted that when Anadara shell does fracture, it does so in a radial fashion, with fractures spreading from the point of pressure to edge of the shell.

Microstructure plays an important role determining a shell's strength, and it's reaction to applied force. The microstructure of Anadara antiquata is cross-lamellar (Zuschin and Stanton 2001; Figure 4). This is one of the more complex microstructures,
compared to prismatic, which breaks along a vertical plane, or sheet nacre, which breaks along a horizontal plane (Barthelat et al. 2009). Cross-lamellar microstructures feature several layers of variably angled planes. This microstructure provides great strength when combined with other factors, such as the thick calcite layer in *Anadara antiquata*.

![Figure 4: Cross-section of a bivalve](image)

Finally, it is worth noting that although this study has focused exclusively on *Anadara antiquata* valves, there are other bivalves with ventral edge modification within the material collected by Burley. The dominant genus is *Codakia*, but scrapers produced from this species are less frequent than the *Anadara* equivalent. Due to the marked differences in shell microstructure between *Codakia* and *Anadara* valves, I have excluded the former from my analysis.
Linguistic and Ethnographic Background

Early ethnographers identified many tasks that required shell scrapers. Specifically, shell scrapers were used in the preparation of tapa cloth (Figure 5; Collocott and Havea 1922: 68, Williams 1777: 905) and in the cleaning of kava (Williams 1777: 907). Linguistic evidence suggests that shell scrapers were used by the earliest colonizers of the Pacific. Specifically, the proto-lexeme kasi (shell scraper, or to scrape with a shell) is found within the principal subgroup of the Austronesian language family, Malayo-polynesian (Table 2). The word changes remarkably little as it spreads throughout Oceania. Species identified as “kasi” include Asaphis violasceus (Buck 1932a), Asaphis tahitensis (Lemaitre 1973), Arca spp. (Pratt 1911), Vasticardium spp. (Pratt 1911), and Asaphis deflorata (Stokes 1955). Of note is the fact that the words for the shell and the word for scraper are often the same. These data reflect the fact that bivalves were used throughout Oceania as scraping implements.

Figure 5: Samoan woman using Anadara shell in the preparation of Tapa cloth (used with the permission of Te Papa museum, Wellington, NZ.)
### Table 2: List of meanings for the lexeme/proto-lexeme “Kasi” from Greenhill and Clark (2011)

<table>
<thead>
<tr>
<th>Language</th>
<th>Word</th>
<th>Proposed Meaning</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malayo-polynesian</td>
<td>Kasi</td>
<td>Bivalve Shellfish (<em>Asaphidae</em>)</td>
<td>NA</td>
</tr>
<tr>
<td>Proto-oceanic</td>
<td>Kasi</td>
<td>&quot;to scrape; scraper or grater made from robust circular bivalve shell, such as Asaphis and cockles; shellfish taxon, esp. Asaphis spp.&quot;</td>
<td>NA</td>
</tr>
<tr>
<td>Proto-western Malayo-polynesian</td>
<td>gasgas</td>
<td>&quot;scratch&quot;</td>
<td>NA</td>
</tr>
<tr>
<td>Anuta</td>
<td>Kati</td>
<td>A shell used to extract coconut.</td>
<td>Feinberg, R. (1977)</td>
</tr>
<tr>
<td>East Futuna</td>
<td>Kasi</td>
<td>Bivalve Shellfish sp.</td>
<td></td>
</tr>
<tr>
<td>Emae</td>
<td>Kasi</td>
<td>A type of bivalve shellfish</td>
<td>Capell, A. (1962)</td>
</tr>
<tr>
<td>Ifira-mele</td>
<td>Kasi</td>
<td>A bivalve shellfish</td>
<td>Clark, R. (1998)</td>
</tr>
<tr>
<td>Luangiuia</td>
<td>(?)Asi</td>
<td>Shellfish, scraping shell</td>
<td>Salmond, A. (1975)</td>
</tr>
<tr>
<td>Mangaia</td>
<td>Ka?i</td>
<td><em>Asaphis violaceus</em>; small shellfish of various kinds; shell scraper, hand grater</td>
<td>Clerk, C. (1981)</td>
</tr>
<tr>
<td>Mangareva</td>
<td>Ka/Ka?i</td>
<td>Lobster sp.</td>
<td>Janeu, V.F. (1908)</td>
</tr>
<tr>
<td>Manihiki-Rakahanga</td>
<td>Kahi</td>
<td>Shell sp. Used for scraping</td>
<td>Buck, P.H. (1932b)</td>
</tr>
<tr>
<td>Penrhyn</td>
<td>Kasi</td>
<td><em>Asaphis violacea</em>; <em>Asaphis violaceus</em>; small shellfish of various kinds; shell scraper, hand grater</td>
<td>Buck, P.H. (1932a)</td>
</tr>
<tr>
<td>Rotuman</td>
<td>(?)Asi</td>
<td>Cockle; shell used for scraping</td>
<td>Churchward, C.M. (1940)</td>
</tr>
<tr>
<td>Samoan</td>
<td>(?)Asi</td>
<td>Edible mollusc (Arca sp.); Coconut scraper cockle (Vasticardium sp.)</td>
<td>Pratt, G. (1911)</td>
</tr>
<tr>
<td>Tikopia</td>
<td>Bivalve shell</td>
<td>Bivalve shell (<em>Asaphis violaceus</em>)</td>
<td>Firth, R. (1985)</td>
</tr>
<tr>
<td>Tongan</td>
<td>Kahi</td>
<td>Kind of shellfish</td>
<td>Churchward, C.M. (1959)</td>
</tr>
</tbody>
</table>
**Discussion**

Tonga's geography has significance for the present research because its unique make-up of volcanic and uplifted coral limestone islands places importance on shell as a raw material. Discussion of global archaeomalacology served to illustrate how the issue of identification of expedient shell tools is not a phenomenon restricted to the South Pacific. Archaeomalacology has garnered research from across the world and in different archaeological contexts. In a similar vein, archaeomalacological research in Oceania has sought to produce a set of rules for identifying human intent in shell tools through experimentation, quantitative analysis of breakage, study into the biological make-up of shell, the mechanics of shell fracture, and starch analyses. Discussion of the mechanics and biology of *Anadara* shell specifically examines the physical traits of the shell at the macro and microscopic levels. Shells are biologically and physio-chemically diverse. The set of general rules that apply to flaked lithics do not necessarily apply to shells (Szabó 2007). Some may fracture concoidally, but others are more likely to break along incremental growth lines. This makes creating a material-wide set of rules for identifying worked shell from naturally broken shell difficult, causing much work to rely on researcher intuition (Szabó 2013). This information is relevant to how the material would react to various natural taphonomic factors. Finally, ethnographic and linguistic information relating to the use of bivalves as scrapers has demonstrated the geographic spread and potential time-depth of the artifacts throughout the Near and Remote Oceania.

<table>
<thead>
<tr>
<th>Vaeakau-Taumako</th>
<th>Kai</th>
<th>Lilac Clam shell (used to scrape coconuts); scraper (only for coconuts)</th>
<th>Hovdhaugen, E. (2006)</th>
</tr>
</thead>
</table>
Chapter 3. Experimental Analysis

Introduction

A significant question relating to *Anadara* scrapers is whether or not edge breakage is intentional or can occur through natural, taphonomic processes. In this chapter, I test the physical qualities of the valves, and determine whether the physical characteristics of the observed specimens could have been produced by natural factors (Objective 1). These tests were initially carried out on modern samples, but verified by additional tests on archaeological specimens. Also, after completion of the initial series of tests attempting to determine the mechanism responsible for the visible modification, further tests were undertaken to demonstrate the appropriateness the modified edges have for scraping.

Methods

I performed a variety of experiments designed to better understand breakage patterns of *Anadara antiquata* valves subjected to different taphonomic pressures. I also undertook flaking and grinding tests to examine if a modern experimenter could convincingly reproduce the modification visible in the archaeological specimens. The valves used in the experiments largely derive from the Nuku’alofa fish market, where *Anadara antiquata* are sold for food. A small number of archaeological valves from the SFU shellfish reference collection were tested to determine if fracture mechanics differed between fresh and weathered specimens. The first test undertaken was a tread test, where shells, simply put, were trampled. Other tests included a drop test, edge flaking and edge grinding. Finally, replicated modified valves were used in scraping experiments to determine their viability as artifacts. The specific methods are presented below.
Tread Test

The tread test, much like Spennemann’s (1989) previously noted experiment, was designed to determine whether walking upon the Anadara valves could produce the modification visible on the archaeological samples. This experiment compares the mechanics of tread, under the most punishing of circumstances. The valves used in this experiment were thin with shallow inflations, and comprised the least robust specimens within the available testing population, with an average anterior-posterior length of 4.5 cm. These valves were chosen to allow for breakage with minimal application of weight. The test was conducted through the following steps. Importantly, the shells were placed on a concrete surface prior to treading, in order to approximate the hardest possible basal surface in prehistoric contexts.

1. The valve is placed margin down between pages of graph paper on a concrete floor.
2. The participant is weighed fully clothed and note is made of their footwear. Although wearing footwear is unrealistic, it was required for safety, and benefited the experiment by providing a harder surface against the valve, increasing the likelihood for breakage.
3. Participants tread leisurely over the valve 3 times.
4. Valve was examined for breakage.
5. If the valve was not broken, the participant would then stomp aggressively on the specimen until breakage was achieved, or it became apparent that participant would be unable to break the valve.
6. The broken fragments, if there were any, were then photographed on graph paper, and flakes were characterized.

A total of 6 participants of varying weights assisted with this experiment.

Drop Test

This test was designed to evaluate Spennemann’s (1989) assertion that significant breakage could result from the shells being thrown into a midden pile after consumption. Shells were consequently dropped from increasing heights up to 8m onto concrete. The descent from 8m took 0.8 seconds, resulting in a maximum velocity of approximately 10m per second. If the shells did not break, they would be dropped up to five more times from the maximum height of 8m. The damage was then observed and characterized.
Dropping from a greater height might have simulated the behaviour of some seabirds, which drop shells onto rocky surfaces to access the meat. However, seabirds are not likely to have produced fractured shells in the same numbers as they have been recorded in archaeological contexts.

**Flaking/Grinding Test**

Flaking and grinding tests focused on reproducing the modification visible on the valve margins. A variety of common techniques were used in order to reach the most accurate analogues, including margin grinding, free flaking (flaking without an anvil), and anvil flaking. Free flaking quickly dismissed as it did not produce any visible modification to the valve, and was very uncomfortable to experimenter. Anvil flaking was divided into Outside-In flaking, and Inside-Out flaking. Outside-In refers to striking the shell on the exposed, outer potion, and Inside-Out refers to striking the glossy inner portion of the shell (Figure 6).

In the flaking test the valve was supported by a granite anvil and struck with a large basalt stone. The following specific steps were carried out during this test:

- The valve was oriented with the hinge oriented upward, away from the anvil.
- The valve was struck firmly, but carefully along its margin, from the anterior to the posterior. This removed small irregular flakes along the margin.
- A second pass was made, in which specific portions of margin that had been made jagged during the first pass were targeted in order to create the smooth, continuous edge visible in the archaeological specimens.
- Additional passes were made until the valve resembled the archaeological specimens as closely as possible, or the valve broke.
- The cycle was then repeated on additional valves.

The Outside-In flaking test was conducted using the same procedure as outlined above, but with the valve oriented so the hinge faced downwards toward the anvil (Figure 6). The inside margin of the valve was struck continuously along the edge over a series of passes.
I undertook all knapping activities myself, having a sufficient amount of experience flaking lithics prior to carrying out this research. Pressure flaking was considered initially as an additional component to these tests, but early attempts clearly demonstrated that pressure flaking, while possible, dulled the edge rather than producing a continuous scraping plane.

**Figure 6: Diagram of experimental flaking techniques**

The grinding tests were performed by vigorously grinding the ventral margin of a shell against a coarse granitic stone for five minutes. Initial tests demonstrated that through flaking, an excellent working edge could be produced very quickly, and so a comparable time limit was given to the grinding test. This time limit was imposed to test the expedience of grinding as a manufacturing technique, in comparison to flaking. The valve produced during the grinding test was used in the scraping tests below to determine the valve’s functionality. Additionally, I have been unable to identify a naturally available material in Tonga that would be more robust or rougher than the granite stone used in this test.
Functionality Tests

In addition to the tests described above, the functionality of the potential scrapers was determined through two further tests. In the first, a ground valve, flaked valve, and unmodified valve were all used to peel sweet potatoes (*Ipomea batatas*). Sweet potato was chosen as a general proxy for tubers (Figure 7), as it is widely available and inexpensive. Each valve was matched with a tuber, and the experimenter drew the valve back and forth across the skin for 30 seconds, attempting to remove as much skin as possible, while removing as little of the flesh as possible in the allotted time. In the second test, the valves were used to attempt to scrape the bark off of a pin cherry tree (*Prunus pensylvanica*). Pin cherry bark (Figure 17) was chosen, as it was the closest immediately available proxy to paper mulberry (*Broussonetia papyrifera*) due to their membership to the same order (Rosales) and their similar bark texture. Each valve was used to scrape a small section of bark for 30 seconds. These valves were produced according to the outline in the flaking and grinding experiment section.

![Figure 7: Unpeeled Sweet Potato (*Ipomea batatas*), with letters indicating the type of tool to be used on each. "U" indicates an unmodified edge, "F" indicates flaked edge, and "G" indicates ground edge.](image-url)
Experimental Results

Tread Test

Table 3: Diagram of tread test outcomes

<table>
<thead>
<tr>
<th>Gender, Footwear and Weight (Kg)</th>
<th>Tread 1</th>
<th>Tread 2</th>
<th>Tread 3</th>
<th>Stomp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual 1</td>
<td>Female Boot 53.9</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
</tr>
<tr>
<td>Individual 2</td>
<td>Female Boot 54.8</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Radial Breakage</td>
</tr>
<tr>
<td>Individual 3</td>
<td>Female Running Shoe 65.7</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Radial Breakage</td>
</tr>
<tr>
<td>Individual 4</td>
<td>Male Boot 72.4</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Radial Breakage</td>
</tr>
<tr>
<td>Individual 5</td>
<td>Male Running Shoe 87.9</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Radial Breakage</td>
</tr>
<tr>
<td>Individual 6</td>
<td>Female Boot 105.3</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Radial Breakage</td>
</tr>
</tbody>
</table>

The primary finding of this test was that no tread could ever produce damage to the valve (Table 3; Figure 8). In the lightest individual, even stomping produced no effect. In the heavier individuals, stomping produced radial breakage, but nothing that resembled the edge morphology visible in archaeological specimens.
Figure 8: Damage produced during tread test

Drop Test

This test demonstrated the significant robusticity of the valves, but more importantly, it demonstrated further that taphonomic actions tend to produce radial fractures, with fracture lines emanating from the point of impact outwards (Figure 9; Figure 10; Table 4). This is a very similar outcome to the tread test, despite the different mechanisms at work. In all cases, the valves initially broke radially outwards from the point of impact, with continued drops producing less predictable fragmentation. In no case did a valve break continuously along the margin.

Table 4: Drop Test Results

<table>
<thead>
<tr>
<th></th>
<th>1m Drop</th>
<th>2m Drop</th>
<th>4m Drop</th>
<th>First Drop at 8m</th>
<th>Second Drop at 8m</th>
<th>Third Drop at 8m</th>
<th>Fourth Drop at 8m</th>
<th>Fifth Drop at 8m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell 1</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Broken Umbo</td>
<td>Broken Umbo</td>
<td>Broken Umbo + Radial Breakage</td>
</tr>
<tr>
<td>Shell 2</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Broken Umbo</td>
<td>Broken Umbo + Radial Breakage</td>
<td>Broken Umbo + Radial Breakage</td>
</tr>
<tr>
<td>Shell 3</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Broken Umbo</td>
<td>Broken Umbo + Radial Breakage</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>-------------</td>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td>Shell 4 (Archaeological)</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Broken Umbo</td>
<td>Broken Umbo + Radial Breakage</td>
<td>Too fragmented to warrant final drop</td>
</tr>
<tr>
<td>Shell 5 (Archaeological)</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Broken Umbo</td>
<td>Broken Umbo + Radial Breakage</td>
<td></td>
</tr>
<tr>
<td>Shell 6 (Archaeological)</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Broken Umbo</td>
<td>Broken Umbo + Radial Breakage</td>
<td>Too fragmented to warrant final drop</td>
</tr>
<tr>
<td>Shell 7 (Archaeological)</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Radial Breakage</td>
<td></td>
<td>Too fragmented to warrant final drops</td>
</tr>
<tr>
<td>Shell 8 (Archaeological)</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Broken Umbo</td>
<td>Broken Umbo + Radial Breakage</td>
<td>Too fragmented to warrant final drop</td>
</tr>
<tr>
<td>Shell 9 (Archaeological)</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>No Damage</td>
<td>Broken Umbo</td>
<td>Broken Umbo + Radial Damage</td>
<td>Too fragmented to warrant final drop</td>
</tr>
</tbody>
</table>

Figure 9: Damage produced on freshly picked shells during drop test
I continued dropping the shells after initial damage was incurred. This increased fragmentation, but notably, the shell edge remained intact throughout fragmentation in all five cases. This result is similar to fragmented specimens of *Anadara antiquata* from a Nukuleka shell midden column sample (Figure 11). The shells also demonstrated great robusticity, with all valves surviving two consecutive 8m drops onto concrete, including the two valves taken from the archaeological reference collection. It also noteworthy that the archaeological samples broke in the same way as the non-archaeological samples (Figure 9, Figure 8).
Figure 11: Damaged valves from Nukuleka shell midden column sample

Grinding

The grinding experiment failed to produce the edge modification visible in the archaeological collection. The shell was ground vigorously for 5 minutes, and at the end of the allotted experiment time, the corrugation along the valve’s edge remained largely intact. A slight edge had been produced, but was only apparent in comparison with the completely unmodified valves. Continued attempts after the initial time allotment of five minutes also failed to produce a significant edge (Figure 12). It would seem that *Anadara antiquata* valves are too robust and protected by their porcellaneous layer from the abrasion of grinding.

Figure 12: Valve after attempted grinding on the ventral margin
Flaking: Outside-In

Striking the shell from the outside produced a working edge on the valve, but the edge was unrefined, varying in sharpness and thickness. I also found the edges produced by outside-in flaking are susceptible to crumbling after production, and carry a higher risk of unpredictable fracturing. Specifically, if the valve is struck too high on the margin, it produces radial fractures and renders the tool useless. In one scenario, the first strike on the valve was placed too high and the valve fractured radially from the point of impact (Figure 13).

![Figure 13: Example of damage produced by striking too high on the outside of the valve](image)

Flaking: Inside-Out

Inside-out flaking produced the results most consistent with the shapes and forms visible in the archaeological collection (Figure 14). Using the same hammer and anvil set-up as Outside-In method, the Inside-Out flaking produces a continuous, sharp working edge without considerable effort. I was able to produce a convincing specimen in under a minute.
Figure 14: Edge morphology produced by using Inside-out technique

During the inside-out flaking experiment, blows struck the inside of the margin near the flange produced the precise “scoop” morphology identified many times in the archaeological sample. In one case, a single blow to the inside of the flange produced the scoop form. Another fracture mechanic feature of the shells involves the layer lining the inside of the valves. This layer thickens near the end of the ventral corrugation and the blows tend to not break any further than this area.

Inside-out flaking also produces a very specific type of flake not produced by other means of flaking (Figure 15). The fracture line extends straight through the porcellaneous layer, and when it reaches the outer layer, it curves to follow the natural contour of the shell. This flake morphology produces rounding just above the working edge. This rounding is visible in the archaeological specimens as well (Figure 16).
Figure 15: Top Left: shell flake produced during flaking exercise; Mid Left: profile of shell flake; Bottom Left: exaggerated illustration of shell flake; Right: direction of breakage through valve when struck from the inside out

Figure 16: Left: Experimentally produced edge; Right: archaeological specimen edge
Functionality Test Results

The test demonstrated that the ground edged valve was less effective at removing the bark from the branch than the flaked specimen (Figure 17 and Figure 18). The flaked specimen removed more bark in the same amount of time, and again, left a smooth surface underneath. The ground-edged valve left the grating-marks from the corrugated edge (Figure 18).

The valves were all found to be capable of removing the skin from the sweet potato. There was a marked difference, however, in the quality of scraping. The flaked shell was able to smoothly and easily remove the skin, while removing virtually none of the flesh underneath. Both the ground-edged valve and the unmodified valve produced significant grating and gouging due to their corrugated edge, which resulted in significant amounts of flesh being lost during the scraping process (Figure 18).
Figure 18: Clockwise from top-left: Flaked-edge peel result, ground-edge peel result, flaked and ground edge bark scraping result, unmodified peel result.
Summary

The preceding experiments demonstrated specific outcomes of approximated taphonomic forces and assessed the functionality of the modified valves. Of the forces applied to the valves over the course of the experiments, only inside-outwards flaking produced an edge modification comparable to that visible in the archaeological sample. In addition, the flaking experiment demonstrated the speed and ease of producing such an implement. In terms of damage, the drop test and tread test produced radial fracturing in every scenario where force was applied to the shell indiscriminately. Finally, the functionality tests illustrated that, while even unmodified valves can be used to remove bark and peel tubers, a retouched valve does so more effectively.
Chapter 4. Morphological Analysis

Introduction

The following morphological analysis was designed to identify uniformities, determine the range of variability within the proposed artifact type, and characterize the visible modifications that are being evaluated as tool edges. This analysis used archaeological specimens recovered from four sites located throughout the Tongan island groups. Specifically, there are samples from Nukuleka in the Tongatapu group, Mele Havea and Vaipuna in the Ha’apai group, and Otea and Falevai in the Vava’u group. These samples were selected because they derive from excavated contexts, have chronological associations, and were identified as potential scrapers by Burley. Additionally, because these are suspected to be expedient tools, I expect variation, albeit Burley’s selection criteria retention will have removed some of the range of variation. The metrics used and their purposes are outlined below, and the data for each individual specimen is located in the data table (see Appendix 1).

Methods

Modification Morphology

During the preliminary examination of Burley’s specimens, it became clear that the profile of the modification of the potential scrapers varied, but it did so apparently within a confined series of forms. I was able to describe the morphology of every valve analyzed using nominal descriptions of the modified edge’s profile. These included Posterior Scoop, Ascending to Posterior, Concave, Convex, and Flat (Figure 19). In addition to these forms, there were also a variety of incomplete valves and valves that featured combinations or derivations of the above listed forms, which were classified as “irregular.” Convex forms are identified by the modification extending deeper into the shell towards the anterior and posterior, and then have the edge protrude outwards at the center. The Posterior Scoop form is difficult to distinguish from the concave form, but
can be identified by its narrow length, and relatively deep reduction into the posterior flange of the valve. Concave forms, on the other hand, have an even edge across the entire margin with inwards curvature. Ascending to Posterior forms begin with a shallow modification that becomes deeper towards the posterior of the valve. A flat edge morphology is identified by the ability of the shell edge to sit flush on flat surfaces. With these forms, I am able to identify and determine the frequency of some of the less quantifiable traits of the valves that relate to their use or production. For example, if the scoop is a recurring phenomenon, this could imply that it is related to a specific use for the scoop feature; abundant concavity could be an innovation designed to scrape rounded objects.

Figure 19: Edge morphologies present in sample
Dimension Measures

Figure 20: Anatomical reference points and directions

Several measurements were used to describe general shape of the shell. These included an inferior to superior measure, a dorsal-ventral measure, and a measure of inflation (Figure 20). Inflation refers to the maximum height of the valve when it is placed aperture down. These measures serve to give a sense of tool size. They also potentially shed insight on uniformity of production.

Location of Modification

The location of edge modification on the lip is highly important, as it may be related to the tool’s functionality, yet it is difficult to quantify. Measurement of the length of modification is also important, but does not give a sense as to the anatomical location of the modification. As mentioned previously in chapter 2, other researchers have split up the valve into nominal sections, to acquire qualitative, descriptive data. For example, in Lima et al. (1986), the researchers would use descriptors such as “arciform ventral.” A
description of the location is a good way to begin studying, as it allows for qualitative comparison, but verbal descriptions lack the means for quantitative comparison. The geometry of the shell provides a more quantitative means to acquire information on the location of the edge relative to the rest of the shell. The valve is roughly a semicircle with 180 degrees. This means that if a shell is placed margin down and always oriented anatomically with the umbo serving as the top and the bottom of the hinge as the bottom, one can identify the specific degrees of worked edge (Figure 20). To do this, the hinge of the shell forms the 0-180° axis, with the vertex being in the center of the hinge. Rays extend outwards from the vertex to the beginning and terminus of the worked area, and the arc between them identifies the specific worked area of the shell. For example, in Figure 20, the beginning of the modification occurs at 60° and the modification terminates at 135°. This creates an arc, which can be used to identify the relative worked area as well its location on the valve’s ventral margin. This provides a quantitative data for comparison of worked areas across a series of artifacts.
Length of Modification, and Percentage of Edge Modified

The length of modification and the percentage of edge that is modified provides an indication of how much of the shell edge is worked. Although unable to identify the relative location of the modification, “length” does add the dimension of physical size to the location, providing the most complete cataloguing of the modification possible. It also serves as a check on the location metric, as the percentage of modified shell edge can be derived from both (Figure 21).

![Figure 21: Location of physical length measurements](image)

**Hinge Length**

This metric was taken to allow size-based interpretations when the shell was incomplete in such a way that size could not be directly measured. Hinge length is positively correlated with the general size of the shell (Faulkner 2010). This allows researchers to speculate a general shell size based on the hinge measurements.
Results

Area of Modification

The morphological analysis revealed several trends. The most relevant was the identification of a commonly worked zone. This zone generally refers to the area of the shell between 60 degrees and 120 degrees. There is some variance, as expected when the shape depends on an organic structure, but the majority of shells are modified in this area (Figure 22). In terms of direct measures, the average total modified area was 93.65° and it featured a standard deviation of 22.8°. The minimum amount of modified area was 40° and the maximum was 80°. Further, all valves were modified between 100° and 120°. This speaks to the continuous nature of the modification. The specimen with the smallest worked area still featured a modification that encompassed 20% of the valve’s margin, and is an outlier. In Figure 22, the individual black lines identify the length and position of each specimen’s worked edge, laid out linearly and described in terms of degrees. Further, this graph is sorted by the location of the center of each specimen’s working edge in ascending order. This means of visualization allowed me to determine where, and how large each specimen’s modification is compared to the other specimens. Figure 23 was constructed as a means to compare the distribution of worked areas to what would be expected in a population with a normal distribution. Each worked area value was indexed into a 10° category (e.g. 0°-9°, 10°-19°, etc.), and the frequencies of values that fell into those categories were plotted on a histogram. Figure 23 demonstrates that the worked areas (total degrees out of a potential 180) for each shell adhere to the mean more than a normal distribution would predict. A strong adherence to the mean indicates homogeneity in the sample. This may be a consequence of Burley selectively collecting the shell artifacts based on his mental template for scrapers.
Figure 22: Diagram illustrating location of edge modification. X-axis indicates specimen, Y-axis indicates degree at which modification starts and where modification ends.

Figure 23: Histogram of Actual Total Modified Area in Degrees vs. Normal Distribution
Morphological Type

The morphology of the wear generally tends towards the posterior flange of the valve (Figure 24). This may have to do with the increased thickness of the valve near the posterior ligament attachment. However, when considering a natural taphonomic origin for these forms, one would expect not to see such a variety if the shells were indeed breaking along a naturally occurring plane. For example, if there were an anatomical weakness in the valve that had the potential to break and cause reoccurring forms, one would not expect the forms to vary from convex to concave. Two valves were too incomplete to make a typological determination.

Significantly, even in my small sample, there was one modified valve that did not meet the criteria for classification as a scraper (Figure 25). Unlike all other specimens, this artifact did not have a single uniform edge; instead the edge was characterized by jagged redirection and crushing. This crushing was more consistent with outside-in impact or point loading very near the ventral edge, rather than intentional flaking from the inside out. The radial fracture extended at an extreme obtuse angle as a consequence.
Summary

The metric analyses from the archaeological specimens revealed a number of insights. First, the location of modification on these shells varies. However, it always falls on the ventral edge, generally between 60° and 120°, with the area between 100° and 120° being modified in every case. Furthermore, the total modified area of the shell is more homogenous than would be expected by chance. Compared to a normal distribution, the distribution of worked area centers tightly around its mean, featuring a standard deviation of 22.8° (Figure 23). Finally, I have identified four dominant edge morphologies: Ascending to Posterior, Concave, Flat and Posterior Scoop. These morphologies tend to fall toward the ventral flange of the shell; likely because that portion of the shell is more robust. Four other morphologies were also identified but were far less common (Figure 24).
Chapter 5. Starch Analysis

Introduction

Starch analysis is a powerful tool for determining whether the modified valves collected in Tonga from different excavations, projects and temporal contexts were the product of intentional human construction. Finding starch on the working edges of the artifacts would be considered evidence for the use of the modified valves as tools. Furthermore, the specific method used in this analysis demonstrated the value of Lugol’s solution tests to identify gelatinized starch globules, as suggested by Torrence and Barton (2006).

Methods

The specific test used in this research is known as a Lugol’s Test. Lugol’s Test involves producing a chemical reaction between the Amylose in the starch granule and a solution of iodine-potassium-iodide (IKI) (Torrence and Barton 2006). This reaction changes the colour of the starch granule, generally to a dark purple or black, but a variety of shades, including yellow brown, are possible. My research also demonstrated that given approximately 24 hours, dark purple/black staining would turn brownish yellow in the case of taro and potato, which were used as controls to determine the efficacy of the solution before it was applied to archaeological samples (Figure 26; Figure 27). Starch analysis was conducted on 20 shells from across the five sites to determine whether or not vegetable-tool contact could be demonstrated, allowing some insight into the potential function of the scrapers. The shells were selected because they featured macroscopic material adhered to their ventral edges. Lugol's Test, as applied here, allows for distinctions of starch on a presence/absence scale, but is ill-suited to species level identifications. This technique was conducted following the protocols set forth in Torrence and Barton (2006: 121) as follows:
1. Create a solution of iodine-potassium-iodide (IKI), by mixing 0.3 g crystalline iodine and 1.5 g potassium iodide in 100 mL of ultrapure water.
2. Identify globules of potential starch from along the working edge of the valve.
3. Scrape material onto a microscopic slide using a surgical scalpel.
4. Apply a cover slip, and secure it in place with nail polish.
5. Place the slide under a microscope (in this scenario, a Nova FST 651 was used with a magnification range of up to 45x).
6. While observing the slide through the microscope, inject a small amount of IKI solution under the slide using a disposable pipette.
7. Observe the slide for changes in the material colour, from white or pinkish-white to dark purple or black.
8. If globules turn black, identify the specimen as starch positive.

Figure 26: Control Sample with Dark Matter Indicating Starch
To prevent contamination, the microscope was cleaned after each examination using ultra-pure water and tissue. The tissue used was tested independently for starch, and was found not to react with the IKI solution. Furthermore, gloves were worn while handling the specimens. These gloves were also tested for IKI reaction and were found not to react with the solution. The scalpel used for scraping material was also cleaned thoroughly after each use to ensure non-transference of materials and examined at maximum magnification (40x) for potential contaminants before use.

To demonstrate that the starch on the shells was not transferred from naturally occurring starch in the soil, control valves (N = 50) from the same sites were also analyzed using Lugol's Test. Control samples are unmodified *Anadara antiquata* valves taken from midden columns used for shellfish quantification. For each specimen, I scraped areas of potential residue onto slides and completing the same test as above. If the control samples are negative for starch, while the scraping tools are positive, then the latter results are considered more robust.
Starch may be absent on used shells for a variety of reasons that does not detract from their potential identification as tools. These include use for tasks not directly related to starchy vegetables, cleaning/wiping away residue before discard, or simple loss of residue due to taphonomic factors. It is also possible that although full effort was applied to locate starchy material, that potential globules escaped identification due to the coarseness of the Lugol's test examination at 40x magnification. Additionally, all scrapers analyzed in my thesis have undergone some level of washing. The valves from Nukuleka, for example, were washed exceptionally well, while those from the other sites were washed less thoroughly. The test status of each valve is located in the data table (see Appendix 1).

**Results**

The analysis found starch on eight of the 20 tested tools (Figure 28, Table 5, Table 6). All 50 of the control samples were negative for starch (Table 7). These positives are mostly from sites outside of Nukuleka, the primary source of specimens for this analysis. This likely has to do with specimen washing after field collection. As a result of the differential washing, the valves from Otea, Vaipuna, Mele Havea, and Falevai featured a variety of unidentified residue material on the working edges and adhered to the outside of the exterior of the valve. The negative control samples, which had not been washed, add additional robusticity to the interpretation of this analysis.

In terms of context, Falevai provided the most positive samples (n=3), and the cultural context most often associated with positives was Lapita (n=5). Much like the overall association of scrapers with the Lapita period, this is likely skewed by the fact that Burley’s fieldwork was Lapita-focused while the *Anadara* scraper collection was being assembled.

**Table 5: Frequency of positive Lugol's Test by site**

<table>
<thead>
<tr>
<th>Starch Positive?</th>
<th>Site</th>
<th>Mele Havea</th>
<th>Nukuleka</th>
<th>Otea</th>
<th>Vaipuna</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Falevai</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Untested</td>
<td></td>
<td>1</td>
<td>5</td>
<td>68</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
<td>4</td>
<td>7</td>
<td>80</td>
<td>9</td>
<td>111</td>
</tr>
</tbody>
</table>
### Table 6: Provenience of starch-positive specimens

<table>
<thead>
<tr>
<th>Site</th>
<th>Accession #</th>
<th>Provenience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nukuleka</td>
<td>To2.408</td>
<td>Lapita</td>
</tr>
<tr>
<td>Falevai</td>
<td>Ka2.03:6</td>
<td>Aceramic</td>
</tr>
<tr>
<td>Falevai</td>
<td>Ka2.03.49</td>
<td>Lapita</td>
</tr>
<tr>
<td>Falevai</td>
<td>Ka2.03.15</td>
<td>Pit Feature</td>
</tr>
<tr>
<td>Otea</td>
<td>Ka1.03:134</td>
<td>Aceramic</td>
</tr>
<tr>
<td>Vaipuna</td>
<td>Ui4.225</td>
<td>Lapita</td>
</tr>
<tr>
<td>Mele Havea</td>
<td>HF1:75</td>
<td>Lapita</td>
</tr>
<tr>
<td>Mele Havea</td>
<td>HF1:61</td>
<td>Lapita</td>
</tr>
</tbody>
</table>

### Table 7: Number of control samples tested by site

<table>
<thead>
<tr>
<th></th>
<th>Nukuleka</th>
<th>Falevai</th>
<th>Otea</th>
<th>Vaipuna</th>
<th>Mele Havea</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Shells Tested</strong></td>
<td>21</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>50</td>
</tr>
<tr>
<td><strong>Positive</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Negative</strong></td>
<td>21</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>50</td>
</tr>
</tbody>
</table>
Figure 28: Three examples of starch collected from archaeological specimens. Red circles indicate starch globules. Scale is 40x magnification.

**Summary**

Approximately 25% of the scrapers analyzed had come in contact with a starchy substrate before deposition. The entire control sample tested negative for starch, despite being taken from the same contexts as the archaeological specimens. These results provide further support for classification of the modified valves as scrapers, and more specifically, as vegetable scrapers.
Chapter 6. Discussion and Conclusion

Introduction

This chapter synthesizes the results of my thesis and places them into the broader context of their archaeological significance. It begins with a discussion of the physical characteristics of the shells and how the results can help to define types. It synthesizes the primary findings of the experimental tests as well as speaking to the implications of the starch analysis.

Natural Breakage

The experiments conducted regarding the trampling and dropping of *Anadara antiquata* valves point to patterns in natural breakage, specifically, radial fracturing. Radial fracturing outwards from the point of impact was described by Zuschin and Stanton (2012) during crushing experiments and was observed during experimental tests in my research. The treading and dropping tests are admittedly poor analogues for the long-term compaction of shell in a midden context, but Zuschin and Stanton’s (2012) point-loading experiments are a closer proxy, and identify the same result.

With this in mind, one must be cautious when identifying shell scrapers in midden contexts. Radial breakage very near the ventral margin can produce the appearance of a broad, uniform, working edge. However, close inspection for crushing or jagged redirection of the edge allows a researcher to identify natural damage. The compacting force within a midden is multi-directional and may apply pressure to the interior of the ventral margin producing small sharp chips. The small chipping is not necessarily anthropogenic, and in this case, the broadness of the worked area is the determining characteristic of intentional modification. In order to classify a valve with ventral edge damage as a scraper, it must be determined that the edge is not a single removed flake, but several removed flakes along a broad section of the margin.
The experimental component of this study has also shown that once the structural integrity of the shell was compromised, further shattering from natural processes occurred rapidly and much less predictably. The radial nature of the breakage became difficult to characterize, with some pieces breaking into squares, or long breaks stretching from the umbo to the edge. These long broken shards may give the appearance of being a utilized tool, and it is for this reason that caution must be exercised when identifying incomplete valves as tools.

There are taphonomic factors that could not be modelled for within the scope of this study. These include root action and bioturbation related to pigs. Perhaps most importantly, I have no means to control for long term midden compaction, where the shell undergoes chemical changes potentially affecting the structural integrity of the shell. The archaeological samples used in the drop test seemed to follow the fresh shell pattern of radial breakage, but the physical forces at work during both the drop and tread tests are not comparable to long term midden compaction.

**Establishing an Artifact Type**

The primary lesson learned from the morphological analysis was one of relative homogeneity. There appears to be a desired outcome in the modification process, which produces similar morphological characteristics in each specimen. The kind and amount of modification produce a single sharp, but robust edge that appears rounded in profile. In addition, the method of producing the edge is corroborated in other archaeomalacological studies. Toth and Woods (1989) and Stiner (1993) found that inside-out flaking was required to produce the modifications in their archaeological samples, although the species being examined were not *Anadara antiquata*. The data presented here agree with that conclusion and may point to a potential common feature of shell working, where the geometry of bivalves lends itself to a specific knapping procedure.

**Expedience**

Expedience is an ambiguous term and different authors describe it in a number of ways. Andrefsky (1994) regards expedient tools as a subset of informal tools. The classification of informality applies when the researcher believes the tools are
“manufactured, used and discarded in a relatively short period of time,” (Andrefsky 1994: 22). O’Day and Keegan (2001) address the issue of expediency with specific regards to shell tools. They suggest it simplest to refer to expedient tools in contrast to formal tools, which generally exhibit signs of retouch.

Expedience, as used within this thesis, follows Andrefsky’s (1994) definition, where the duration of time in which a tool is manufactured, used, and discarded determines its expedience. This definition stands closer to the dictionary definition, wherein expedience is defined as “characterized by concern with what is opportune,” (Merriam Webster Online Dictionary 2014). The issue of advanced forethought, presented by O’Day and Keegan (2001), should not play a role in the determination of expedience. This means that even if a tool is retouched or reworked later in its life-cycle, it remains an expedient tool if it can still be readily produced, and discarded the moment it becomes easier to produce another than to rework the tool at hand.

With the above definition in place, even by the harshest standards, it stands to reason that if a tool were theoretically capable of being produced in less than 60 seconds by an unskilled experimenter, it should be classified as expedient. This is the specific means by which I have come to refer to the modified valves as expedient.

Expedience is likely responsible for the variation that occurs within this artifact type. Expedience is a difficult concept to quantify, but in this context, it is an appropriate descriptor. Basalt/andesite earth-oven stones and hand stones are abundant in Tongan archaeological contexts and could easily be utilized as hammer stones and anvils with no modification. Anadara antiquata are also highly abundant throughout Tonga, with the exception of Vava’u. If one can produce an excellent scraping edge in under a minute (pg. 30), with the locally available materials, it is logical that the items vary slightly in their specifics, but are generally homogenous in their overall form.

**Starch Analysis**

This analysis has shown that the archaeological samples proposed to be scraping implements have indeed come in contact with starchy substrates. This result sheds some light on the potential use of these bivalve scrapers. It appears they were, at
least in certain cases, used for cleaning starchy crops. When this conclusion is paired with the cultural association of the artifacts, it appears that root crops constituted a component of the Lapita diet. Of the specific valves that identified as positive for starch, five were from a Lapita context. Researchers (Allen and Ussher 2013; Lima et al. 1986) have demonstrated many times the longevity of starch in archaeological records, which suggests that any argument regarding degradation of starch would have to be supported by taphonomic circumstances. Continuity in the use of shell scrapers over long periods of time is not surprising, given the profusion of Anadara in Tongan lagoons and the continued use of traditional starchy staple crops by contemporary Tongan people.

**Synthesis of Data**

To summarize the evidence accumulated in this study, Anadara antiquata scrapers exhibit a relatively homogenous morphology, with the area of modification being limited to the ventral edge of the valves. Attributes allow me to identify eight potential subtypes, though it was not possible to determine if they have different functions through the course of this research. No modelled taphonomic factors were able to reproduce these characteristics. Additionally, I found that the use of a bivalve to scrape vegetables is documented ethnographically and indeed is borne out in a variety of indigenous names for such (Greenhill and Clark 2011). Tests regarding the functionality of the valves demonstrated the viability of modified Anadara as scraping implements for soft materials such as tubers, as well as harder materials such as bark. In terms of starch presence or absence, a low powered analysis revealed starchy materials on the suspected scrapers, but found no traces on the control samples. Attempted reproduction of the specimens demonstrated that convincing replica scrapers could be produced by flaking in less than a minute, featuring the same edge micromorphology as was visible in the archaeological specimens. Intentional flaking from the inside out, as described by other authors answering similar research questions (Stiner 1993, Toth and Woods 1989), was able to produce the desired effect. The evidence gathered in this experimental research supports the hypothesis that Anadara antiquata valves with edge modification are intentionally modified for use as expedient scraping tools.
Avenues for Future Research

Cross-species analysis has always been very difficult in archaeomalacology due to the highly differential nature of shell between species (Szabó 2010, 2013). This research has provided a suitable review of a single species, but additional work focusing on inter-species commonalities would be useful. One potential commonality identified here and in other research (Stiner 1993, Toth and Woods 1989) has been the requirement for flakes to be struck from the inside out. This may be a facet of bivalve geometry playing a role in the fracture mechanics of bivalves, and further research would be helpful in determining whether or not this claim can be supported.

Additionally, Lugol's test proved to be a useful and cost-effective means of analysis at a presence/absence level of identification, but lacks the ability to make species level identifications. High-powered starch analysis using cross-polarized light microscopy is currently a popular means of making these distinctions (Allen and Ussher 2013, Barton 2007). Such an analysis on the present suite of artifacts would reveal further insights into the crops used during the earliest occupation of Tonga.

Relevance to the Field

This thesis has demonstrated that bivalve scrapers exist as an identifiable artifact type in Tonga. My research provides guidelines for identification of such artifact types to researchers working in Tonga and throughout the South Pacific. The identification of this artefact type is one more contribution in the broad archaeomalacological effort to "hone our methods for recognising, describing, and interpreting past shell-working," as stated by Szabó (2013: 24). Szabó (2010: 125) also suggested that archaeologists should work toward the goal of understanding the various properties of shell as a raw material and to provide analyses of various shell-tool production techniques. These problems are addressed, to a degree, by the research undertaken here. Specifically, in this study I found Anadara antiquata valves to be highly resilient to fracture. I identified a characteristic breakage pattern when fracture was achieved and I demonstrated the most parsimonious explanation for the visible edge-modification by matching characteristics of experimentally produced scrapers to those found in archaeological contexts.
Despite the effectiveness of these tests in the present research, they do not provide data for species of shells other than *Anadara antiquata*. Schmidt et al. (2001) conducted the same experiments (drop and tread tests) as performed here and came to very different conclusions. They found that many of their suspected artifacts could be produced by taphonomic factors. The differential results between their research and the research here further highlights the importance of understanding the properties of various kinds of shells and how these properties differ between species. This is a common problem in archaeomalacology and has been highlighted as an area requiring more research (Szabó 2013: 284).

Spennemann (1993) suggested that use-wear would be the way forward in determining whether or not ambiguously modified tools were anthropogenic in nature. Use-wear was not used as a component in my research despite its use in other archaeomalacological work. It was deemed unnecessary because residue analysis provides information about the specific material being processed, which I believe is more useful than determining directionality of use and the hardness of the substrate. The experimental and starch analysis performed within this thesis has demonstrated that use-wear is not the sole method of determining whether ambiguously modified shells represent artifacts, nor is use-wear required to provide an explanation for the function of an artifact. O'Day and Keegan (2001: 289) identified scrapers in their Caribbean assemblages through “the careful search for recurrent forms and evidence of use,” and it is using these principles that I have identified expedient tools in the Tongan collection.

This research provides direct evidence for Lapita period horticultural practices and direct evidence for marine gathering. In the case of Nukuleka, the results of this thesis imply that the founders of Nukuleka were both exploiting marine resources for raw material, as well as harvesting starchy plant materials immediately upon arrival in the archipelago. This result supports other contemporary research (Davidson and Leach 2001: 118, Green 1979: 37, Szabó and Amesbury 2011:15), providing further evidence for a Lapita horticultural economy at first settlement. In contrast to Anderson (1996: 367), who suggested that early predation of marine species would be more relevant to settlers than horticulture, we find the by-products of the latter in great abundance in the earliest strata of a site considered to be the founding settlement (Burley et al. 2010). In this
discussion, the shell-scraper is a highly relevant tool. By their nature, shell-scrapers suggest a lifestyle that is tied both to the lagoon and to agricultural production.

The shell scrapers identified in this study occur through all periods in Tongan prehistory. This suggests some degree of cultural continuity, a notion supported by Connaughton et al. (2010) in their research on the game Taupita and in other areas such as Cypraea octopus lures and other types of fishing gear (Burley and Shutler 2007). This continuity can be observed clearly among many of the shell artifacts produced by both ancient and modern Tongans, despite the lack of continuity in ceramic manufacture (Burley 1998a).

**Conclusion**

Research presented within this thesis has been called for on a number of occasions (Burley, pers. comm. 2014, Smith 2001:151, Spennemann 1989, Szabó 2010: 125, Szabó 2013: 24). Researchers often note the hazard of misinterpreting naturally broken shell as constituting shell artifacts (Sand 2001: 83; Spennemann 1993: 47). There has been a relative dearth of research on expedient shell-tools and recently more researchers have begun to address them in a similar way to expedient lithics. Identifying what natural taphonomic forces can and cannot do is vital, and experimental archaeology has allowed insight into these problems.

The implications of this research in the context of Tongan archaeology are significant. Specifically, the identification of a widespread tool used for cleaning starchy vegetables allows insight into the dietary lives of early Tongans, and provides evidence to support a mixed economy from initial settlement of the archipelago. This research provides physical evidence to support the Kirch and Green’s (2001) linguistic, and archaeological reconstruction of the Lapita peoples as having an agricultural component to their economy. With the addition of this non-formal artifact type to the suite of tools used by Lapita peoples and their descendants, other researchers gain a valuable means to better understand and interpret the lives of ancient Tongans.
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Appendix A.

Data Table

The data table attached contains the raw data produced through the course of the thesis. Specifically it includes the following information gathered from each specimen:

**Site:** The specific site from which the specimen derives.

**Accession Number (Acc. #):** The catalogue number associated with specimen.

**Morphological Form (MacroMorph):** A physical description of the profile of the modification.

**Ant-Post:** Maximum anterior to posterior measurement in centimeters.

**Med-Dist:** Maximum inflation measurement measured in centimeters.

**Modification# (Mod#):** The number of modified areas per valve.

**Mod Start Degrees:** The degree at which modification begins, measured as per the description in Chapter 4.

**Mod End Degrees:** The degree at which modification ends, measured as per the description in Chapter 4.

**Total Area:** The total length of the modified area in degrees, determined by subtracting the Mod Start Degrees measure from the Mod End Degrees measure.

**Mod Length:** The physical length of the modification measured in centimeters.

**Length of Edge:** The length of the entire ventral margin, measured in centimeters.

**Hinge Length:** The length of the hinge measured in centimeters.

**Side:** The anatomical side of the valve

**Broken Umbo:** Yes (Y) or no (N) classification to determine whether the valve features a broken umbo.

**Unit:** The excavation unit from which the specimen derives.

**Level:** The archaeological level from which which the specimen derives.

**Culture:** The cultural phase associated with specific level and unit from which the specimen derives.

**Comment:** Additional comments unrelated to the above measures and classifications.

**Residue:** “Yes,” “No” or “Untested” classifications related to the starch analysis results with “Yes,” being positive, “No,” being negative.