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EXPLAINING CULTURAL DIVERSITY IN ANCIENT FIJI: THE TRANSMISSION OF CERAMIC VARIABILITY

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ABSTRACT

The explanation of human diversity, in biological, linguistic, and cultural realms is a defining problem of anthropology, including archaeology in Oceania. This dissertation develops a theoretical and methodological program for explaining material culture similarities as products of cultural transmission and mechanisms such as natural selection and innovation. The analyses concentrate on the 2,700 year prehistoric ceramic sequence represented at eleven archaeological sites in the Yasawas Islands of western Fiji. Four dimensions of ceramic variation are examined: rim form, temper, surface modification, and clay elemental composition. Analysis of clay composition was undertaken with Laser-Ablation Inductively Coupled Plasma Mass-Spectrometry. Compositional analysis indicates that over the first 1,700 years of the prehistoric sequence ceramics in the Yasawa Islands derive from a large geological province stretching to the Mamanuca Islands in the south. By 1000 BP, however, ceramics are made only from clays originating in the Yasawa Islands, suggesting that the spatial scale of cultural transmission contracted by this time. The remaining dimensions of ceramic variation were examined with paradigmatic classes designed to track homologous similarity, or similarity resulting from cultural transmission. Using cladistics and seriation these classes are arranged into transmission lineages that span the prehistoric sequence. The phylogenetic hypotheses produced through cladistics indicate that cultural diversity, as measured by ceramic transmission lineages, declines at approximately 2000 BP. At approximately 600 BP a new clade, or group of related ceramic transmission lineages, develops. The clade defines an increase in cultural diversity late in the prehistoric sequence. Two possible explanations are offered for this late expansion of cultural diversity. First, the origins of this clade may be explained as the selective retention of variation related to environmental and subsistence change c. 600 BP and performance differences associated with ceramic vessels described by the classes in the clade. Second, the origins of the clade may be explained by a continuation of the spatial contraction of cultural transmission identified by the compositional analyses and increased intra-group transmission of selectively-neutral variation. The transmission lineages defined in this research suggest that no large scale population movements in Fiji disrupted cultural continuity.

TABLE OF CONTENTS

Pocket Material: CD-ROM of ceramic data tables

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER 1. EXPLAINING HUMAN DIVERSITY

> It is not always appreciated that the problem of theory building is a constant interaction between constructing laws and finding an appropriate set of descriptive state variables such that laws can be constructed. We cannot go out and describe the world in any old way we please and then sit back an demand that an explanatory and predictive theory be built on that description.
>
> Richard C. Lewontin (1974:8)
>
> *The Genetic Basis of Evolutionary Change*

The Venus figurines of Europe tell us that ceramic manufacturing techniques are at least 30,000 years old. Pottery containers first appear in several regions around 11,000 years ago and at the same time people were increasingly incorporating agricultural practices into their lives. In the Near East, the earliest pottery vessels come from sites in Turkey and are dated to approximately 8,500 BC. In the Far East, the Jōmon pottery of Japan is dated to approximately 10,000 BC. In the New World, the earliest pottery appears somewhat synchronously in several areas around 4,500 years ago including the southeastern United States, western Mexico, and Columbia.

Why did pottery appear at similar times in the Old World and then again in the New World? It seems obvious that the early presence of pottery at Çatal Hüyük in the Near East and Odai-Yamamoto in the Far East is not a product of interaction between far-flung populations. Other processes must explain these cultural similarities. In the New World the earliest pottery from both the southeastern United States and Columbia is fiber tempered. What processes may explain this similarity? Is the appearance of fiber tempered pottery in these two regions a product of interaction between human groups or the result of independent solutions to similar problems?

Other aspects of pottery variability invite similar kinds of questions. The complex decorative forms, called Lapita, found on early pottery both on Manus island in the Bismarck archipelago and 3,000 km away on Lakeba island in Fiji surely represent cultural similarities resulting from populations with a shared history. But what of the later loss of this decorative style in these quite different areas of the Pacific? Can that cultural similarity be explained by interaction and sharing of ideas?

While there are many similarities among pottery-using populations, there are also differences. Glazed wares are found throughout the Old World, yet true glazes were never produced in the Americas. How can we account for this difference: is it explained by the limited interaction between populations from the two regions, environmental differences, chance, or some combination of all of these.

In Island Melanesia the Lapita decorations found on the earliest ceramics are different than the contemporaneous incised wares found on nearby southeast Asian islands. How do we explain these differences? Can we explain them as a result of interaction that is structured by cultural boundaries, or does geography also play a role?

Questions about human similarities and differences often confront these explanatory possibilities. Generating explanations that account for any pattern of similarity or difference within and between populations may involve a combination of all possibilities: the environment, the transference of ideas and materials between populations, and independent invention. The explanation of human diversity then is more complicated than may be appreciated at first glance.

1.1 EXPLAINING HUMAN CULTURAL DIVERSITY

Explaining human cultural diversity has been the defining problem of anthropology, a problem developed, in part, by Tylor, Morgan, Durkheim, and Boas, the founders of the discipline (Moore 1997:15-16). But why do we care to explain the observation that human populations sometimes share similarities and at times display striking differences? Why we care depends on what is meant by explanation. When folk or common sense explanations are developed the reason for doing so is usually left unexamined; common sense explanations are "natural" to their progenitors and may apply to the totality of experience. Common sense explanations of human similarities and differences account for human variation by generalizing, sometimes inaccurately, across a series of observations (Dunnell 1982; Marks 2002; Willer and Willer 1974:14-32). When these generalizations are considered explanations, such as agricultural surplus leads to cultural elaboration (see Dunnell and Greenlee 1999), they conflate a contingent summary of observations with a cause-effect relationship. As common sense explanations are always based on a contingent set of observations, they do not build lasting, cumulative knowledge. e The non-cumulative nature of common sense is also indicated by a fundamental observation of anthropologists: common senses as knowledge-making systems have changed over time and differ across space. Moreover, within a common sense framework there are rarely competing explanations where potential correctness is evaluated by definitive criteria.

In contrast to common sense explanations, scientific explanations are generated for the purpose of systematically ordering a particular bounded portion of the empirical world using a set of ideational concepts or "laws" to predict future events, or to determine what could *not* account for observed phenomena. When explanations generated within a scientific framework are compared to those in a common sense framework, three characteristics of scientific explanations are apparent (Bell 1994; Binford 2001; Dunnell 1982; Hull 1988a; Kelley and Hanen 1988; Sagan 1997; Sellars 1962; Watson, et al. 1971; Wilson 1998; cf. archaeological discussions exemplified by Wylie 2000). First, scientific knowledge is generated within an explicitly constructed ideational (sensu Dunnell 1971) system that includes theoretical laws or principles. This ideational system is linked to the phenomenological world through a set of related ideational units or observational classes that may be applied to the phenomenological world of things. An observational class has no objective existence, but is a measurement unit such as an erg or a kilogram. Second, competing scientific explanations or hypotheses are evaluated based upon their parsimony of construction and breadth of coverage in accounting for observations in the empirical world. Scientific hypotheses are evaluated by an empirical truth standard. The third characteristic of scientific explanations is their cumulative nature. Answers to separate questions in related sciences are brought together in a systematic body of knowledge such that particular explanations have both direct entailments on other explanations and suggest further questions and courses of analysis.

This is an admittedly simple description of scientific explanation, but it serves to emphasize that if explaining human diversity is an important contribution to knowledge, then scientific explanations will help ensure that this knowledge is cumulative, thus useful over a potentially greater amount of time, and empirically tested. The empirically tested nature of our explanations is important if we want to use our knowledge to have an effect on the distribution of similarities and differences in the world. To exemplify the importance of such explanations, consider the incorporation of non-industrial populations as laborers in a global capitalist economy. In the 1990s many companies (e.g., The Body Shop International, Ben & Jerry's Homemade Holdings, Pirelli) tried to incorporate indigenous Amazonian populations into the world economy by paying them for their labor, traditional products, or both. Very few of these ventures continue today and the benefits they brought to indigenous populations are debatable (Margolis 2004). Is changing these cultural traditions beneficial to the populations? The answer will be different in each unique circumstance, but to accurately predict (even somewhat) the consequences of our actions we will depend upon empirically tested knowledge that explains why and how some populations continue to exist in pre-industrial systems (cf. Diamond 1997:405-425). The remainder of this section introduces some of the theoretical concepts necessary to build scientific explanations of human diversity.

1.1.1 Historical Explanations of Human Diversity

Explanations of human diversity will always incorporate a historical aspect, for the cultural, biological, and linguistic characteristics of human groups are the product of the passage of time and other mechanisms. The study of historical change in these dimensions of human variation is the purview of archaeology, evolutionary genetics, and historical linguistics with the data from these three fields often synthesized to generate accounts of the evolution of human diversity in particular regions of the world, including Africa (e.g., MacEachern 2000; Nettle 1996), Europe (e.g., Cavalli-Sforza and Minch 1997; Renfrew and Boyle 2000; Zvelebil 1995), the Middle-East (e.g., Tehrani and

Collard 2002), North America (e.g., Bettinger and Baumhoff 1982; Kaestle and Smith 2001), and the Pacific Islands (e.g., Bellwood 1989; Diamond 1988; Kelly 1996; Kirch and Green 2001; Lum, et al. 1994; Melton, et al. 1994).

Syntheses of historical data are valuable for they may summarize the current state of knowledge and, perhaps more importantly, demonstrates what we do not know or should investigate further. These syntheses (e.g., Diamond 1997; Renfrew 1997) often use contemporary patterns of human diversity, such as language distributions, to interpret the past spatial and temporal characteristics of human groups. Terrell and his colleagues (Terrell 1988; Terrell, et al. 1997; Terrell 2001; Terrell, et al. 2002; Terrell and Welsch 1997) have consistently criticized this methodology arguing that contemporary measures are conflated with the evolutionary history provided in the time-transgressive data of archaeology. The root problem in these explanations that Terrell and others identify is essentialism or the idea of timeless uniformity inherent in empirically recognized groups. Essentialist thinking suggests that modern language distributions track the spatial and temporal boundaries of past human populations as bounded groups of individuals. This view also implies that the movement of a temporally and spatially cohesive human population is identifiable in the archaeological record.

To supplement the synthetic explanations of human history and their often essentialist underpinnings we can measure past human diversity using the concept of lineages applied to time-transgressive data (e.g., artifact variation, ancient DNA). The concept lineage refers to a sequence of entities related through a single line of ancestry (de Queiroz 1998:60). Using the concept lineage, we can measure aspects of human population diversity within particular temporal and spatial parameters. Temporal and spatial variation among the entities defined as lineages, the abundance of lineages at particular times and places, and other characteristics of entities in lineages, all describe characteristics of human diversity.

1.1.2 Cultural Lineages and Diversity

While a variety of definitions for the notion "culture" are often invoked by anthropologists, most suggest that culture is something learned and shared. Goodenough writes, "[culture is] all those things that had been cumulatively devised by humans and thereafter learned by them from one another (2002:430-431; see also Roscoe 2002:109). Goodenough's definition references culture as both things and learning. One way in which culture is often used is to reference a human population. When culture is used this way, for example the Trenton Argillite culture, or the Lapita culture, the concept loses most of its explanatory power; it simply marks differences between groups. Ingold (2000:330, emphasis in original) seems to make a similar distinction when he states, "it might be more realistic, then, to say that people *live culturally*, rather than they *live in cultures*."

Instead using culture in the essentialist, reified sense, culture is most profitably referred to as a mechanism of learning. Culture as learning involves both imitation and social learning. Each of these processes involve the transference of information between individuals (Bonner 1980; Boyd and Richerson 1985; Bruner 1956; Cavalli-Sforza and Feldman 1981; Shennan 2002). The transference of information between individuals defines the concept of cultural transmission. Material culture similarities resulting from cultural transmission defines a cultural lineage or more specifically a *material* culture lineage to separate them from other realms of cultural variation such as language. To explain the continuity and diversity of material cultural lineages we can ground our explanations in the concept cultural transmission. Other processes are important and discussed below, but they rest upon the idea that culture is a transmission system, and this idea has substantial empirical support summarized by Boyd and Richerson (1985:40-60, tables 3.1, 3.2, and 3.4).

This then is a first step in generating archaeological explanations of past human diversity: the definition of material culture lineages. The second step involves generating potential explanations for variation within and between these lineages: why did particular material culture lineages follow particular courses, why do some lineages describe increasing human diversity, and why do some lineages go extinct. Shennan (2003:66) offers typical questions that may guide the second step of examining variable qualities of material culture lineages: how stable are the lineages; do some change more quickly in response to external factors; do particular material culture lineages correlate with subsistence practice lineages; do lineages in different areas converge on similar patterns because of environmental or other constraints?

1.1.3 Accounting for Lineage Variation

Questions posed at the beginning of this chapter regarding ceramic similarities and differences are questions about variation between material culture lineages. There are several concepts that we may propose to explain lineage variation such as chance factors in cultural transmission, invention, and the effects of different natural and social environments. How specifically can these concepts be used to explain variation?

1.1.3.1 Populations are Lineages

Before proceeding we should further examine the concept population, as most archaeologists consider explanations of past cultural diversity to be directed at some empirical unit referencing a group of individuals.

Archaeologists have long used artifact distributions to identify human groups in the archaeological record (e.g., Bishop, et al. 1982; Caldwell 1964; Crown 1994; Emory 1933; Feinman, et al. 1992; Holmes 1903; Kirch 1997; Lightfoot and Jewett 1984; Plog 1980; Sassaman 1993; Shepard 1964; Upham, et al. 1981; Zedeño 1994). The identification of human groups in archaeology is also sometimes aided by research from allied disciplines such as comparative linguistics (e.g., Bettinger and Baumhoff 1982; Hunt 1987; Kirch and Green 2001; Renfrew 1997; Zvelebil 1995), modern population genetics (e.g., Lum 1998; MacEachern 2000), and ancient DNA studies (e.g., Caramelli, et al. 2003; Hagelberg 1994). The link between these identified groups and the explanatory processes used by archaeologists are not, however, always made clear (Kelly 2002; Lipo 2001a).

To examine cultural diversity we must define at least two populations. A Darwinian population is an ideational concept defined as an aggregate of entities related by descent with modification. Descent implies transmission and modification implies change in form. Thus populations—our comparative groups—are simply transmission lineages and groups of related transmission lineages. This definition of population is equally applicable to biological and cultural transmission, but there are important differences between populations defined by cultural transmission and those defined by biological transmission due to the nature of transmission (of either kind) as a mechanism of inheritance.

For Darwinian populations, boundaries are defined by the frequency of transmission. When biologists consider the species as a population (defined by the possibility to transmit genetic information), intra-population groups of individuals are often specified on the basis of greater likelihood to breed due, for example, to relative geographical propinquity. Such intra-population groups are called "demes" or "local populations."

The situation is considerably more complicated in the case of cultural transmission. In cultural transmission, information is not transferred in a clearly identifiable empirical "package." Instead, information can be passed between individuals with no a priori specifiable temporal or spatial boundaries. Additionally, with cultural transmission, all humans have the capability to transmit and receive information from any other human. Thus, populations must be carefully defined relative to a problem, because unlike genetic transmission, there are no inherent boundaries formed by the transmission mechanism. However, like the demic structure recognized by biologists studying species, human transmission tends to be spatially constrained due to costs and thus the frequency of transmission tends to be inversely proportional to distance. In this way, cultural transmission may produce localized patterns of similarity

Following this strategy, and expanding upon the population as lineage concept, a population can be defined as a group of individuals who engage in cultural transmission with other individuals in the group at a higher frequency than they do with individuals outside the group. Note that since transmission is continuous along multiple dimensions, population must be recognized as an ideational concept, not empirical, and the term can only be used on a relative scale, where populations of different scales are defined by the frequencies of cultural traits at different classificatory levels and for different problems.

1.1.3.2 Sorting of Material Culture Variation

As mentioned at the beginning of this chapter, the distribution of culturally transmitted variation may be explained by a number of factors. For example, the stochastic (i.e., chance) nature of cultural transmission may result in some traits being more often transmitted than others. Explanations for the frequencies of traits available for transmission that are both non-randomly distributed and not explained by stochastic processes are referred to as sorting mechanisms. Sorting mechanisms explain the differential persistence of cultural traits over time and space (Hurt, et al. 2001; Vrba and Gould 1986). The most well-known sorting mechanisms is natural selection. Natural selection is the statistical outcome of trait persistence when traits differ in their characteristics in such a way that copies are produced from some traits at the expense of others. Importantly the copying-success of traits is relative to the natural and cultural environment in which they exist. Different environments generate different constraints and opportunities for cultural traits and their transmission, thus a "successful" trait in a particular time and place will not necessarily be successful in other times and places. Consequently, monitoring environmental difference is important if we are to develop explanations that rely on natural selection.

The concept natural selection explains many of the most significant changes in human populations, including changes in the frequency of hunting and gathering versus agricultural behaviors (e.g., Bar-Yosef and Meadows 1995; Flannery 1986; Ladefoged and Graves 2000; O'Brien and Wilson 1988; Rindos 1984; Smith 1994), changes in settlement patterns (e.g., Binford 1990; Braun 1987), tool technologies (e.g., Braun 1983; Cochrane 2002a; Dunnell and Feathers 1990; Hoard, et al. 1995; Lyman, J, et al. 1998; O'Brien, et al. 1994; Schiffer and Skibo 1987), and social complexity (Brown 1985; Dunnell and Wenke 1980; Field 2004; Hommon 1986; Kirch 1984; Rosenberg 1994) to name a few. As natural selection explains these and other similar cultural patterns in many regions, natural selection must be considered in our analysis of human cultural diversity. Specifically, we must evaluate the degree to which similarities we identify in the archaeological record are the result of the transmission of ideas, or can be explained as having been structured by natural selection in different populations.

1.2 CULTURAL DIVERSIFICATION IN THE PACIFIC

The distribution and patterning in time and space of material culture lineages is potentially explained by the interplay of sorting processes such as natural selection acting on culturally transmitted traits relative to the effects of local transmission systems in natural and cultural environments. Variation in material culture lineages is what we reference when speaking of cultural diversity in an archaeological framework, and what we wish to explain when trying to understand changes in diversity over time. The generation of scientific explanations of the evolution of human cultural diversity is predicated upon a historical record adequately representing past variation, an understanding of environmental variation, and spatial and temporal boundaries for the analysis. Although explanations of human cultural diversity have been proffered for almost every region of the world, the particular environmental characteristics of some regions may facilitate the explanation of cultural diversity.

The islands of the Pacific (Figure 1.1) are one of the most fruitful arenas for studying the evolution of cultural diversity and as a region, have been the focus of cultural evolution studies since the 1950s (Terrell, et al. 1997). Several characteristics of the Pacific Islands make this region an excellent choice for studying cultural diversity. First, the remote Pacific Islands were the last region on earth to be settled by a substantial human population. The recency of this settlement, in the last 3,300 years for the area termed Remote Oceania (Green 1991), has created an archaeological record that includes large portions of the entire span of prehistoric human occupation, particularly when compared to much longer occupied areas of the world.

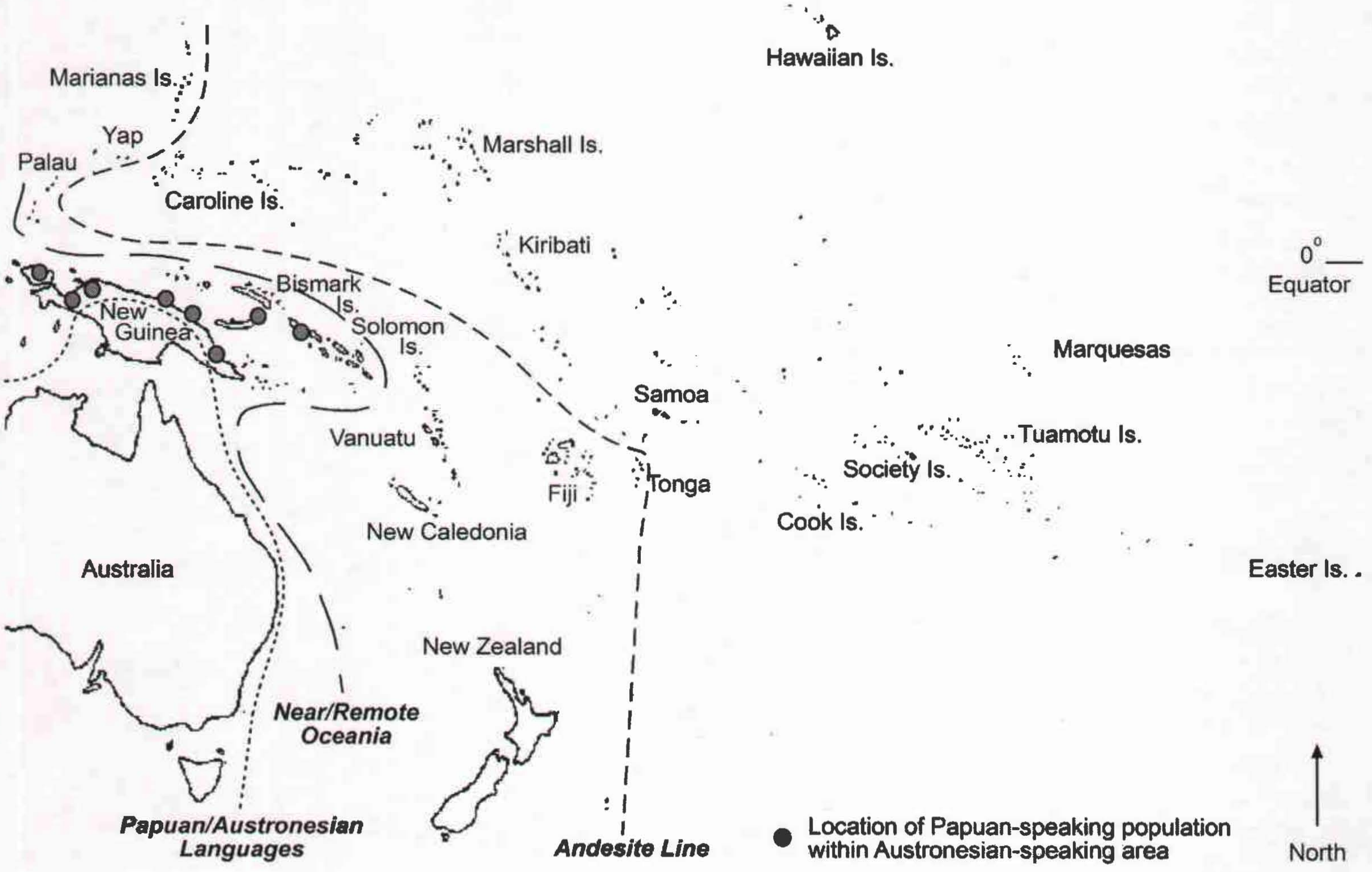

Figure 1.1. Map of the Pacific Islands showing some aspects of cultural and environmental variation.

Second, the islands of Oceania present unique sets of ecological, geographical, and environmental parameters, each island with its own relative degree of isolation. Consequently, we can conduct comparative assessments between islands to explain the varying effects of these parameters on the outcome of population diversity. In addition to their function as geographic references for populations, the paleo-floral and fauna of islands is well-documented with definitive spatial boundaries (e.g., Athens, et al. 2002; Dickinson 1998d; Kirch 1994; Nunn 1997).

Third, after more than 50 years of research on Pacific Island populations, past and present, there now exists an impressive corpus describing the cultural, linguistic, and biological diversity in the region. Scholars have begun to piece together these data in an attempt to explain cultural diversity in the region (e.g., Kirch and Green 2001; Spriggs 1997; Terrell 1986b) and Hurles and colleagues (2003:531) have recently noted that this large body of research makes the region foremost in the world for exploring, among other topics, "the origin and dispersal of human groups and their domesticated plants and animals, [as well as] cultural and linguistic evolution."

1.2.1 Explaining Cultural Diversity in Fiji

Fiji is a large archipelago of over three hundred islands (Figure 1.2) and embodies numerous contrasts of diversity and similarity in the Pacific. This makes Fiji one of the most fruitful areas for studying the evolution of diversity. Fijians are often superficially grouped with populations to the west based on biological traits such as skin color. The so-called Melanesians were first described by d'Urville who grouped a diverse set of peoples into a single category (Clark 2003). Culturally and linguistically, Fijians are often placed with Polynesians, another of d'Urville's groups. The Fijian archipelago itself straddles that boundary by which d'Urville separated Melanesia from Polynesia. An environmental boundary also delimits Fiji's eastern extent as there runs the Andesite line separating the continental Indo-Australian plate from the Pacific Plate. In this way, the geologically complex Fijian islands are quite distinct from the oceanic islands to the east that are almost all formed by mid-plate volcanic eruptions (Nunn 1994).

Fiji's first inhabitants were those groups who left the inter-visible islands of Near Oceania to settle the far-flung islands of Remote Oceania. Archaeologists have argued that within Fiji this supposedly homogenous colonizing population[1] diverged over time (Green 1995; Hunt 1987; Kirch and Green 2001). Hunt (1986:20) suggests "that understanding the course of Fijian prehistory will be an integral part of understanding the historical events or processes of diversification that lead to the origins of the Polynesians and to the ethnic boundary which Fiji represents today."

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[1] The colonizing populations of Fiji and western Polynesia (mainly Fiji, Tonga, and Samoa) are often considered culturally and linguistically the same (e.g., Golson 1961, Kirch 1997). Some archaeologists (e.g., Green 1995, Kirch and Green 2001) argue that after colonization of these archipelagos, Fijians diverged from the rest of the Polynesians in terms of language and culture. The timing, meanings, and reasons for this supposed divergence are, however, debated (e.g., Best 2002, Terrell 1986).

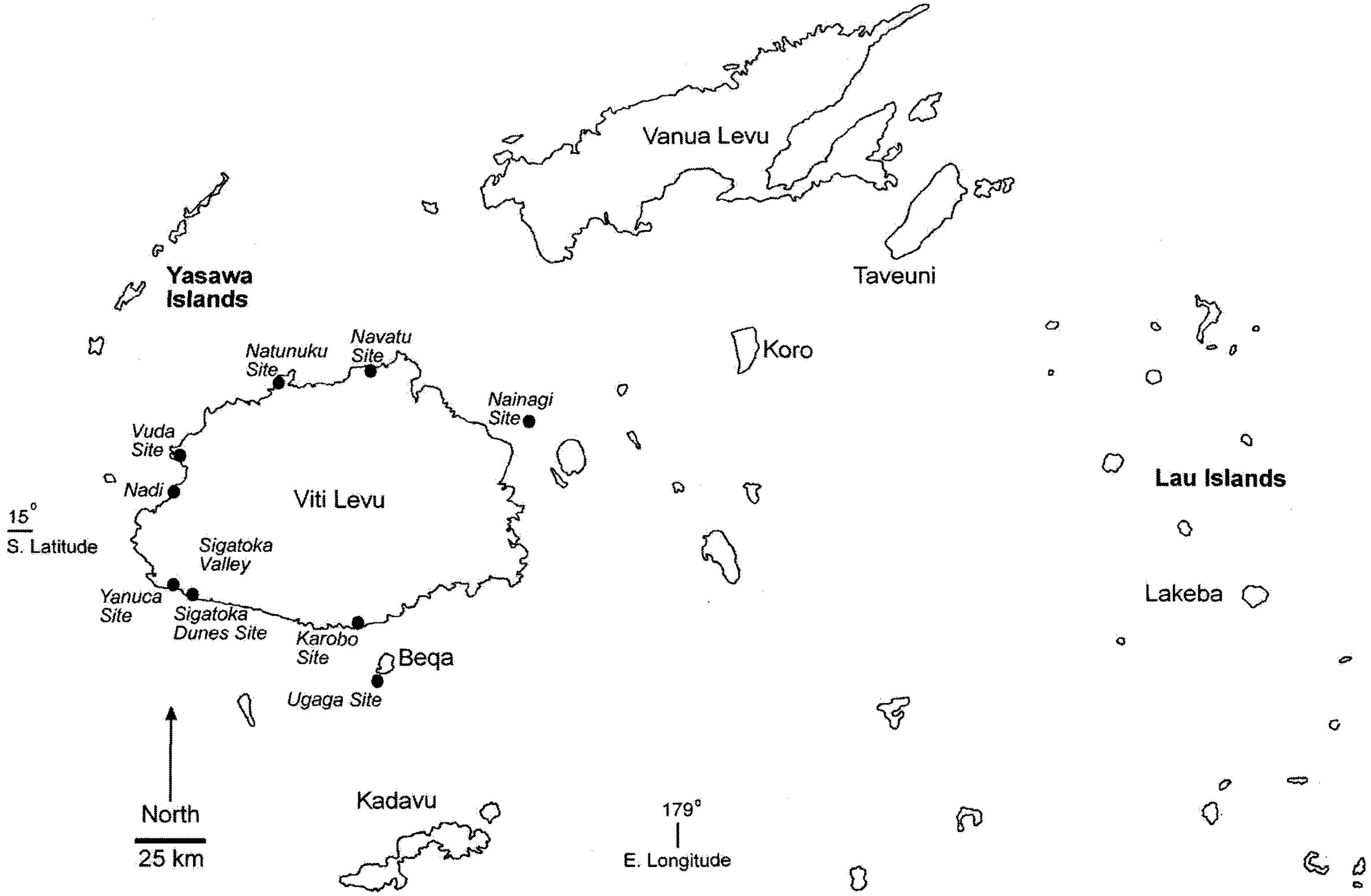
Vanua Levu
Taveuni
Yasawa Islands
Koro
Natunuku Site
Navatu Site
Nainagi Site
Vuda Site
Nadi
Viti Levu
15°
S. Latitude
Sigatoka Valley
Yanuca Site
Sigatoka Dunes Site
Karobo Site
Beqa
Ugaga Site
Lau Islands
Lakeba
North
25 km
Kadavu
179°
E. Longitude

Figure 1.2. Map of the Fiji Islands showing archaeological sites and islands discussed in text.

In a recent study of Fijian ceramics, Clark (1999:1-2) sought to specifically examine "the diversity in . . . Fiji and the processes that have generated differences in language, material culture and social customs between proximate human groups." Clark examined a 1500 year period in the middle of Fiji's prehistoric sequence to determine how human interaction during this time developed and the relationship of interaction to cultural diversity.

Clark's research will be more thoroughly examined in Section 2.3.2, but here it is important to briefly describe Clark's explanatory framework to contrast it with the approach developed in this dissertation. For Clark, the similarity of ceramic assemblages is assumed to reflect the degree of contact between groups. Clark measured a constellation of traits including decoration type, orifice diameter, rim-body contour, and others (Clark 1999: Appendix 2). Clark did not justify his choice of attributes to measure ceramic similarity, but it is apparent that he chooses attributes because they measure, in a commonsense way, "style," or a way of doing something (see Conkey 1990b; Hegmon 1992:517-518). Clark's approach assumes, presumably, that if individuals are doing things similarly, this similarity can be explained by interaction.

While this is certainly a reasonable assumption for explaining cultural similarities and differences, when generating scientific explanations we can not, as the Lewontin quote that opens this chapter states, measure the world using any observational unit and expect that our explanations of variability will produce cumulative knowledge that is theoretically defensible and empirically sufficient. To generate scientific explanations we must construct observational units that are logically linked to the theoretical concepts (e.g., natural selection) in our explanatory system. Moreover, our observational units must measure variation within acceptable tolerance limits (Dunnell 1982) so that variation of interest is not swamped by measurement error. This process of constructing observational units proceeds in tandem with the construction and evaluation of our explanatory theoretical concepts. If, for example, we want to use the concept "human intention" to generate scientific explanations of cultural variability, we must be able to empirically measure the effects of intention in the archaeological record.

When trying to build scientific explanations of cultural variability, commonsense concepts are problematic for one over-riding reason. Like many natural language words, commonsense concepts, for example "style," have multiple meanings and no explicitly constructed relationship to observational units or explanatory processes (e.g., Conkey 1990a; Hegmon 1995; Plog 1980; Wiessner 1983; Wobst 1977). If we rely on common sense concepts for our explanations, the relationships between explanatory processes and observational units remains cryptic and ethnocentric and it is impossible to definitively evaluate how well different explanations perform in the empirical world.

In this dissertation, the use of particular concepts to generate theoretically defensible and empirically sufficient explanations of cultural variation is not a personal choice among equally viable alternatives (cf. Hegmon 2003). The choice is based upon the goal of producing explanations of cultural variability that can be definitively and empirically evaluated such that cumulative and lasting knowledge is generated. Here then, the use of particular concepts reflects the goal of building an explanatory framework linking theoretical concepts to the archaeological record via definitive empirical expectations. In this regard sets of concepts can be judged better by specific criteria (see Lewontin 1974): does a set of concepts account for all the possibilities based on our epistemological assumptions; are these concepts logically related to each other; do these concepts have definitive empirical referents, that is, can we construct observational units that unambiguously link these concepts to the empirical record; is observed variation of explanatory significance or is variation primarily a product of inadequate tolerance limits?

Unfortunately, archaeologists in Fiji have not often evaluated their explanatory frameworks and concepts in this fashion but, like archaeologists elsewhere in Oceania, have "simply assumed that certain . . . attribute similarities are diagnostic of cultural affinities and chronological change" (Pfeffer 2001:165). The results are that it is difficult or impossible to definitively evaluate the conclusions of others and one set of explanations simply replaces and does not build upon other explanations.

1.2.1.1 Three Questions about Cultural Diversity in Fiji

This dissertation investigates the evolution of material cultural diversity in the Yasawa Islands in the northwestern corner of the Fijian archipelago. This work builds upon several field seasons of basic research in the Yasawas (Hunt, et al. 1999), as well as other large-scale ceramic analyses in Fiji (e.g., Best 1984; Clark 1999). In an important departure from much previous research in Fiji, the work presented here constructs answers using an explanatory framework explicitly designed to account for the evolution of cultural diversity in prehistory. This explanatory framework combines the effects of cultural transmission, natural selection and other sorting processes, and innovation.

Using this explanatory framework this research will attempt to answer the following three questions:

1) what domains of ceramic similarity in the Yasawa Islands can be used to define culturally transmitting populations or lineages,
2) what are the spatial and temporal distributions of transmission lineages defined along different avenues of transmission, and
3) what are the possible explanations for the distribution of these lineages?

These three questions form a nested hierarchy. The first question is necessary to answer the second. Using classificatory analyses and techniques for explaining variation within a transmission framework we can identify cultural similarities best explained by transmission. Second, analyses including seriation and cladistics arrange this variation into transmission lineages or cultural phylogenies with different temporal and spatial characteristics. Finally, the distribution of these phylogenies can be explained by crafting hypotheses that address particular characteristics of those lineages. Do the number of lineages in the Yasawa Islands increase over time; when do changes in lineage diversity occur; do lineages conform spatial to historically recognized measures of diversity such as language? In summary this research seeks to build a theoretical and methodological framework for explaining cultural diversity as measured by transmission lineages.

1.2.2 Research Significance

This research is both substantively and theoretically significant. Resolution of the cultural transmission history of Yasawa populations is important for larger scale questions in the Fiji-West Polynesia region concerning the descent relationships among colonizing populations (Kirch 2000:162), including inter-archipelago transmission that has potentially shaped local culture histories (e.g., Bedford and Clark 2000; Best 1984; Burley, et al. 2002; Clark 1999; Frost 1974; Green 1981; Pawley 1981; Terrell 1986a; Thomas 1989), and the presumed divergence of the colonizing Fijian population over time (e.g., Green 1995).

Perhaps more important, however, this dissertation develops a theoretical and methodological foundation for generating scientific explanations of human cultural similarities and differences. The benefit of scientific explanations is that they are empirically testable and result in the creation of cumulative knowledge. These explanations begin with the definition of material culture lineages in the empirical record and apply concepts such as transmission, natural selection and other sorting mechanisms, and innovation to explain lineage variation. This terminology is somewhat new to Oceanic archaeology, but is necessary to clearly differentiate explanatory mechanisms and empirical observations. The methodological questions this research addresses, however, are not new. Since the earliest archaeology in the Pacific scholars have tried to define relationships of cultural relatedness among artifacts and recently Spriggs (2004:139) has suggested that this problem "may be one of the next big debates in western Pacific archaeology." This dissertation sets the theoretical and methodological foundation for that undertaking.

1.3 DISSERTATION SUMMARY

The next chapter examines some of the previous archaeological and other research in Fiji that has attempted to explain or document cultural, biological, and linguistic diversity. Chapter Two pays special attention to the detailed ceramic analyses of Best (2002; 1984) and Clark (1999) as they have produced the most comprehensive work (Best), and that which explicitly aims to explain cultural diversity (Clark). Using Best and Clark as a foundation we will be better able to determine what aspects of ceramic variation may define transmission lineages.

Chapter 3 more completely develops the theoretical framework used to explain prehistoric ceramic similarities and difference in terms of transmission lineages. This chapter contains a detailed discussion of archaeological classification related to cultural transmission-based analyses. Theoretical concepts such as cultural transmission, natural selection, and innovation are also discussed. These concepts and others are used to explain variation in material culture lineages defined through seriation and cladistics. Cladistic and seriation techniques are outlined, and issues in the application of phylogenetic analyses to cultural phenomena are presented.

An outline of the natural and cultural history of the Yasawa Islands is presented in Chapter 4. This chapter sets the archaeological backdrop for the following analyses and describes the depositional context of the ceramic assemblages that influence analytical decisions presented later. The Yasawas Islands were first inhabited c. 2700 BP. Human occupation occurred in a variety of settings including prograding coastal terraces, uplands, caves, fortified ring-ditch villages, and defended hilltop hamlets. Artifact assemblages from the Yasawa Islands contain a number of artifact types, including lithics, faunal remains, and ceramics. There is also both change over time and intra-Yasawa Group differences within each of these artifact categories The ceramic sequences identified in the Yasawa Islands display both similarities and differences with other assemblages in Fiji.

Classifications of ceramic variation and other analyses are presented in Chapter 5. The classification procedures focus on four realms of variation: rim form, temper, surface modification, and clay elemental composition. As a part of the classification process, sample representativeness is also evaluated. Simple analyses of distributional data suggest that variation in rim form, temper, and surface modification likely reflects similarities and differences that may be explained by cultural transmission.

In Chapter 6 cladistic and seriation analyses generate hypotheses for the transmission history of Yasawa Islands populations. The various transmission patterns, generated are remarkably similar and both suggest that for the entire prehistoric sequence in the Yasawas, we can define a single population composed of a group of related transmission lineages.

Transmission lineages form multiple groups at various hierarchical levels and suggest different events have shaped cultural transmission histories in the Yasawa Islands. The transmission history of the Yasawas Islands as defined by ceramic variation includes a period of early lineage diversity and a period of late lineage diversity likely connected by lesser numbers of transmission lineages for the 1,000 years from 1,500 to 500 BP. While early lineage diversity may represent a continuation of processes that explain Lapita ceramic variation, two possible explanations for the origins of late cultural include selective retention of variation associated with environmental change c. 600-500 BP, or increasingly localized transmission of selectively-neutral variation.

Chapter 7 reviews the results of this research in the context of other archaeological work in Fiji. The approach to explaining cultural similarities and differences employed in this dissertation indicates that prehistoric cultural diversity can be examined using cultural transmission, selection, and innovation to produce empirically testable hypotheses regarding the historical relatedness of Darwinian populations. The further development of this approach by scholars in the region will do much to answer long-standing questions of cultural similarity in Oceania.

CHAPTER 2. EXPLORING DIVERSITY IN ANCIENT FIJI

> I have found from their own genealogies and legends that, approximately speaking, during the first and second centuries of the Christian era many and properly organized migrations of the Polynesians into the Pacific Ocean took place from various points of the archipelago . . . their general rendezvous during this migratory period was on the Fiji group, and principally on the west side of Viti-levu . . . they were of superior cultivation to the Papuans then and now inhabiting that group . . . they stayed there long enough to introduce a large amount of their vocables in the Fijian language and no inconsiderable part of their legends and customs . . . when finally after several generations of séjour, they were expelled from the Fiji group, they scattered over the Pacific, taking up their present positions on the principal groups.
>
> Abraham Fornander(1969 [1878-1885]:2)
>
> *An Account of the Polynesian Race,*
> *Its Origin and Migrations and*
> *the Ancient History of the Hawaiian*
> *People to the Times of Kamehameha I, Volume II*

The first Europeans to navigate the waters of Remote Oceania developed explanations for the many similarities and differences they observed between island populations (e.g., Dumont 1832). Fornander, a historian writing of Hawaiian origins, argued that cultural and linguistic variation in Fiji was a result of the historical mixing of two populations, Papuans and Polynesians. Since Fornander, archaeologists have also explained aspects of Fijian diversity as a result of interaction with non-Fijian populations in addition to in situ cultural change (Hunt 1986).

This chapter summarizes previous explanations of Fijian cultural, linguistic, and biological diversity to provide a background against which the results of this research may be compared. The second half of this chapter explores two major ceramic research projects in Fiji, those of Best (1984) and Clark (1999), to help determine which aspects of ceramic variation may usefully define transmission lineages. Examination of this research also identifies some of the explanatory problems that may arise when explanations of ceramic variation are not explicitly linked to the observational categories we use to create this variation. This chapter concludes with a discussion of the necessary steps for producing explanations that are both theoretically and empirically sufficient explanations of ceramic variation.

2.1 THE CULTURE HISTORY OF FIJI

The human history of Fiji begins with the arrival of voyagers from the west. These initial inhabitants of the islands were present in enough numbers by c. 2800 BP to leave a convincing radiocarbon record distributed across several sites and associated with distinctive Lapita pottery (Anderson and Clark 1999). Lapita and later pottery occupied the attention of almost all archaeologists in Fiji for the several decades following Gifford's (1949; 1951) early work. Green noted that Gifford's "early period" characterized by paddle-impressed relief patterns post-dates the earlier presence of Lapita pottery in Fiji. Green's(1963) restructured four-phase ceramic sequence has since defined Fijian archaeology with revisions and elaborations by subsequent researchers (e.g., Best 1984; Burley 2003; Burley and Dickinson 2004; Clark 1999) usually generated to create more precisely defined regional sequences (Figure 2.1).

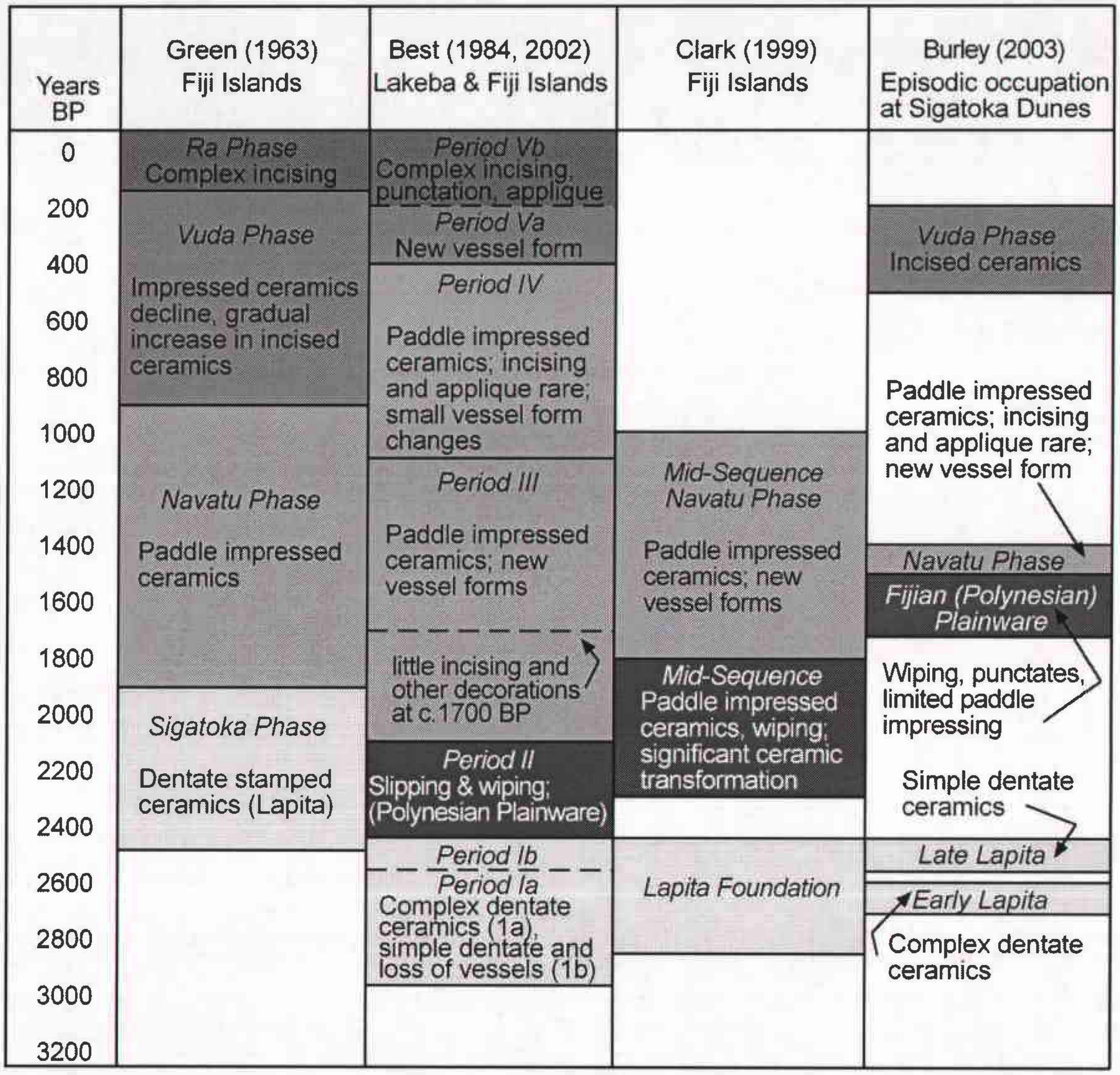

Figure 2.1. Comparison of Fijian ceramic sequences. Period names in each sequence derive from the authors at column heads and are identified by italicized text. Brief descriptions of ceramic characteristics are in plain text. Periods which have been similarly defined by different archaeologists are shaded alike. Dashed lines are less significant divisions noted by the authors.

2.1.1 Ceramic Chronologies

While Green's four ceramic phases have been modified, these periods still structure or have been referenced in almost all subsequent work. Figure 2.1 displays how archaeologists have both expanded the defining ceramic attributes of the Sigatoka, Navatu, Vuda, and Ra phases, and changed the temporal boundaries of these phases. Best (2002; 1984) has produced the only (relatively) continuous ceramic sequence that covers the entire human history of Fiji. Using data from Lakeba and surrounding islands in the Lau Group Best produced a fairly extensive reworking of Green's phases, although he does correlate his "Periods" with Green's phases (Best 2002:19) as indicated by shading in Figure 2.1.

The Sigatoka phase marks the first arrival of human colonizers to Fiji. These early populations used dentate decorated Lapita pottery, a pottery horizon associated with the rapid first colonization of the New Caledonia, Vanuatu and the Fiji-West Polynesia region (Green 2003; Kirch 1997). Ceramic assemblages that contain dentate decorated pottery are referred to as Lapita assemblages (and no longer as Sigatoka phase assemblages). The populations in Fiji who deposited Lapita assemblages had a diverse vessel repertoire with a variety of jars, bowls, and pot-stands. Some jars were spouted with handles. Bowls with sharply carinated shoulders are also present in the earliest Fijian assemblages. Undecorated vessels were also used; undecorated sherds usually account for 90% or more of all sherds in early Lapita assemblages (Kirch 1997:146). Dentate decorated vessels seem to have been used mostly for serving and storage (and possibly as exchange items) as there is relatively little evidence of carbonization of dentate vessel surfaces from cooking fires or carbonized food remains (Kirch 1997:122-124).

Complex dentate decorations and many vessel forms were quickly abandoned in Fiji (Anderson and Clark 1999), although plain wares and other decorative forms continued. The abandonment of complex dentate decoration and the continuation of simple dentate designs defines the boundary between Early and Late Lapita (Burley and Clark 2003) or Periods Ia and Ib using Best's (1984) labels. There is also a reduction in the number of vessel forms in Late Lapita assemblages.

Although Green (1963) originally described the Navatu phase as stemming directly from the Sigatoka phase, many archaeologists in Fiji now suggest that ceramic change is more accurately described by noting an additional period between the Sigatoka and Navatu phases. Best (2002; 1984)[2], Clark (1999), and Burley (2003) all identify a post-Lapita period containing ceramics generally called Polynesian Plain Ware. These assemblages have high proportions of undecorated vessels, some slipping, and wipe-marks around the collar made with a fibrous material, and a few other surface modifications (e.g., "side tool cuts" [Best 1984:Tables 3.1, A.1, and A.5]). Polynesian Plainware assemblages typically consist of only one or a few jar and bowl forms, mostly differentiated by minor rim variations (Clark 1999:221). Clark (1999:226) states that carved paddle-impressed wares belong to these assemblages and Best agrees, but confines the appearance of carved paddle impressing to the end of the Plainware period (Best 2002:29). Burley (2003:239) also notes that small amounts of punctuating and other decorative techniques occur in the Fijian Polynesian Plainware assemblages in western Fiji. Significantly, these three archaeologists all argue that the Polynesian Plainware period ends with major ceramic changes. The transition between Polynesian Plainware and the Navatu phase is described as "the only major ceramic change in the Fijian sequence" (Best 2002:28; see also Best 1984:654-655), and "so abrupt that

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[2] Actually Best (2002) correlates his Period II with Green's Sigatoka phase. In Figure 2.1 I have differentiated Best's Period II from the Sigatoka phase by different shadings. The dark shadings of Best's "Period II," Clark's "Mid-Sequence," and Burley's "Fijian Plainware" are meant to highlight their similarity.

alternative explanations [besides ethnic group replacement] are difficult to fathom" (Burley 2003:312).

While Best, and Clark place the Plainware-Navatu transition at different times (Figure 2.1), their difference in timing may be a result of the slightly different period definitions each archaeologist presents. Note, for example, that the minor change in Best's Period III (indicated by hashed line) occurs at a similar time as Clark's Mid-Sequence to Navatu Phase transition. If Best admitted carved paddle-impressing into his Period II definition then he might re-conceive his Plainware-Navatu transition at essentially the same time as Clark's (i.e., c. 1800 BP). Best does identify some new ceramic variants at this time as indicated by the dashed line at c. 1700 BP in Figure 2.1 (Best 2002:17). Moreover, Best (2002:31) found imported Vanuatu obsidian in archaeological deposits just slightly older ("years or tens of years") than the deposits with the new ceramic variants. Best argues that the new ceramic variants are also similar to some Vanuatu ceramic decorations and therefore suggests increasing contact between Fijian and Vanuatu populations c. 1700-1800 BP (Best 2002:30-31; Best 1984:655).

The Navatu phase in Fiji is generally defined by carved paddle-impressed ceramics, incising, appliqué, and finger-pinched decoration, often executed on the shoulders of jars. Best(1984:356-357) also notes that Navatu assemblages (his Period III) exhibit a high proportion of shell-tempered ceramics compared to the predominantly lithic tempered Polynesian Plainware (his Period II). The change in temper type frequency across the Plainware-Navatu transition is an "archaeologically sudden occurrence" (Best 1984:357). Close examination of temper type frequencies for sherds per excavation layer as reported by Best (2002:figure 6; Best 1984:figure 4.2) demonstrates that increasing frequencies of "calcareous" temper and concomitant decreasing frequencies of "lithic" temper occur between his 2050 and 1730 BP dates at Site 197 on Lakeba. Both Best and Clark also note that a new vessel form originates in the Navatu phase. Burley (2003:238) has identified several new vessel forms in his Navatu phase ceramics from the Sigatoka Dunes including "several new jar and bowl types, handled pots, flattened trays, and spouted vessels" (Burley 2003; Burley and Dickinson 2004).

Both Best (2002:30-31; 1984:655-656) and Burley (2003:312) suggest that ceramic change at their Plainware-Navatu transitions is possibly in part a result of a new human population inhabiting the southern Lau Group, or the Sigatoka Sand dunes, respectively. Clark (1999:221) also identifies "a relatively sharp break" in ceramic similarity at c. 1800 BP. He, however, does not attribute this to different human populations, but rather (tentatively) to low levels of social interaction and changing economic patterns from c. 2300 to 1900 BP (Clark 1999:219-228; cf. Marshall, et al. 2000; see also Rechtman 1992).

Best, Clark, and Burley all interpret ceramic variation at the time of their Plainware-Navatu transition to indicate "the end of a c. 1500 year continuity in ceramic forms" (Burley 2003:312; cf. Frost 1979:79). A few archaeologists (e.g., Green 1981:139, 144; Hunt 1980; 1986), however, do not agree and suggest the ceramic discontinuities that these researchers see may be a product of uneven sampling of the archaeological record or a result of archaeologists dividing continuous change through time into discrete periods (i.e., phases), where variation *within* periods is analytically treated as noise and variation *between* periods, encompassed by the horizontal lines in a time-space chart such as Figure 2.1, is significant. Hunt (1986:29) summarizes by stating that "periodization—albeit often necessary—may obscure continuous change and conflate rapid change and discontinuity." Best (2002:28-29; see also Best and Geraghty 2002) has recently defended the separation of his Period II (Polynesian Plainware) from Period III (Navatu phase) based on ceramic discontinuities that are presumably not a product of archaeological sampling. In section 2.3.1 we examine Best's work in more detail.

The Vuda phase was conceived by Green (1963) to begin c. 900 BP and last until the time of sustained interaction between Fijians and Europeans, c. 150 BP. Since Green, archaeologists have placed the beginning of the Vuda phase at different times (see Figure 2.1) and it seems likely that ceramics described as Vuda-phase increase in frequency at different times in different parts of Fiji. Vuda phase assemblages exhibit a gradual increase in the frequency of incised decorations and a concomitant decrease in paddle-impressed decorations over time. Frost (1979:68) notes that the Vuda phase may be more readily defined by a "sudden decrease" in paddle-impressed decorations than an increase in incised motifs, as incising as a decorative technique also occurs in assemblages by at least 1700 BP. Vuda phase assemblages also exhibit punctate (i.e., end-tool produced) decorations, and appliqué. A new vessel form is also present in Vuda phase assemblages, the *dari* (Fijian), or flared-rim bowl (Best 1984:293).

The origin of the Vuda phase has been linked to population immigration to Fiji from the west. Frost (1974; 1979) detailed this position in his ceramic research linking the appearance of Vuda ceramics to the rise of fortifications on Tavenui Island in northern Fiji. Frost argues that Vuda ceramic decorations are imported by people from Melanesia (particularly Vanuatu) and that the arrival of this immigrant population also increased competitiveness stimulating the rise of fortified occupations. The hypothesis that Vuda ceramics and fortifications are linked to a migrating population from the west has been challenged by subsequent analyses (e.g., Babcock 1977; Bedford and Clark 2000) and on theoretical grounds (e.g., Hunt 1986; Rechtman 1992). Moreover, Field (2004) has recently demonstrated that defended occupations and competition between populations have a longer history in Fiji (at least in the Sigatoka Valley) than previously thought (see also Best 1993; Best 1984). Defended habitations may have been constructed as early as c. 1250 BP and there is strong evidence that defended habitations and competitiveness among Fijian populations is a strategy to cope with temporal and spatial variation in food resources (Field 2004; Parry 1977, 1982, 1987, 1997)

The Ra phase is the final ceramic period identified by archaeologists in Fiji and is generally noted by ceramics that have increasingly complex incised and appliqué patterns. Ra-phase ceramics also include new vessel forms, such as double-spouted jars. Much of the increased variation in decoration and new vessel forms in the Ra phase is attributed to increasing contact between Fijian and European populations. Archaeologists recognize the Ra phase as early as 450 BP (e.g., Bedford and Clark 2000:68) and often suggest it continues to the present as traditional ceramics are still made in Fiji, although predominantly for sale to tourists.

2.1.2 Three Millennia of Change in Fijian Subsistence, Settlement, Exchange, and Social Complexity

While most archaeological research in Fiji has concentrated on ceramic change, researchers have increasingly studied other aspects of Fijian prehistory. This section provides a brief review of research on subsistence, settlement pattern changes, exchange of materials within and beyond Fiji, and changes in social complexity (see also Burley and Clark 2003).

Fijian populations associated with Lapita pottery were likely generalized marine foragers who also relied on some domesticated animals such as dog and chicken (Best 1984:650-653; see also Leach, et al. 2000), as well as wild avian resources. Artifact inventories from Lapita assemblages include marine fauna procurement implements (e.g., fishhooks) and shellfish remains that indicate populations exploited gregarious near-shore species for food (e.g., Clark, et al. 2001; Szabó 2000). The earliest populations in Fiji likely also practiced swidden agriculture (Hunt 1981; Kirch 1997:192-220), but there is little direct archaeological evidence of this. Given their reliance on marine resources it is no surprise that the earliest archaeological sites in Fiji are found near the coast.

By c. 2000 BP, however, some populations are located inland and likely changed their subsistence practices in these new environments. The limited paleoenvironmental studies in Fiji (e.g., Clark and Hope 2001; Clark 1999) have documented increased grasses and charcoal in deposits that are interpreted as possible signs of forest clearance and burning. These activities may be related to inland agricultural practices that began around 2000 BP. Additionally, Field (2004) has dated the original occupation of the Tatuba cave site, approximately 50 km inland up the Sigatoka river, at c. 2000 BP. The Tatuba population presumably relied, at least partially, on agricultural-based subsistence. Dickinson et al. (1998d) also document anthropogenic landscape change in the Sigatoka Valley, c. 2000 BP, including slope erosion and deforestation resulting in increased sediment loads in the Sigatoka river. Population sizes must also have been growing as suggested by Field's documentation of the increasing abundance of prehistoric habitations and use of more economically marginal agricultural land over time in the Sigatoka Valley. Throughout the prehistory of agriculture in the Sigatoka Valley both dryland and wetland taro were likely cultivated as well as yam (Field 2003). Ceramics trays perhaps used for salt production at the Sigatoka Dunes site (Birks 1973; Burley 2003) have been found inland up the Sigatoka Valley (Field 2004) suggesting that coastal and inland populations may have maintained contact.

The increasing abundance of inland settlements c. 2000 BP is one of several settlement changes documented over Fiji's 3000 year human history. Fijian populations also developed defended habitations throughout their history, possibly as early as c. 2000-1500 BP (Field 2004). A comprehensive analysis of defended habitation sites and associated agricultural resources has recently been conducted by Field (2002; 2003; 2004; 1998; see also Parry 1987) for the Sigatoka Valley, but others have also identified defended habitations, both villages protected by ditch and bank systems and mountaintop forts, throughout Fiji (e.g., Best 1993; Hunt, et al. 1999; Palmer 1969a; Palmer 1969b; Parry 1977, 1982; Rechtman 1992; Sand, et al. 1999). Field's work suggests defended habitations are linked to control of agricultural land and that habitations exerting control over territory begin appearing by c. 2000 BP. Somewhat later, c. 1500 BP, mountaintop habitations that are naturally defended by escarpments and steep slopes appear in the Sigatoka Valley. Only in the last 400 to 300 years did Sigatoka populations live in palisaded villages on the valley bottom surrounded by defensive ditch and bank systems. Field (2004) presents evidence that environmental changes influenced the settlement and subsistence choices of Sigatoka Valley populations. Both consistent El Niño Southern

Oscillation (ENSO) events throughout prehistory and a particular environmental change at c. 700-600 BP (the Little Climactic Optimum/Little Ice Age transition [LCO/LIA]), affected these populations. Field's research builds on that of Nunn (1997; 2000a; 2000b; 2001) who has documented cultural changes correlated with the transition from the c. 650 year long LCO (beginning c. 1350 BP) and the start of the LIA at c. 700 BP. Nunn argues that this transition not only precipitated settlement change, but also resulted in the decline of long-distance voyaging, and through sea-level fall, the virtual destruction of reef ecosystems upon which Fijian coastal populations depended for a large portion of their subsistence.

The frequency and distance over which materials were moved in ancient Fiji has also changed considerably over time from the early intra-archipelago movement of pottery, the later inter-archipelago transfer of basalt adzes and volcanic glass, to the proto-historic Tongan maritime empire incorporating Fiji and Samoa (Aswani and Graves 1998). Using chemical and petrographic data, Clark (1999)and Best (1984) suggest modest levels of pottery movement throughout Fiji for the first 1000 years of Fiji's prehistory, although Best's data indicate higher levels than Clark's (see also Kennett, et al. 2004). Few studies have generated information on the movement of pottery or pottery raw materials for the period from c. 1000 to 500 BP, but both Aronson (1999) and Bentley (1997; 2000) have demonstrated the possible movement of pottery between the Yasawa Islands and Viti Levu late in Fijian prehistory.

Variation in the movement patterns of lithic materials, primarily volcanic glass and basalt, has also been examined by several archaeologists. No volcanic glass sources have been chemically characterized in Fiji, but there are several characterized sources in the Pacific. Tafahi (an island a little more than halfway between the Lau Group and Samoa) volcanic glass has been recovered in Lapita deposits on Lakeba, along with volcanic glass from Tonga (Best 1984:431-434). Volcanic glass from Vanuatu has also been found on this island associated with Navatu phase assemblages (Best 1984:434). Information on the prehistoric movement of basalts suggests that basalt adzes (or basalt raw material) were imported to Fiji primarily from Samoa. Samoan basalt in Fiji has been identified through X-ray fluorescence, mineralogy, petrology, and formal characteristics. The earliest movement of this material may have begun c. 900 BP (Best 1992), but this time frame has recently been considered to old and has been revised to c. 650-450 BP (Clark 2002). Samoan adzes and adze flakes in Fiji are confined to the eastern part of the archipelago, but adzes and adze flakes have been recovered from throughout Fiji.

Changes in Fijian social complexity are difficult to identify in the archaeological record until c. 1000 BP with the appearance of defensive habitations that signal competition between human groups (but see Crosby 1988; Field 2004). Monumental architecture has also been used to signify social complexity in Fiji-West Polynesia (e.g., Aswani and Graves 1998; Burley and Clark 2003; Herdrich and Clark 1993), but in Fiji monumental architecture is rare (see Frost [1979] and Palmer [1971b] for discussion). House-mounds in contemporary Fijian culture are linked to particular descent groups and different house-mounds represent groups of different status. Archaeologists (e.g., Best 1984; Field 2004) have suggested that the size and position of house-mounds are indicators of relative status within a community.

Finally, Fijian social and political complexity in the late 1800s was documented by the increasing numbers of Europeans in the islands and has been investigated archaeologically (Crosby 1988; Kirkendall 1998). The writings of several individuals (e.g., Waterhouse 1866; Wilkes 1845) speak of the chiefdoms in regions such as Rewa, Navua, and Cakaudrove. The most powerful chiefdoms were situated in southeastern Viti Levu with other areas of the archipelago (particularly inland Vanua Levu and western Viti Levu) apparently less sociopolitically complex (Derrick 1968).

2.2 FIJI'S CULTURAL, BIOLOGICAL, AND LINGUISTIC DIVERSITY

The archaeological review above summarizes the continuous culture change that took place over the approximately 2,900 years of Fiji's prehistory. This cultural variation is one component of changing patterns of diversity within Fijian populations. In this section we will review the current understanding of population diversity in Fiji as it has been investigated through ceramic materials (the primary archaeological data used to examine this issue), analyses of human biological variation, and linguistics. Different analyses of these dimensions of human variation often subscribe different and sometimes conflicting, relationships between Fijian groups and human groups to the east and west. This is not surprising, considering our earlier discussion of populations. We define populations via similarities along some measurement scale such as language or skeletal morphology. Different measurement scales and different sets of empirical phenomena will generate different population "boundaries."

2.2.1 Fijian Ceramics and Cultural Diversity

The similarities among Lapita decorative motifs in Fiji, Tonga, and Samoa, and the rapidity with which these archipelagos were settled has convinced most archaeologists that Fiji and west Polynesia was colonized by a single related population (Anderson and Clark 1999; Golson 1961; Green 1995; Kirch 1997). These archaeologists do not explicitly reference a transmission-defined population in their work, but instead use the term population to mean a group of individuals who share a range of similarities, or as Green (2003:113) states a "group of peoples who possessed a sense of ethnicity derived from a common origin." Regardless of how the colonizing populations of Fiji are defined, we can briefly examine previous archaeological work that proposes to identify both population diversification and coalescence in Fiji and suggest how the analysis of temporal and spatial variation in transmission lineages presented in this dissertation can build upon previous work.

The first human groups in Fiji and West Polynesia are linked through the similarities of ceramics in the earliest archaeological deposits in the region. These ceramics[3] have similar complex dentate stamped motifs and are found in Fiji, Tonga, Samoa, and other islands (Kirch 1997). The corpus of dentate motifs in the Fiji-West Polynesia region, termed Eastern Lapita, are distinguished from Western Lapita (and Far Western [Summerhayes 2001]) motifs found in Island Melanesia by their greater simplicity (Green 1979; Kirch 1997:69-74). Vessel forms in the Eastern Lapita assemblages of Fiji-West Polynesia are also similar throughout the islands. Various bowl

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[3] Dentate ceramics are known as Lapita. But as Green (2003) has recently re-emphasized, it is somewhat misleading to call only the dentate decorated ceramics Lapita as these highly decorated ceramics are also found with plain wares and more simply decorated forms.

and jar forms are present along with handled jugs, and bowls with carinated shoulders (Kirch 1997:157-159).

The decorative and formal similarities of the earliest ceramic assemblages in Fiji and West Polynesia have been used by different authors (Anderson, et al. 2000; Burley, et al. 2002; Green 2003; Kirch and Green 2001:78) to suggest that these ceramics represent an archaeological horizon (sensu Willey and Phillips 1958). In Near Oceania, where the time depth of Lapita ceramic deposits is greater, these similarities have also been used to suggest a Lapita tradition (sensu Willey and Phillips [1958], but see Anderson, et al. 2000:2]). Green (2003:104) referencing Willey and Phillips (1958:33) suggests that Lapita pottery in the central Pacific (i.e., Fiji and West Polynesia) is a manifestation of a "style horizon"[4] and indicates a "a kind of close historical relationship among those who manufactured, used, dispersed and disposed of it."

Although he does not use these terms, Green appears to be suggesting that the population using Lapita pottery in Fiji and West Polynesia is a group of individuals who maintain ceramic similarity through cultural transmission, in other words, a Darwinian population. That the shared Lapita decorative system is a result of cultural transmission is also implied in Green and Kirch's view of the Western and Eastern Lapita provinces. Green and Kirch (1997:30) suggest that the differences in the decorative systems between the Western and Eastern Lapita provinces are products of "communication" boundaries between the regions.

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[4] Willey and Phillips (1958) use the terms "horizon" or "horizon style" and note that previously they used these terms interchangeably.

Cultural historical archaeologists who employed the concepts horizon and tradition, conceived of them in terms of cultural transmission: horizons indicate "a rapid spread of new ideas over a wide geographic space" (Willey and Phillips 1958:32); "a tradition is a socially transmitted cultural form which persists through time" (Thompson 1956:39). Traditions therefore are transmission lineages defined by the temporal distribution of particular artifact classes. Culture historical archaeologists had not, however, developed the theoretical apparatus necessary to explain how cultural transmission operated or how the frequencies of transmitted variants could be explained by selection and other processes to produce differences in cultural lineages (Lyman, et al. 1997).

To summarize, the human groups that colonized Fiji and West Polynesia may be described as a Darwinian population when Lapita decorative classes (at varying levels) are used to track transmission. This proposition, however, has yet to be evaluated through transmission analysis. Sometime after colonization this hypothesized Fiji-West Polynesian population may be defined by increasing numbers of traditions or lineages (Burley, et al. 2002; Kirch 1988b:246; Sand 2001). In Fiji specifically, human groups may be defined by increasing numbers of lineages over time (Best 1984; Clark 1999; Hunt 1987), and as some argue (e.g., Best 2002; Burley 2003), the cultural lineage or lineages defined for the colonizing population of Fiji may abruptly end between 2100 and 1500 BP. A consequence of this position is that the transmission lineages whose temporal origins begin after this period are much less closely related to Fiji's founding populations.. This does not mean that Fiji's colonizers were physically replaced. Instead, the transmission of similar traits over time may have been disrupted to such a degree that archaeologists are unable to track transmission continuity with those classes. Best (1984) and Clark (2000; 1999) have both examined the proposed divergence of Fijian populations over time and the possibility of lineage termination. Their work is examined in more detail in Section 2.3.

2.2.2 Fijian Biological Diversity

Archaeological analyses of cultural diversity in Fiji are often focused on two topics: the Lapita colonizing population and its relationship to populations in the west (e.g., in Vanuatu); and the relationship between Fiji's colonizers and the colonizers of West Polynesia, the purported Ancestral Polynesian Society homeland (Kirch and Green 2001; Pawley 1971). Analyses of Fijian biological diversity are similar. Most human biological research in Fiji has been aimed at characterizing the colonizing populations vis-à-vis the Lapita colonists of West Polynesia and the non-Austronesian populations of Near Oceania to the west.

Depending on which genetic markers are analyzed or which metric and non-metric skeletal attributes are examined (and how these are statistically analyzed), scholars have suggested that the colonizing population in Fiji derived from an original Melanesian population, a southeast Asian population in Melanesia, or a mixture of both[5]. There are only three sets of fairly complete remains associated with colonizing populations in Fiji: one from Waya Island and two from Lakeba[6]. Metric and non-metric analyses by

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[5] This begs the question of biological variation present within Greater Near Oceania c. 3500 BP, but that question will not be examined here. The literature on biological variation in Near Oceania, Island Southeast Asia, and the settlement of the Pacific is voluminous (Oppenheimer 2003).

[6] An approximately 2,900 year old female skeleton has been recovered from Moturiki Island in central Fiji by Patrick Nunn and his team. Details of the find have not yet been published.

Pietrusewsky (1997) and Houghton (1989) suggest that these skeletons are similar to other Lapita-age skeletons in Tonga and Near Oceania and also share affinities with other skeletal series suggesting an island southeast Asian or Chinese coastal biological homeland.

No analyses of ancient genetic material from Lapita-age skeletons in Fiji has been successfully performed. The genetic variability of modern populations has, however, been used to suggest the biological characteristics of Fiji's colonizers. Again, results differ depending on which genetic markers are examined and which population samples are assayed, but in general modern Fiji populations are similar to West Polynesian populations (work on the mtDNA 9-bp deletion [Hertzberg1989]) and Melanesian populations (various genetic markers [Kirk1989]), with some studies showing fairly equal gene flow between Fijian populations and populations to the east in Samoa and the west in Vanuatu and New Caledonia (e.g., Kirk, et al. 1987; Lum, et al. 2002). Several researchers (e.g., Hurles, et al. 2002; Kelly 1996) have linked such biological complexity to a likely population bottleneck in Fiji as the colonizers of Remote Oceania continued to move east from Vanuatu, the Santa Cruz Islands, and New Caledonia into the remote Pacific.

The biological diversity of Fiji after colonization has been assessed through study of a single set of remains from the Natunuku site (Pietrusewsky 1989) and two studies of over 60 burials in a large cemetery at the Sigatoka Sand Dunes (Pietrusewsky, et al. 1994; Visser 1994). One bone collagen sample from the Sigatoka material is dated to 2050 – 1650 cal BP at 2 σ (calibration performed with OxCal 3.8 [Ramsey 2003] on data presented in Best [1987]) and the set from Natunuku is dated to c. 2062 – 1728 cal BP at

2 σ (Davidson and Leach 1993); the Natunuku remains were previously considered to be associated with Lapita age deposits, but those dates have since been reconsidered.

The Natunuku skeleton's lower limb bones were most similar to other Melanesian series, but the partial mandible of this find was most similar to Tongan material along with remains from Lakeba (Pietrusewsky 1989). The Sigatoka materials were described as both similar to modern Fijians through non-metric cranial data and infracranial analyses (Pietrusewsky, et al. 1994) and like Lapita samples and other skeletal series in Remote Oceania (Visser 1994). These analyses of skeletons belonging to populations that post-dated Fiji's colonization by perhaps 850 years suggest continued population-contact between Fiji and island groups to the east and west (Visser 1994:249).

Analyses of contemporary Fijians also suggest that Fijian biological variability is a result of continued genetic exchange between populations to the east and west. Recent Fijian crania are grouped with series from Vanuatu, the Bismarks, and New Caledonia, while using multivariate metric analyses, but the same crania may also be grouped with Tongan and Samoan populations, as well as Southeast Asia using non-metrics (Pietrusewsky 1994). Kirk and colleagues(Kirk 1988; Kirk, et al. 1987) examined diversity in the red-cell enzyme system in three Fijian populations from eastern (Lau Group), central (Koro Island), and western (Nadi) parts of the archipelago. While his data support several possible conclusions, Kirk argues that the Koro islanders and the Nadi population are more similar to west Pacific populations while the Lau sample is more similar to Samoan populations to the east. Kirk and colleagues (1988) suggest that the red-cell enzyme variability identifies an east-west split in the modern Fijian population that links the Lau group with West Polynesia, while the rest of Fiji is biologically more similar to Vanuatu, New Caledonia and other islands to the east. The timing of this hypothesized divergence is unclear.

In summary, biological variation in Fijian populations from the archipelago's colonization up to the present indicates that Fiji's biological heritage includes populations in Greater Near Oceania, likely including island southeast Asia. Importantly, Fiji's population has probably continued to exchange genetic material with populations to the east and west throughout the human history of the archipelago. Kirk's analyses tentatively demonstrate that at sometime in Fiji's prehistory, the archipelago population may have developed a demic structure, with the eastern and western halves of Fiji becoming increasingly different.

2.2.3 Fijian Linguistic Diversity

The languages spoken in Fiji are part of the Austronesian family, a group that contains about one-sixth of the world's languages and has the largest historical distribution of any (Pawley and Ross 1993). Historical linguists have extensively studied the Oceanic group of Austronesian languages in attempts to identify past population dispersals, particularly those associated with the colonization of Remote Oceania (for the Fiji-West Polynesia region see Green 1966, 1981; Pawley and Green 1973, 1984). Here we will not evaluate that research, but instead examine the diversity of Fijian languages to identify patterns of linguistic diversity that may be related to population diversification in other domains of human variation.

In general various Fijian languages share similarities both to languages spoken by populations in island groups to the east and the west (Geraghty 1983; Pawley 1971).

Instead of Fijian languages, however, it is more accurate to speak of Fijian communalects. Communalects in Fiji refer to "a community whose native-born inhabitants share a homogenous speech tradition, quite free of regional variation"(Pawley 1971:407). Communalects are well-recognized by native speakers and may be differentiated by a few differences in vocabulary, pronunciation, and intonation. The number of communalects in Fiji is unknown but probably numbers from 100 to 300 (Geraghty 1983; Pawley 1971). Geographically contiguous communalects are often arranged into dialect chains, so that adjacent communalects share much in common, but communalects at either end of the chain may be quite different; for example, the communalects on Vanua Levu are arranged in a chain so that those spoken on the southwestern end of the island are distinct from those on the northeastern end, but both ends are connect by intermediate communalects distributed across the island.

There is one major speech-community boundary in Fiji (Geraghty 1983, 1981; Pawley 1971). Fijian communalects can be divided into a western dialect chain and a group of eastern dialect chains (Geraghty 1981) with the boundary between them running along the eastern border of the central mountain chain on Viti Levu, then south along the Navua river. Communalects that are on either side of this boundary do not grade into each other as in the dialect chains throughout Fiji. With only a few exceptions, there are discontinuities between the communalects across this boundary so that phonological, syntactic, and lexical differences mark this divide.

The specific importance of the western-eastern language division for prehistoric human diversification in Fiji is still unclear (but see Green 1999:9). Based on the great number of shared innovations across all Fijian communalects, Pawley and Sayaba

(1971:411) argue that western and eastern Fijian developed from a Proto-Fijian ancestral stage spoken throughout the archipelago. They suggest that this divergence occurred sometime before 1400 BP, but note that this date is tenuous (Pawley 1971:416). Regardless of the timing of this hypothesized divergence, the communalect distinction between western and eastern Fijian suggests that cultural transmission of language variation was not panmictic, but that language diversity is comprised within a simple demic structure, not unlike that suggested by Kirk (1988) based on red-cell enzyme variability.

Geraghty strengthens the distinction between western and eastern Fijian by arguing that a subset of eastern Fijian communalects from the Lau Group and Vanua Levu share a number of unique lexical innovations with Polynesian languages to the east (Geraghty 1983:379-382). Geraghty suggests that these communalects may be evidence of a Tokalau-Fijian-Polynesian subgroup whose speakers may have been the population to settle Polynesia (Geraghty 1983:381; see also Kirch and Green 2001:56-59; Pawley 1996)[7]. Somewhat symmetrically, western Fijian communalects share more features exclusively with the Oceanic languages of Melanesia to the west than with Polynesian languages to the east, but many eastern Fijian communalects share features with both. Others working in Fiji have noted sociocultural differences between populations in the west and east (e.g., Capell 1940-41:318-319). In summary, Geraghty (1983:389) notes "suffice it to say that the Oceanic languages of Melanesia, like the Polynesian languages, show a complex relationship with the Fijian languages."

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[7] Such a hypothesis is difficult to evaluate with potentially undetectable borrowings of unknown age between speakers of proto-eastern Fijian communalects (especially in the Lau Group) and proto-Polynesian speaking populations (Best and Geraghty 2002, Clark 1979).

Communalect diversity in Fiji has also been analyzed in a slightly different fashion by Hunt (1987). Using Geraghty's data, Hunt plotted similarity relationships among communalects to determine if communalect similarity was explained largely by geographic propinquity. In many cases, the similarity of two communalects was accurately predicted by distance between communities. However, for at least 12 communalects, similarity was not predicted by distance between speech communities and interestingly, these communalects are all spoken in a contiguous area of central Fiji comprising eastern Viti Levu, western Vanua Levu and Kadavu (Hunt 1987:Figure 11). In the most parsimonious interpretation of these data, Hunt (1987:319) states "it appears that the 12 dialects representing central Fiji reveal evidence of a strong degree of continued historic interaction and/or migration unlike other areas of the archipelago" where an isolation-by-distance model explains local divergences from a postulated early period of more widespread cultural transmission across the archipelago.

In summary, Fijian language diversity suggests a complex history of cultural transmission between Fijian populations and those to the east and west. A significant division between eastern and western Fijian communalects also suggests that sometime after colonization (or as part of the colonization process, see Clark and Anderson [2001]) the probability of cultural transmission between individuals within the archipelago is not well accounted for by a simple distance-equation, but instead cultural transmission lineages would be spatially differentiated into western and eastern groups. Finally, patterns of communalect similarity suggest that at some point an isolation-by-density model may explain frequencies of language transmission in much of the archipelago, except for central Fiji where language transmission appears to have been structured around different parameters.

2.3 USING CERAMIC VARIATION TO EXPLAIN DIVERSITY

One goal of this dissertation research is to develop a theoretical and methodological framework for the scientific explanation of cultural diversity. In pursuit of this goal, we can examine how archaeologists have previously attempted to explain cultural diversity in Fiji's past and build upon their work. The most detailed examinations of ceramic change over a large portion of Fiji's prehistory have been conducted by Best (1984) and Clark.(1999). Neither Best nor Clark explicitly state that their goal is to produce scientific explanations, so we can not expect that their methods will necessarily be the same as those developed here. We can, however, examine one particular aspect of their research to see how it may effect the generation of scientific explanations. That aspect is the reliance on empirically derived measurement units instead of the ideational classes that link explanatory theory to the empirical world.

The use of empirically derived units, or groups, as measurement units in scientific explanations of change are problematic for two reasons. First, the definitions of empirically derived groups are generated from the object or set of objects themselves. Such *extensional* definitions (Dunnell 1971:15-16) are idiosyncratic, bound to the particular time and place of the objects in the group. Thus it is impossible to transfer extensional definition of an empirical group to a different set of phenomena without changing the definition. As a consequence we can not use the same extensionally defined unit to examine distributions of multiple groups of phenomena across time and space.

Archaeologists may circumvent this problem by extracting descriptive generalizations from multiple, extensionally defined groups and then attempt to explain differences among such generalizations. These explanations, however, are often not directly useful in constructing evolutionary explanations as they address modal tendencies in observed variation (Dunnell 1995). They neglect the variation that is a key component of scientific frameworks that employ concepts such as transmission and selection (see discussion of the materialist paradox in Clark [1997:313]; and O'Brien and Lyman [2000a:25-27]).

The second problem concerns the linkage between the extensional definitions of empirically derived units and explanatory theory. Such units may not be linked to explanatory processes in a theoretical framework and, if so, the meaning of those units is ambiguous. In these instances, explanations for the relationships between empirical units are often ad hoc and preclude any definitive empirical testing of possible explanations. This section examines the ramifications of using empirically derived observational units to explain the prehistory of Lakeba Island.

2.3.1 The Ceramic Prehistory of Lakeba

The importance of Best's dissertation (1984) and subsequent analyses (2002) of ceramic change on Lakeba Island in the Lau Group can not be underemphasized. His ceramic analytical procedures have served as a template for subsequent researchers (e.g., Clark 1999; Crosby 1988; Rechtman 1992) and the Lakeba ceramic sequence has been described as the "de facto type sequence for Fiji" (Clark 1999:18). Because of the thoroughness of Best's work, all subsequent ceramic studies in Fiji (and many elsewhere in the region), refer to the Lakeba sequence and Best's conclusions.

2.3.1.1 Lakeba Research Goals and Methods

Best sought to generate a thorough, but general culture historical description of a Fijian island. As he notes, his "work examines no specific and isolated problem, but rather will attempt to establish the outline of a Fijian island's prehistory, and examine as many aspects as possible of any observed variation" (Best 1984:21). A main aim was to construct "a comprehensive ceramic sequence covering the entire prehistory of the island, together with the investigation of technological aspects of the ceramics" (Best 2002:16). While Best does not use the phrase "cultural diversity" to describe the object of his analyses, he does offer explanations for various aspects of changing ceramic diversity. It is also apparent from his writing that Best is interested in explaining material cultural diversity as a result of interaction between human groups both within and beyond the Fijian archipelago (e.g., Best 1984:661-663)

Best conducted a thorough site survey of Lakeba (209 sites recorded), with several deeply stratified rockshelters, fortified sites, and open sites identified. The main Lakeba ceramic sequence was developed from the sherd inventories at three sites representing the early and middle ranges of the sequence, rockshelter sites 197, 2b and the early open site 196; two coastal fortified sites, one dated to c. 930-460 BP; and several surface collections surmised to represent recent deposition, c. 200 BP.

Best's Lakeba sequence is characterized by five major ceramic periods, within which ceramic variation is minimized and between which ceramic variation is maximized. These periods are described by a combination of their constituent vessel forms (identified by rim variation and other diagnostic sherds), decorative techniques present, and sometimes additional characteristics such as temper types and quantity. Best argues that each ceramic period develops out of the proceeding one, but that there is an abrupt break between Periods II and III at c. 2100 BP, "representing the greatest ceramic change in Lakeba's prehistory" (see also Best 2002:17; Best 1984:643), a change that appeared, "either as a local development from somewhere in Fiji, or more likely as a result of contact with the west, probably New Caledonia" (Best 2002:29).

2.3.1.1.1 Analytical Protocol of the Lakeba Analyses and its Relationship to the Classification Debate in Americanist Archaeology

To assess Best's conclusions, we must first understand the construction of Best's ceramic periods. Best forms periods by arranging ceramics so that the empirical groups created exhibit some degree of internal homogeneity. The generation of groups is accomplished mainly through statistical similarity measures applied to the sherd assemblages in provenience units, such as aggregated excavation strata. Best used two similarity statistics, Jaccard coefficients and Robinson indices, to assess similarity between provenience units. Best then displayed the similarity of provenience units through both shaded similarity matrices and dendrograms (e.g., Best 2002:18, figure 3). Provenience units judged to be similar enough were grouped into a ceramic period. The periods created are further refined by comparison with diagrams that chart frequency changes in particular ceramic categories in stratified assemblages. Such a technique has been described as "percentage stratigraphy" (Lyman, et al. 1998; O'Brien and Lyman 2000b) and has been widely applied in Fiji. Best's periods are extensionally defined as each period (e.g., Best 2002:17) is a summary presenting the typical ceramic variants in each corresponding group of ceramics.

The extensional period definitions are a product individual sherd descriptions, so we may gain a better understanding of the relationships between periods by examining Best's sherd description procedures. Best described each sherd in as much detail as possible (Best 1984:159, 180), defining 300 possible ceramic categories from 126 observations (termed "attributes" by Best)[8]. After several re-workings of his data, Best collapsed his observations into 269 ceramic categories, each category described by different and numerous characteristics in dimensions of variation such as form and surface modification (Best 1984:Table 3.1). For example, sherd category 4 (Best 1984:Table A.1) is described as (attribute identification numbers in parentheses): rim sherd (1); either everted (17), inverted (19), or vertical (21) orientation; indirect contour (24); concave-even rim course (27); rim profile of very abrupt thickening and then thinning towards lip (34); lip shape being flat, normal to rim axis with sharp edges (39), or rounded edges (40), or rounded entirely (45), or rounded-pointed (50); decorated (52); rim, external decoration position (60); dentate stamping, simple shell arcs decoration (82); rim eversion from 0-22.5 degrees (107), or inversion from 0-30 degrees (110); and rim length of greater than 15 mm (117).

Best's rationale for such a descriptive scheme derives from the principles of numerical taxonomy (Best 1984:180). As the rationale for generating particular observational classes is intimately linked to explanation of class distributions, we must examine Best's rationale in more detail. Numerical taxonomy is one possible technique for applying phenetics in the arrangement of phenomena (Mayr 1981; O'Brien and

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[8] Best's (1984) terminology is not consistent calling his sherd types "attribute categories," but also "primary ceramic categories", and "ceramic categories" making it sometimes difficult to dissect his procedures. It appears that Best most often used "ceramic categories."

Lyman 2000a:194; Sokal and Sneath 1963). Phenetics arose in modern (post-synthesis) evolutionary biology as a way to arrange organisms into taxa. Pheneticists describe organisms with as many phenotypic traits, called unit characters, as possible. Organisms are then grouped (using numerical taxonomy or another technique) based on the similarity of unit characters into Operational Taxonomic Units (OTUs). OTUs are the final products of phenetic analysis.

Phenetics has further developed in response to competing methods in evolutionary biology for arranging organisms, one of which is evolutionary taxonomy(Mayr 1982:217-235; O'Brien and Lyman 2003:32). Evolutionary taxonomists choose those characters they hypothesize are homologous, or related to ancestry, when creating classes. Taxonomic trees showing branching and descent relationships are the product of evolutionary taxonomy. However, the method of choosing supposedly homologous characters, and thus the taxonomic tree produced, sometimes still seemed intuitive and subjective to the pheneticists, or inadequate to represent ancestry because of gaps in the fossil record (Davis and Heywood 1963:xviii). To alleviate the presumed subjective nature of evolutionary taxonomy, pheneticists applied their methods using unweighted unit characters, but pheneticists acknowledge that their classificatory schemes may not represent homology and descent. Phenetics is simply a method for arranging phenomena based on similarity. The processes that explains the similarity is left unstated.

Phenetic creates groups of things after which group-descriptions, that is extensional definitions, can be extracted. O'Brien and Lyman(2000a) provide a succinct and thorough description of phenetics and other statistical grouping methods, that is perfectly descriptive of Best's (1984) analysis:

> The objective of a clustering exercise is to produce groups—clusters—of things, each of which is more like the other things in that group than things in other groups. To produce clusters, objects are taken one pair at a time and scored in terms of their similarity to each other. Similarity is generally measured as the number of shared attributes or characters. Similarity coefficients are calculated in like manner for all pairs of objects, and the coefficients are linked in descending order of similarity, producing the familiar dendrogram pattern of linkage. Clusters then are identified either by visual inspection or by the use of threshold values. This type of approach to object clustering is termed *numerical taxonomy* (Sokal and Sneath 1963), or *phenetics* (Mayr 1981)" (O'Brien and Lyman 2000a:194, emphasis in original).

O'Brien and Lyman (2000a:194) add that clustering approaches are valuable as pattern-recognition devices. These methods suggest patterns of variability in the empirical world that may be further examined with problem-oriented classifications. However, because the groups created by these methods may have no necessary link to any explanatory theory—there is no required expectation for why objects are similar—they are not particularly good at explaining empirical distributions.

Americanist archaeologists began using statistical grouping methods (e.g., Spaulding 1953b) at about the same time phenetics was being investigated in biology (O'Brien and Lyman 2003:31-32). In Americanist archaeology the mid-20th century debate regarding how to classify artifacts was primarily carried out between James Ford and Albert Spaulding and represents a clash between problem-oriented or theoretically-linked classification and statistical grouping (Ford 1952, 1954a, 1954b, 1954c; Spaulding

1953a, 1953b, 1954a, 1954b; see O'Brien and Lyman [2000a:207-213] for extended analysis of the debate). Ford's culture historical types were constructed by combining different dimensions of ceramic variation, primarily decoration and temper, to produce classes whose empirical distributions suggested that they were tracking cultural transmission. These distributions were the familiar battle-ship curves of culture history and served the purpose of ordering assemblages in time and space. The rationale for choosing dimensions and modes was not couched in an explicit transmission framework, but was recognized instead as the "popularity principle" (Krieger 1944; Lyman, et al. 1997)—an empirical generalization. Spaulding correctly argued that the Ford method for constructing classes lacked explicit theory whereas his technique (based on the statistical work of Robinson [1951]) appeared to discover consistent non-random attribute associations in archaeological assemblages. Spaulding rationalized the existence of non-random attribute associations in a particular assemblage as reflecting the cultural norms of the makers. In this way, Spaulding's technique seemed superior to Ford's.

Ultimately, however, neither Ford nor Spaulding explicitly noted the primary difference between their procedures for arranging archaeological phenomena. Ford's types were ideational classes built specifically for measuring change through time and space. Thus Ford's types were not tied to the phenomenological world and could be applied to any assemblage. The theoretical foundation of the classes, however, was ultimately based on an empirical generalization that classes constructed in a particular way tended to sort temporal variability.

Spaulding's types on the other hand were not ideational or theoretical classes, but empirical groups. They are descriptions of a particular set of empirical objects. Even if the attributes used to construct groups are chosen in relation to a particular explanatory process, it is still impossible to compare groups across multiple assemblages as the empirically derived group definitions will be different in each case.

Programmatic statements regarding the need for statistical grouping as a means for creating artifact types have been prevalent in archaeology since Spaulding's initial paper in 1953 (e.g., Aldenderfer and Blashfield 1978; Aldenderfer and Blashfield 1984; Duff 1996; Gilboa, et al. 2004; Whallon and Brown 1982). Their success may be attributable to the appearance of objectivity in statistical grouping methods and the lack of generally accepted explanatory theory in archaeology used to rationalize the characteristics of observational classes (Dunnell 1986).

Because Best uses grouping methods to construct his ceramic periods, the periods must be defined by the contingency bound set of empirical descriptions used to form them. We can not therefore unambiguously apply these same period definitions to new assemblages. We also do not know the meaning of these periods as Best did not make observations in a way that is linked to an explanatory theory. Instead, Best (1984:159) justifies his ceramic categories by their repeated presence in different deposits and suggests that this repetition is likely not a product of chance. This is Spaulding's justification that non-random attribute associations reflect a mental template of the artifact-maker and that the artifact type as mental template constitutes part of a sound explanatory system. We have no reason to believe this is true except for within our common sense framework. Consequently, explanations are also constructed from common sense that explain differences in mental templates in time and space

2.3.1.1.2 Determining the Tempo and Mode of Ceramic Change on Lakeba

One of Best's most notable conclusions regarding ceramic change on Lakeba is the inference of sudden and dramatic change between Periods II and III (c. 2100 BP). To infer the meaning of "the greatest ceramic change in Lakeba's prehistory" (see also Best 2002:17; Best 1984:643) we must examine Best's identification of this change. Best's depiction and analysis of the ceramic changes that occur between Periods II and III is representative of other portions of his work, thus an exposition of the logic behind these units will shed light on Best's overall approach.

Best identifies the Period II-III boundary within a dendrogram ordering sixty provenience units from the rockshelter sites (197 and 2b), the early open site (196), and most of the inland sites on Lakeba (Best 1984:272). The dendrogram displaying provenience unit similarity and ceramic periods (Figure 2.2, see Best 2002:18, Figure 3; Best 1984:276-278, Figures 3.49, 3.50) "is taken to be representative in all but minor detail of every ceramic assemblage so far retrieved from Viti Levu and the islands in the Koro Sea (allowing for obvious disturbances or lack of stratigraphy in the sites)" (Best 2002:17). Best's Periods I-V are displayed along the top of the dendrogram and comprise particular provenience units and sites identified at the tip of each dendrogram branch. The provenience units are arranged by average linkage cluster analysis of Robinson similarity indices for each provenience unit. For example, the small cluster containing provenience units S2, S1, R2, and R1 (at the left of the dendrogram) are linked by an average Robinson Index of approximately 158, while all the provenience units in Period I are linked by an average Robinson Index of approximately 75. The dendrogram arranges provenience units in roughly chronological order, oldest on the left, based on stratigraphy, chronometric dates, and association with similar sites (e.g., some fortified sites are assumed late based on other chronometric analyses).

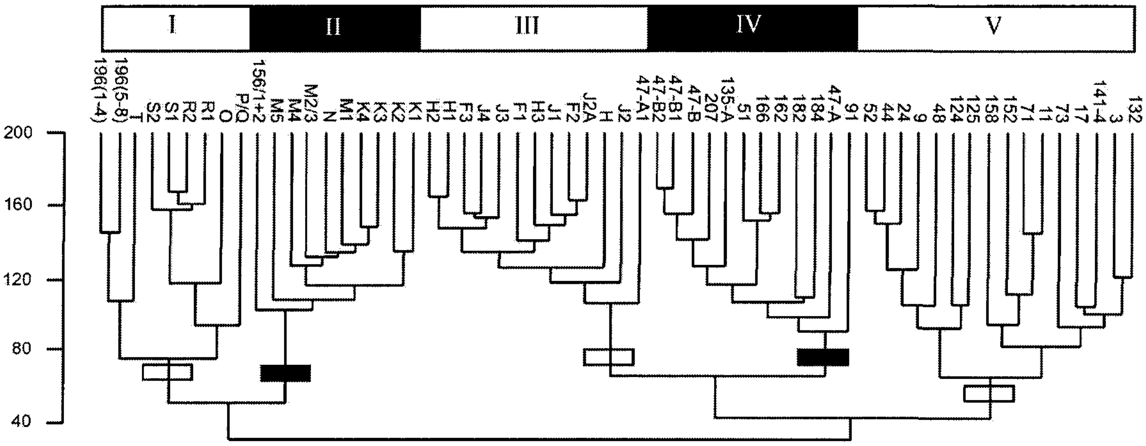

Figure 2.2. Dendrogram redrafted from Best (2002:18, Figure 3) displaying clustering tendency of provenience units based on Robinson Index similarity. The level of similarity for a particular cluster is indicated by the scale at the left. Best identifies five clusters (Roman numerals and corresponding rectangles on cluster branches) in the dendrogram representing five periods of relative ceramic similarity.

Given that the assemblages in each provenience unit are described with over 260 ceramic categories, what are we to make of the different clusters that Best defines in the dendrogram? In other words, are there any definitive criteria which can be used to define one cluster relative to another? Best suggests that the assemblages of Periods II and III are separated by a few important characteristics, "a totally new vessel shape and rim form, and a new decoration, that of carved paddle impressing, enters" with Period III (Best 2002:17). Best also supports his Period II-III division with other aspects of ceramic variation not arranged by the dendrogram. For example, Best notes that around the time of the Period II-III boundary lithic tempers decline and there is an increase in calcareous sand or shell tempers (Best 1984:324, Figure 4.2, 356-357).

Best's interpretation of dramatic ceramic change is, in part, a product of the grouping methods he uses. This is demonstrated by examining the frequency changes in particular attributes that make up Best's groups. A set of Best's ceramic data linked to assemblages in Periods II and III has been compiled in frequency format in Table 2.1. These data illustrate some aspects of the underlying change in Best's Period II-III transition.

Table 2.1. Ceramic change across Periods II and III on Lakeba Island with double line dividing Best's (1984) Period II and III assemblages.

Clustering Unit from Best (2002: Figure 3)	**Associated 14C dates, 2σ, BP**	**Total N**	**% of all Decorated[‡] Sherds that are Paddle-Impressed (raw count)**	**% Decorated Sherds of Total Sherds[‡]**	**% of Kuro** Rim Sherds of Total Identifiable Rim Sherds (raw count)**	**% of Kuro-like Everted Rim Cooking Pot Sherds of Total Identifiable Rim Sherds[◊] (raw count)**
Site 47: A1		1447	88% (107)	8.3%	100% (22)	(0)
Site 2b: J2	1520-1300	246	94% (65)	28.0%	66.7% (2)	33.3% (1)
J2a		493	91% (158)	23.7%	45.5% (5)	25.0% (3)
Site 197:F2*		519	91% (158)	33.0%	22.9% (8)	60.0% (1)
Site 2b: J1*		319	100% (132)	28.2%	100% (3)	0% (0)
Site 197:H3*		214	100% (66)	30.8%	0% (0)	16.7% (1)
F1		218	76% (52)	23.9%	40.0% (4)	33.3% (3)
Site 2b: J3		338	91% (166)	49.1%	23.5% (4)	76.5% (13)
J4		272	100% (83)	30.5%	7.7 % (1)	78.6% (11)
Site 197:F3	1900-1510	430	100% (201)	46.7%	24.2% (8)	46.7% (14)
H1		612	100% (225)	36.8%	2.6% (1)	77.4% (24)
H2		345	100% (157)	45.5%		53.8% (7)
K1	2340-1890	453	100% (97)	21.4%		13.6% (3)
K2		708	100% (48)	6.6%		16.7% (6)
K3		194	100% (10)	5.2%		
K4		450	100% (6)	1.3%		
M1		958	67% (2)	0.3%		
N*	2470-2000	917				
M2/3		714				
M4		538				
M5		550	100% (1)	0.2%		
Site 156:1&2		762	5% (38)	5.0%		2.1% (2)

* Assemblages not in stratigraphic order.

[†] Total sherds calculated from Best (1984:295, Figure 3.55 and from Appendix A, Tables A.2-A.7).

[‡] Decorated sherds do not include slipped, polished, or burnished sherds.

** Best (1984:294, Table 3.2) identifies *kuro* rim forms with sherd categories 58-75. Some of these groups (62, 63, and 69-73) include rims whose angles are not measurable, or not in the medium to large angle categories, or listed as indeterminate orientation. As these characteristics are all important to the description of *kuro* given by Best, I have excluded those sherd groups from my tabulation of *kuro* rims.

[◊] These sherds tabulated using sherd categories 55 and 56 from Best (1984:294, Table 3.2).

Each row of Table 2.1 is identified by its provenience unit from Periods II and III as arrayed in Figure 2.2. The bottom half of the table (below the double line) contains the Period II provenience units, while the top half contains Period III. The fourth column shows the proportion of decorated paddle impressed sherds relative to all other forms of decoration. Note that while raw counts of decorated paddle impressed sherds generally increase up the column from Period II to III, the proportion of decoration that paddle impressing represents is fairly equal across periods. Paddle impressing is essentially the only kind of decoration until incising and finger-pinching arise in Period III. An equally interesting way to examine this trend is presented in the fifth column which lists the percentage of decorated sherds out of the total assemblage. These data are presented to suggest the continuous change across Best's Period II-III boundary. Here we see that from Period II to Period III the amount of decoration in general in an assemblage is increasing and begins to decrease toward the end of Period III.

In the case of paddle impressed decoration, Table 2.1 demonstrates that there is no unambiguous break between Periods II and III, but that change across this boundary is more precisely depicted as changing frequencies of classes. Decorative paddle impressing appears, albeit almost invisibly, at the beginning of the stratigraphic sequence of Period II (not counting the surface site 156) and slowly increases in frequency. While Period III assemblages have more decorative paddle impressed pottery than Period II assemblages, Period III paddle-impressing develops from a Period II base (see also Best 2002:29; Best 1984:190).

Along with abundant decorative paddle impressing, Best also defines Period III by the appearance of "a totally new vessel shape and rim form" (Best 2002:17). The new vessel shape is typically called a *kuro*, Fijian for clay cooking pot (e.g., Best 1984:302, Figure 3.59, b). Although there are no necessary and sufficient criteria that define *Kuro*, they are distinguished primarily by their parallel-sided and strongly everted rims. They are restricted orifice vessels that appear to come in a variety of overall body-shapes from spherical to ovaloid (taller than wide), with the widest portion of the vessel very near the vertical center or in the upper half of its height. In contrast, many Period II cooking vessels are often characterized as ellipsoid (wider than tall) and with their greatest width occurring in the bottom half of their height giving them a more squat appearance. Many of these Period II vessels have restricted orifices, and slightly everted rims that are sometimes thickened toward their terminating end (Best 1984:301, Figure 3.58, a-e). They may also exhibit wiping, or striations produced by a fibrous material, around their necks. One of the Period II cooking pots is a *kuro*-like vessel that occurs in the late Period II assemblages. These vessels appear similar to Best's *kuro* except that their rims are not as strongly everted and they may be slightly smaller than typical *kuro* (Best 1984:302, Figure 3.59, a).

Rim attributes have mostly been used to distinguish *Kuro* from other vessels, because of the greater preservation of rim sherds in archaeological deposits. Columns five and six in Table 2.1 tabulate the number of rim sherds of *kuro* and the late Period II *kuro*-like vessel in provenience units. The proportion each type contributes to the overall rim sherd assemblage is also indicated. Column five depicting *kuro* rim sherds demonstrates that this type of vessel appears for the first time in Period III in layer HI of site 197. Column six demonstrates that the *kuro*-like cooking pot is found in both Period II and III deposits. The proportion each vessel represent of the entire rim sherd assemblage changes across provenience units. The proportion of *kuro* relative to other rim-types generally increases across Period III and this type of rim becomes the dominant form for the remainder of the Lakeba sequence. In contrast the proportion of *kuro*-like rims first increase after their appearance at the end of Period II and then generally decrease toward the end of Period III (Best 2002:19, Figure 4; Best 1984:293, Figure 3.54). As there are no necessary and sufficient criteria for membership in *Kuro* as an analytical class, we can chart the continuous frequency change of several seemingly related forms across Best's Period II-III boundary.

Changes in tempering practices also occur from Period II to Period III (Best 1984:356). Period II ceramics are predominantly lithic tempered, while Period III ceramics are predominantly calcareous tempered. The change between lithic and calcareous dominated assemblages occurs over layers K2 to F1 and F2 at site 197(Best 2002:20, Figure 6; Best 1984:324, Figure 4.2), representing perhaps several hundred years. Sampling for temper analysis was limited, so representative temper type frequency data linked to the data in Table 2.1 can not be generated. Both of these temper types, however, appear in small amounts almost from the beginning of the Lakeba sequence. As calcareous temper begins to increase in frequency it is often found in decorative paddle-impressed sherds which are increasing in frequency at the same time. Decorative paddle impressed sherds are not, however, exclusively tempered with calcareous sand, nor are other decorative categories exclusively associated with lithic temper (Best 1984:327-334).

In summary, Best's Period II-III transition is marked by frequency changes in a variety of sherd characteristics, including decoration, general surface modification, rim shape, and temper. It is difficult, however, for Best to reconcile this continuous change with the grouping methods he employs. On the one hand he recognizes the continuous nature of change (Best 2002:29; Best 1984:190), but on the other he is forced to interpret ceramic change as categorical difference. For example, Best (1984:494) states that the appearance of decorative carved paddle impressing on Lakeba "radically affected the existing technology, changing the vessel and rim shape, introducing decoration, and altering the type and amount of temper." This is not entirely true as Table 2.1 indicates that decoration, temper, and vessel forms all change at slightly different times. Moreover, when examined separately, it is apparent that change in each of these dimensions may be explained as a result of different processes.

Best's categorical interpretations are a direct result of the grouping procedures he employs to generate summaries of ceramic variability. Grouping procedures lead to Best's interpretations in two ways. First, the numerical taxonomy approach to artifact description generates artifact descriptions that lack an explanatory framework. Without a justification for the use of a particular characteristic to describe a sherd, there is no way to know what variation in that characteristic means. We can only generate meaningful measurement through a priori definition of measurement units linked to theory. This is analogous to the explanatory quandary of the pheneticists: while they can precisely quantify the similarity between groups (taxa), the meaning of that similarity is unstated and impossible to recover.

This situation accurately describes Best's work. Since Best does not note that meaning is determined during the creation of measurement units, he is forced to take an interpretive approach and "find" meaning in his observations. Consequently, Best has to assert that dramatic differences in ceramic assemblages between periods is caused by the arrival of new populations. In the case of Period III and paddle impressed decoration Best suggests that migrants from New Caledonia inspired the ceramic change (Best 2002:29-30; Best 1984:628), in the case of the incising and later decorative innovations of Period III, Best suggests contact with Vanuatu populations may have been a catalyst of change (Best 2002:30-31; Best 1984). It is not migration, however, that is problematic in Best's argument. Rather, it is the fact that Best asserts migration is a cause of change even though the data he is explaining lack any necessary connection to migration as an explanatory concept.

Best's strategy is akin to the interpretive statements culture historians made to account for differences between phases. Culture historical phases, like Best's ceramic periods, were empirically created groups generalized from the record of continuous change (Fox 1998). Culture historians had no well-developed explanatory framework to explain phase differences (Lyman, et al. 1997; O'Brien and Lyman 2000a:121-125). Instead, they relied on a variety of common sense assertions, but these lacked any definitive tests or any means of determining the veracity of one or another explanation (see Willey 1953:369). Ideas such as diffusion, invention, trade, and, when the break between phases was particularly dramatic, migration, were used to explain phase differences in an ad hoc fashion. These explanations were not linked to the culture historical observational classes, that is, their historical types. Best is in a similar situation with his Period II-III transition. Without any well-developed explanatory theory postulating a set of mechanisms and observational categories, Best interprets ceramic difference in commonsense manner: migration.

This is not to say that migration does not occur in prehistory or that it has no effect on the material culture of populations. But Best has not generated measurements in a way that could be explained by the influx of a new group of people or ideas (beyond citing a historically recorded case of migration). This brings us to the second way in which grouping procedures confound Best's interpretations relative to scientific explanations. Grouping procedures obscures continuous frequency change in the archaeological record. Measurements of continuous frequency change are vital if we are to explain how an influx of new ideas, innovation, and migration may effect cultural change. Data that depict continuous change across multiple dimensions of artifact variation are explicable in an evolutionary framework by different processes such as innovation—for example in the case of new cooking pot forms—and selection—for the rise of decoration in assemblages after c. 2200 BP. When data are generated through the process of applying theoretically informed classes to the phenomenological world, and not by creating groups based on the similarity of objects using ad hoc attributes, our observations can be linked to explanatory mechanisms.

2.3.1.2 Relevance of the Lakeba Research to Studies of Population Diversity

While Best's grouping procedures preclude any explicit relationship between observations and explanation, Best has identified empirical patterns of ceramic variation. These patterns, some of which are depicted in Table 2.1, are suggestive of variation that may be explained by processes such as transmission, selection, and other sorting processes. Other patterns Best discovered, but not examined here, include the disappearance of dentate stamped decoration over time, along with a concomitant decrease in diversity within general vessel forms on Lakeba. There are also several styles of decoration that appear unique to eastern Fiji as evidenced on Lakeba by c. 960-660 BP[9]. This may indicate divergence between Lakeba and western Fijian populations. Finally, the decorative diversity Best identifies toward the end of Fiji's prehistoric sequence (Best 2002:20, Figure 5; Best 1984:295, Figure 3.55) may indicate an accelerated pace of population diversification prior to contact between Fijians and Europeans. At this point, these possibilities are speculative and require problem-oriented classifications linked to a theoretical framework to generate testable hypotheses.

2.3.2 The Ceramic Prehistory of the Mid-Sequence

In his dissertation, Clark (1999) examines ceramic change from the beginning of Polynesian Plainware assemblages, c. 2300 BP, up through much of the Navatu phase to c. 800 BP. Clark terms this period the "mid-sequence" and it is notable for the paucity of research attention received as most work has concentrated on Lapita assemblages or the accelerating appearance of fortified settlements c. 1000 BP and later cultural changes. Like Best, Clark does not explicitly state that he is attempting to construct scientific explanations, but we can examine Clark's analytical procedures and conclusions to determine how they can be integrated into a scientific evolutionary framework.

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[9] Date calibrated from Best's (1984), radiocarbon data for Site 47, sample NZ4585, using OxCal 3.9 (Ramsey 2003) and atmospheric data from Stuiver et al. (1998).

2.3.2.1 Mid-Sequence Research Goals and Methods

Clark's goal is important as he explicitly seeks to explain the "development of human diversity in the eastern Melanesian archipelago of Fiji" during the mid-sequence (Clark 1999:2). Specifically, Clark addressed three issues in his work. First, accepting that other researchers (e.g., Best 1984) have identified periods of accelerated ceramic change, Clark attempted to determine if accelerated ceramic change was either a product of socio-economic factors internal to Fijian populations, or if this change was initiated by populations beyond Fiji. Second, Clark sought to determine if there is variation in the level of social interaction during the mid-sequence? And third, his research focused on whether there changes in the spatial scale of interaction (Clark 1999:45-46).

Clark's concepts of interaction and human diversity are never explicitly defined, so relating his research themes to the definition of human diversity used here—the abundance of and variation between material culture lineages—involves some guesswork. It appears that in Clark's view, interaction includes the transmission of information, and human diversity is a measure of difference between populations in terms of language, material culture, and biology. Thus his first research issue addresses the rate of change in material culture lineages (not Clark's terminology) and possible explanations for varying rates of change. Explanations he considers consist of interaction between Fijian and non-Fijian populations, and subsistence and exchange-system changes within Fijian populations that are linked to variability in interaction. The second research issue addresses possible frequency changes in cultural transmission within the Fijian population. Changes in the frequency of transmission may suggest a spatial structure to transmission within the greater Fijian population. For his third research issue, were there scale changes in transmission, Clark uses compositional data to examine the possible movement of vessels. Here Clark is trying to disentangle the transmission of ideas from the movement of artifacts and transmission of ideas.

Clark examined the ceramic assemblages from three sites: the Navatu site on the north coast of Viti Levu, a site on the small island of Ugaga near Beqa Island, and the site of Karobo on the south coast of Viti Levu (see Figure 1.2). The Navatu site was first excavated by Gifford (1951) with Clark excavating several more units. The small island of Ugaga was examined by Crosby (1988), but had not been excavated before Clark's work there, and the assemblage from Karobo was excavated by Palmer (1965) and examined by Clark at the Fiji Museum.

2.3.2.1.1 Analytical Protocol of the Mid-Sequence Analyses

Clark turns to archaeological theories of style to determine patterns of mid-sequence interaction. His review of archaeological style (Clark 1999:47-51) summarizes the various interpretive strains currently in use including: style as neutral variation (e.g., Neiman 1995), social-interaction theory (e.g., Plog 1983) where stylistic similarity is a function of interaction (this is fundamentally similar to the neutral conception of style), and information exchange theory where style is meant to communicate social information (e.g., Wobst 1977).

While Clark later relates his findings to these various views of style, his system for classifying archaeological ceramics does not derive from any of them. Clark uses Best's (1984:19-181) approach, but collapses his analysis into 42 possible (instead of 126) observations for each sherd, including aspects of vessel form and decoration. Also like Best, Clark uses a grouping procedure to assess the similarity of sherds described by these 42 possible observations. Thus the larger analytical units created by the grouping procedure suffer all the explanatory problems noted with Best's ceramic periods. Clark views *all* dimensions of ceramic similarity as indicators of interaction (albeit different kinds of interaction), referencing both similarities in Lapita decoration as indicators of interaction, as well as similarities in utilitarian aspects of vessels as indicators of interaction. Certainly, any dimension of ceramic variation *may* track interaction or cultural transmission within a population. But, Clark does not develop any distributional expectations that separate ceramic similarity explained as a result of transmission within a population from ceramic similarity that does not indicate population relatedness. In short, Clark has neither a general theoretical framework that posits a set of explanatory processes by which we can account for observed variation, nor the means to make meaningful observations of the empirical world that are explicable by these processes.

To arrange his sherds by the similarity of their 42 observations Clark uses multi-dimensional scaling (MDS). MDS is like other ordination techniques (e.g., principal components analysis) in that similarity between objects described by numerous dimensions is represented in a lower number of dimensions, or components, for easy visual inspection and identification of grouping tendencies in the data (as noted by Clark [1999:64]).

Like all grouping methods, the groups created by MDS have no particular relationship to explanatory theory unless the observations made on sherds used in the MDS analysis are linked to explanatory processes or the components of the decomposed MDS data matrix can be associated to variation of interest (e.g., size or time) that in turn is linked to explanatory processes.

Clark also recognizes that the observations used to describe sherds in MDS analysis should not be arbitrarily chosen. He notes that the observations should be "diagnostic or culturally meaningful" (Clark 1999:65), but what exactly this means is not explicitly stated, except that meaningful observations should measure consciously encoded social information (Clark 1999:65). This rationale for the choice of attributes is circular: attributes which show non-random associations are considered meaningful, but meaningful attributes are those that have non-random associations. This reasoning is exactly the same as Spaulding's rationale in the choice of attributes to create his statistical groupings. Clark is left with observational units whose meanings are ambiguous. Likewise, explanations generated for the variation between units are ad hoc and difficult to test.

2.3.2.1.2 Resolving the Mid-Sequence Research Questions

Four MDS analyses were carried out "to identify patterns of geographical and temporal variation in Fijian ceramics in the transition from Lapita to mid-sequence ceramics and between assemblages of mid-sequence age" (Clark 1999:164). The clustering tendencies of assemblages and sherds arrayed in principal component plots of MDS data underpin three general conclusions (Clark 1999:187-189). First, Clark argues that ceramic similarity was greatest among Lapita-age assemblages and that later assemblages begin to diverge from one another. Second, the divergence of ceramics begins in assemblages dating to c. 2300-1900 BP. These ceramics "are not associated with ceramics of Lapita age nor with pottery of post-1800 BP age" (Clark 1999:188). And third, between c. 1800 and 1000 BP differences between ceramic assemblages develop in a complex fashion that do "not appear to have a geographical basis" (Clark 1999:188).

To illustrate Clark's use and interpretation of MDS data consider Figure 2.3, a plot of the first two principal components of an MDS analysis of nine ceramic assemblages. Each assemblage was described by the presence-absence of 28 observations including decorative, vessel form, and rim form traits (traits listed in Clark 1999:168, Table 20). With MDS, the similarity exhibited by assemblages across these 28 observations, can be decomposed into fewer dimensions (ideally two) and represented graphically.

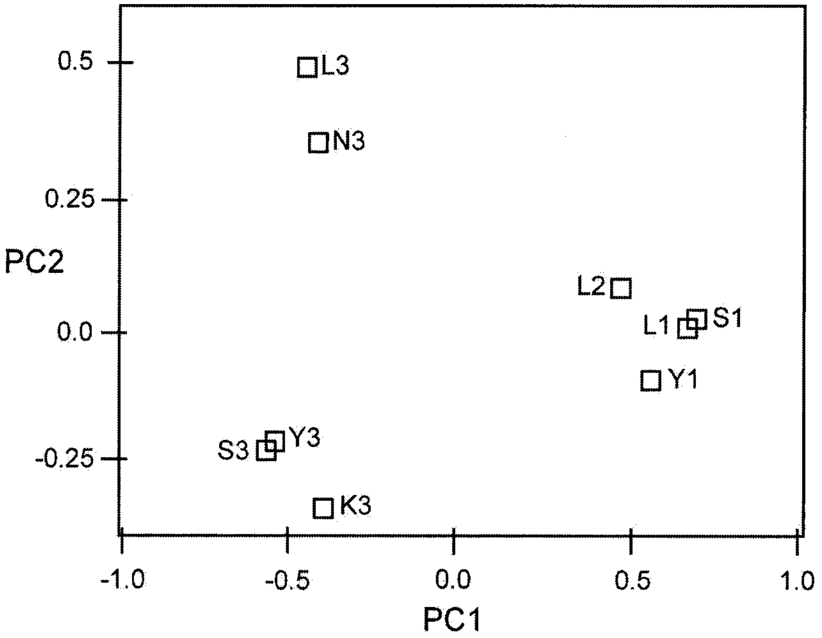

Figure 2.3. MDS plot of analysis 2 from Clark (1999:Figure 32, top). Assemblage names in plot are identified in text. Assemblages are arranged into three groups along principal components (PC) 1 and 2.

The nine assemblages in Figure 2.3 include three early deposits from Sigatoka (S1), Yanuca (Y1), and Lakeba (L1), one immediately post-Lapita deposit (c. 2500-2300

BP) from Lakeba (L2), and four assemblages dating from c. 1800-1000 BP including Lakeba (L3), Yanuca (Y3), Karobo (K3), and Navatu (N3).

The association of the early assemblages (S1, Y1, and L1) with the immediate post-Lapita assemblage (L2) at the positive end of PC 1 (accounting for 64% of the variance) suggest some affinity between the early assemblages and the post-Lapita assemblage. The fact that the post-Lapita assemblage (L2) is not plotted at an intermediate position between the early and late ceramics is interpreted by Clark (1999:170, 188) as evidence of a distinct break in the Fijian ceramic sequence c. 2300-1900 BP beginning with the L2 assemblage. The existence of a dramatic ceramic change at this time is also suggested by Best (1984).

Clark also notes that there is greater variability among the late assemblages than there is among the early assemblages. This is seen by the two separated clusters at the negative end of the PC 1 axis. Moreover, the top cluster contains assemblages from different geographic areas (northern Viti Levu and Lakeba) and for Clark this is evidence that ceramic similarity does not decreases with geographic distance (Clark 1999:170).[10] Clark supports the interpretations of this analysis with several other MDS analyses using different assemblage groupings, frequency data, and one analysis focused on rim sherds as estimators of vessels.

The validity of Clark's conclusions, however, is suspect. The data upon which MDS analyses are performed are a jumble of characteristics whose distributions are likely influenced by different processes. Clark's approach to ceramic grouping mixes variation

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[10] Clark also identifies this variability along PC3 in another MDS plot. PC 3, however, probably only accounts for approximately 5% of the total variance in the MDS data matrix (Clark does not give an exact figure). Therefore, any interpretations about assemblage similarity using PC 3 account for very little variance.

that could be explained by transmission within a population, or convergence in unrelated populations, environmental variability, and other sorting mechanisms. In the end, Clark's inferences made based on his measurements of ceramic similarity (or divergence) admit every kind of causation:

> "ceramics, then, appear to be diverging in a non-predictable fashion, suggesting that potters had greater flexibility in the choice of morphology and surface modification of a vessel. However, the ceramic options, while broad, were constrained by shared stylistic conventions that indicate communication amongst potters and people through the Fiji archipelago from 1800 to 1000 BP" (Clark 1999:189)

Without a theoretical framework to guide his choice of measurements, Clark's inference is understandable: he has no way of deciphering the complex patterns he observes because the measurements reflect a cryptic mix of concepts.

The solution to this confusion is to classify ceramics using observations that are linked to explanatory processes and expectations about how these processes affect the distribution of variability, that is, explanatory theory. To exemplify this form of explanation consider the possibility that we can conceive of decoration as equal-cost alternatives in the overall budget of human cultural expenditure (see Chapter 3). If so, the distribution of these forms will be a product of cultural transmission and the factors that we determine structure cultural transmission such as population size and the spatial structuring of individuals within a population. Figure 2.4 is an MDS plot of the same assemblages depicted in Clark's MDS analysis 2 (Figure 2.3). Here the MDS data matrix is produced only from the presence and absence data of what we can hypothesize are equal-cost decorative alternatives and include kinds of lip termination, paddle-impressing, incising, and dentate stamping among others (tabulated from Clark [1999:168, Table 20]). Observations such as vessel types (e.g., platters, everted bowls), slipping, and others were not included as the distribution of these characteristics may be affected by additional processes along with cultural transmission.

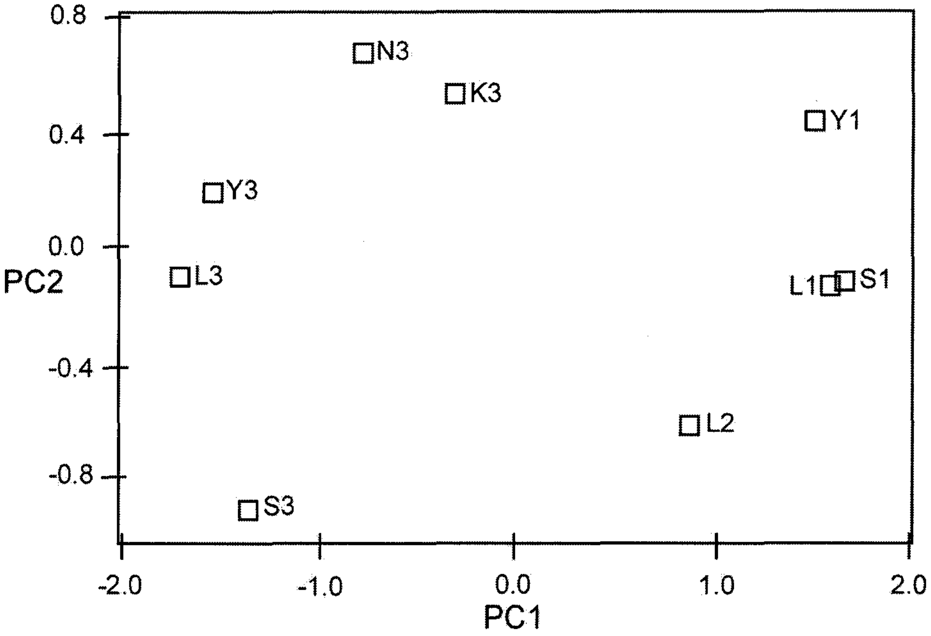

Figure 2.4. MDS plot of decorative data from Clark (1999:168, Table 20). Analysis generated using same parameters as Clark (1999:66). Assemblage names in plot are same as in Figure 2.3. Stress for the MDS matrix is an acceptable 0.045 (Kruskal and Wish 1978).

If Figure 2.4 arranges assemblages based only on variation composed of equal-cost alternatives, this MDS plot is a more easily interpretable and likely more valid representation of similarity predominantly resulting from cultural transmission. Like Clark's MDS plot of the same assemblages (Figure 2.3), this decorative analysis groups the early assemblages (L1, S1, and Y1) far from the late assemblages (L3, Y3, K3, and N3), as we might expect given the likely stochastic nature of much decorative change over time. Here L2, the immediate post-Lapita assemblage, is now in a slightly more intermediate position between the early and late assemblages. Unlike Clark's MDS plot, the late assemblages in the decorative analysis do not display any strong grouping tendencies. This suggests that the decorative divergence of late assemblages may be a function of spatial distance (contra Clark 1999:170).

The MDS analysis of decorative variation does not produce a clear answer due to the lack of a definitive classification for making meaningful measurements and significant problems of post-depositional mixing of ceramic deposits. However, the analysis does shed some light on associations in the later pottery that Clark has found "difficult to track" (Clark 1999:174). For example, Clark's grouping patterns of late assemblages in Figure 2.3 are likely due in part to vessel forms he describes as inverted bowls and platters (see Clark 1999:168, Table 20). The distribution of these vessel forms may be explained by site-specific activities and environmental variation and thus be little influenced by cultural transmission and interaction between the populations occupying different site areas. We may develop a more specific hypothesis regarding the relationships displayed in Figures 2.3 and 2.4: vessels commonly thought of as sea salt evaporative trays (see Birks 1973; Burley 2003) can be classified by particular morphological criteria and possibly by chemical residue and these vessel classes were either independently invented by human groups at different sites, or the idea was quickly transmitted but is not an indicator of continued cultural transmission.

To further investigate patterns of mid-sequence interaction, Clark next turns to provenance analysis of ceramics. With provenance analysis Clark seeks to identify the relative abundance of local and exotic sherds in his assemblages and then use this information to determine whether increased diversity of mid-sequence ceramics a product of changes in the spatial scale of interaction, and whether patterns of ceramic production change over time (Clark 1999:190-191)?

Clark's provenance analyses focused on both tempers and clays. Temper analysis consisted of petrographic identification of sub-samples from Navatu, Ugaga, and Karobo by William Dickinson. Dickinson identified variable numbers of temper groups at each site from these sub-samples. Clark then generated large samples of thin sections from each site and classified them to temper group using the Dickinson identifications as a key. Clay provenance analysis was undertaken only on the Ugaga ceramics and used both electron microprobe and ICP-MS to examine elemental abundances.

Clark identified no unique associations of temper types with either particular forms of decoration or vessel types and in general sherds from all time periods and sites are composed of mostly local tempers. At Ugaga, however, the likely Lapita-age pottery seems to have been tempered predominantly with Quartzose-Feldspathic sands that were not used in later pottery at the site (similar findings at Navatu maybe affected by mixed deposits). The clay analyses also suggest mostly local production of ceramics throughout time. Early assemblages, however, show a more diverse set of clays and a greater abundance of exotic sherds compared to later assemblages, mirroring the findings of other researchers (e.g., Best 1984).

The provenance analyses suggest to Clark (1999:214-215) that pottery production in Fiji has always been a household industry with no centralized production and distribution of vessels. Overtime, however, there is a decrease in the proportion of exotic sherds in assemblages suggesting less long-distance movement of vessels.

2.3.3 Analyzing Clark's Conclusions Regarding Ceramic Change

Clark's research was focused on three issues: the pace of ceramic change in Fiji, the frequency of interaction throughout the archipelago over time, and the nature or type of interaction change over time? With regard to the first issue, Clark marshals evidence from the ceramic deposits dated to c. 2300-1900 BP. Here, like Best's work, Clark (1999:222) has identified "a major ceramic change in the Fiji sequence." Assemblages dated to before this time are quite similar and this similarity is interpreted to result from high rates of interaction within the founding population of Fiji. Around 2300 BP, however, assemblages become rapidly different from the Lapita and Polynesian Plainware ceramics. Additionally, there appears to be increased regional diversity c. 2300 BP in terms of decorative and formal ceramic attributes, at least in a comparison of the Ugaga and Lakeba ceramics (but see Best [2002:26-27]). Clark suggests that the changes from pre-2300 BP to post-2300 BP ceramics are related to large-scale changes in subsistence and settlement. Clark rejects Best's (1984) notion that ceramic changes c. 2300-1900 BP are due to influences from populations beyond Fiji, such as New Caledonia.

Clark's rejection of the migration thesis is based upon the number of similarities between Fijian pottery and pottery from New Caledonia (Clark 1999:222). In particular, Clark argues that parallel-ribbed paddle impressing is the only high-frequency attribute shared between Fijian and New Caledonian assemblages. However, the number of shared attributes is not necessarily as important as the processes that create the similarity. To return to a previous argument, phenetic similarity (that based upon a large number of shared unit characters), does not necessarily equal relatedness.

Clark's second issue concerns the frequency of interaction. His ceramic compositional work, along with Best's (1984) suggest that the frequency of contact between individuals in communities declined with the demise of Lapita assemblages. But Clark argues that interaction may have increased again in the period c. 1800-1000 BP. He supports this statement by noting that "there is little evidence for regional or sub-regional ceramic groupings that would indicate social isolation" (Clark 1999:227). In contrast, the analysis here of only decorative variation presented in Figure 2.4 suggests that Clark has confounded similarity that may be explained as result of cultural transmission between individuals and similarity that is explained as a product of selection in similar environments.

In reference to the third issue, Clark suggests that interaction during the mid-sequence changed in complex ways. According to Clark's analyses, different Lapita-age assemblages are quite similar, and post-1800 BP period assemblages are also similar across multiple dimensions of variation. For the Lapita assemblages, Clark suggests that similarities in Lapita decoration are due to interaction between communities and the symbolic or ritualized communication function of Lapita decoration (after Kirch 1997). Therefore Lapita interaction-related similarity is explained by information-exchange theory (Clark 1999:228) as outlined by Wobst (1977). In the immediate post-Lapita period (c. 2500-2300 BP), however, the morphological similarity of vessels has increased. Clark (1999:228) suggests that this vessel form similarity is "compatible with social-interaction theory which posits that stylistic similarity results from the intensity of interaction between communities."

Vessel form similarities may not, however, reflect the frequency of cultural transmission between communities, but rather we may see similarities in unrelated populations as a result of functional similarity (i.e., convergence or parallelism). The similar vessel forms of the immediate post-Lapita assemblages are widely interpreted as cooking pots, so a possible explanation is that populations may converge on similar utilitarian forms without these similarities being a fundamental result of population interaction. This is especially true if populations across Fiji were undergoing similar subsistence and settlement shifts.

Clark also suggests that the nature of interaction changed after c. 1800 BP. Clark's provenance analyses suggest that the amount of locally-produced pottery does not change substantially from Lapita throughout the mid-sequence, although there are more exotic sherds in the Lapita deposits. The exotic sherds in Lapita deposits, Clark argues, are present because Lapita interaction involved the ritual trading of pots. This ritual trading also generated similarity in other ceramic dimensions during the Lapita era. In contrast, by c. 1800 BP, interaction was no longer focused on "ceramic acquisition" (hence very few exotic sherds in assemblages), but on "social and economic interaction" (Clark 1999:234) that resulted in "formative interaction networks that spanned the archipelago and underpinned the development of an integrated culture within the Fiji Islands" (Clark 1999:249).

This conclusion does not logically follow from Clark's observed variation, for why couldn't similarities in the Lapita-era be described in exactly the same way (i.e., formative interaction networks). Regardless, Clark's evidence of interaction in the c.

1800-1000 BP period conflates a variety of processes that we may use to explain similarity, including those that likely do not indicate population contact.

2.3.4 Relevance of the Mid-Sequence Research to Studies of Population Diversity

In summary, Clark's research has, like Best's, identified broad patterns of ceramic similarity in Fiji, but because these patterns are identified by grouping methods it is difficult to determine what similarities mean. Ceramic similarity is greatest during the Lapita-era in Fiji and included similarities in decoration, vessel forms, and in the archipelago-wide loss of vessel form diversity by the end of the Lapita period. These similarities may be explained by cultural transmission within a population as well as processes of selection operating to produce similarities in separate transmission lineages. Others (e.g., Hunt 1989; Kirch 1991) have suggested that the similarity of Lapita assemblages in Fiji may be a result of exchange systems that persisted from earlier systems in Near Oceania that were in large part adaptive exchange networks for small and isolated populations.

Post-Lapita, Clark identifies an abrupt ceramic change from the Polynesian Plainware ceramics (see Hunt [1980], Spriggs [1984; 2003] for slightly different interpretations). Around 2300 BP, changes occur in Fijian ceramic assemblages in terms of decoration, vessel forms, and temper. Clark links all his observed variation in the c.2300-1900 BP ceramics to settlement and subsistence shifts. But as of now there is no plausible argument linking changes in particular dimensions of ceramic variation and the proposed settlement and subsistence changes(see Clark 1999:224). Thus, the changes in ceramics c. 2300-1900 BP remain unexplained in terms of cultural transmission and processes of lineage diversification.

It is in the period c. 1800-1000 BP that Clark sees potentially contradictory patterns of similarity. Clark suggests that regional isolation, and cultural diversification, does not increase during this time period, but Clark's analyses likely conflate homologous and analogous similarity. The question of deepening community isolation, and cultural diversification remains open in Fiji.

2.4 WHAT IS NEEDED TO GENERATE LINEAGE-BASED EXPLANATIONS OF FIJIAN CULTURAL DIVERSITY?

There is one vital component missing in many studies that attempt to explain ceramic change in Fiji. This component is theory that links explanatory processes to empirically observable phenomena. Without a link between explanatory processes and archaeological classification the meaning of classes and measurement units is unknown. Best (1984) and Clark (1999) attempt to discover meaning from ad hoc measures of similarity among various ceramic groups and infer interaction or contact among human groups. Similarities, however, can arise in any set of observations in ways that have no necessary links to transmission.

Our interest in Fijian ceramics is predominantly focused on linking change in relationships between human populations and between populations and the environment. This avenue of research requires us to build an explanatory framework that considers cultural transmission, the sorting of ceramic variation, and measurement of environmental and demographic variation. In short, our interest in Fijian ceramics can be profitably addressed by employing theory that allows the construction of meaningful units that can be used to measure variation and change in material culture lineages. The choice of explanatory framework is based on two criteria. First, the framework must generate a series of expectations that permit empirical testability of the conclusions produced. Testability is, in part, a function of the links between the observational classes used to describe archaeological phenomena and the explanatory processes proposed by the theory. Testability means the ability to definitively evaluate different possible answers. If the robust units are properly built, testability simply means ensuring that observations are correctly identified as members of appropriate classes. In this way testing is a matter of technique rather than methodology. Second, the choice of explanatory theory is based on the dynamic sufficiency of the theoretical framework. Dynamic sufficiency can by evaluated by asking whether the processes stipulated by theory are logically interrelated and can they possibly account for observable variation? On the basis of these two criteria, an explanatory framework incorporating cultural transmission, selection and other sorting mechanisms, and innovation is thus far the most viable means for producing empirically based knowledge of cultural change in Fiji (for example of research in Fiji see Cochrane [2002a]).

Based on the previous review of archaeological research in Fiji and the surrounding region, several fundamental issues concerning the evolution of cultural diversity remain unsatisfactorily addressed. We need a better documentation of the history of diversification and reticulation of human groups in Fiji and nearby archipelagos. Second, we need to know if a founding group in Fiji continuously diversified into regionally separated groups over time, or if the tempo and mode of diversification varied at different times and places? Third, to develop empirically defensible answers to these questions we must begin with a foundation for determining the dimensions of ceramic similarity that track cultural transmission and can be used to define material culture lineages and other aspects of population histories, such as the potentially nested nature of population relatedness (see Lipo, et al. 1997). Fourth, we must determine how to organize and analyze this similarity so that the transmission histories of populations are revealed. These are the foundational issues addressed in the following research.

2.5 CHAPTER SUMMARY

This chapter presents an overview of Fiji's biological, cultural, and linguistic diversity. Fiji has a complicated history as the islands seem to be "a sort of 'between place'—a foyer of exchange and interaction" (Kirch 2000:156). This complicated history has been the focus of much ceramic research. While not explicitly stated by previous scholars in the region, the reasons postulated for ceramic change can often be linked to those processes that we can use to explain human diversity: cultural transmission, innovation, selection and other sorting processes, and environmental variability.

The review of Best (2002; 1984) and Clark (1999) demonstrates that these authors have identified trends in the Fijian ceramic record, but this identification is the product of grouping procedures so that the units identifying these trends have no clear meaning. Explanations of variation across units must be necessarily ad hoc. Moreover, the units used by Best and Clark, ceramic periods and ceramic categories mix similarities that could likely be explained by several different processes and not always including interaction between individuals.

Therefore the most important addition to the study of human diversity in Fiji is theory that links explanatory processes with observational units. This explanatory theory should incorporate those processes responsible for observed human diversity and produce empirically testable conclusions. The next chapter is a detailed presentation of the theoretical framework for this research and a necessary foundation for the data presented in Chapters 5 and 6.

CHAPTER 3. A FRAMEWORK TO DEFINE AND EXPLAIN CULTURAL LINEAGES

> About thirty years ago there was much talk that geologists ought only to observes and not theorize; and I well remember some one saying that at this rate a man might as well go into a gravel-pit and count the pebbles and describe the colours. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service?
>
> Charles Darwin (September 18, 1861)
>
> Letter to H. Fawcet written aboard *HMS Beagle*

Theory generates a cohesive structure necessary to order reality; it designates explanatory processes and the means by which we make meaning out of observations of phenomena (Dunnell 1982; Lewontin 1974:6-12; Sagan 1997; Sellars 1962; Willer and Willer 1974; Wilson 1998:52-53). Darwin, in the letter quoted above, notes that it is pointless from an explanatory standpoint to make observations without a framework that gives meaning to those observations and provides explanatory processes. In fact, it is impossible, as all observation is theory laden. In some instances, however, that theory may be cryptic and implicit. Moreover, meaningful observation—that is, observations that we can expect to explain—must be explicitly made in a way that links measurements with those explanatory processes. In this sense, all good observers must also be good theorists.

Although all observation involves some kind of theory-function—whether stated or not—not all theories are equally good at explaining the empirical world. Common sense, for example, provides meaning through cryptic inherited structures that cannot easily be explicated or identified. Religion provides an alternative means of generating explanations albeit one that provides internally consistent ideational rationalization, but no means of falsification. In general, scientifically useful theories are those which are explicit, provide a comprehensive dynamic structure for explaining classes of phenomena and have means of evaluating the veracity of claims. This means that theories may be judged inadequate if we are unable to empirically evaluate the hypotheses generated from them. This method of evaluation is due specifically to the link between archaeological theory and how we observe empirical phenomena, a point forcefully made by the New Archaeologists, largely by Binford (1962; 1964; 1965; see also Dunnell 1986; Hill 1972; Hunt, et al. 2001; Ramenofsky and Steffen 1997). It is also a key component of any scientific endeavor (Dunnell 1982) As we have seen in Chapter 2, this link has been broken in much of Fijian archaeology. Here I outline a theoretical framework that I use to explain and observe the archaeological record of prehistoric cultural change in Fiji.

3.1 EXPLANATORY CONCEPTS

In Chapter One we briefly examined three principles used to explain human cultural diversity. First, "culture" is a conceptual feature of an inheritance system whereby information is transferred among individuals. This inheritance system has a significant influence on the empirical distribution of cultural variants, if we recognize that "cultural variants" are those indicative of shared ideas. In addition, if we measure phenomena in a way that reflect shared ideas, that is in terms of homologous similarity, we will be able to map this inheritance. Second, cultural diversity is an observation made by measuring populations. A population is an ideational class that can be profitably defined as a lineage of cultural transmission. Thus, observations regarding the material culture aspect of cultural diversity can be made by measuring the number of transmission lineages defined for a particular portion of the archaeological record, and by noting temporal, spatial, and other characteristics of the empirical phenomena identified by a lineage. Finally, measurements of material culture variants can be explained through additional processes beyond transmission. Sorting processes, such as natural selection and drift must be examined, along with innovation and population structure.

These principles form the backbone of a useful explanatory framework. Consequently, we must be able to articulate them with the empirical record through ideational classes to facilitate observation and through construction of analytical methods designed to evaluate hypotheses generated to account for the distribution of classes. First we will look at the structure of theoretically driven observation, or classification, that is linked to our explanatory framework.

3.1.1 Classification

The distinction between ideational and empirical units is of primary importance in archaeological classification (Dunnell 1971; see also Osgood 1951; Philips, et al. 1951:66), although this has been little recognized over the years(e.g., Gilboa, et al. 2004; Spaulding 1953b; Whallon 1972). Ideational units are measuring scales or theoretical units without objective existence (e.g., centimeters). Empirical units are instances of the physical world that have been identified as members of an ideational unit.. The analysis of ceramics in this research makes use of both ideational units, classes, and empirical units, groups of phenomena. The distinction between classes (e.g., a rim class) and groups (e.g., the sherds placed in a particular class) is important as each kind of unit is evaluated differently (see Rouse [1939] for an early exposition). Classes are first evaluated in the realm of ideas. Class definitions may be logically evaluated in terms of the processes stipulated by theory to act in the natural world. The utility of a class, its meaning, results from the articulation of the class definition and the explanatory processes set out in theory. Groups, or empirical units, are identified and can only be evaluated in terms of whether or not they were placed in the correct ideational class. Our empirical units are phenomenological and thus have distributions in the world, boundaries and spatial locations. The identification of empirical units as members of classes and measurement of distributions of instances of classes in the phenomenological world is a component of explanation. To explain observations, we generally try to match our theoretical expectations with the distributions of real-world phenomena measured with meaningful classes to some theoretically specified confidence interval.

A fundamental problem arises when theoretical units and empirical units are confounded. If a set of empirical entities is brought together as a group without using an explicitly defined class, the meaning of that group, the part those things play in any explanation of distributions, is unknown and cryptic. Unfortunately, this problem has become a basic element of archaeological research in Fiji where ceramic groups are formed without defined and purposeful theoretical classes, but by an implicit set of observations often handed down from one researcher to the next (e.g., Best 1984; Clark 1999; Crosby 1988; Frost 1974; Hunt 1980). In Fiji, it has come to the point where archaeologists may only know generally what their analyses mean because they have no way to evaluate why their measurements of phenomena are grouped together in the way that they are (e.g., Clark 1999:229).

Resolving this problem requires careful construction of theoretical classes. To generate a meaningful classification it must be tailored to a problem (Brew 1946; Dunnell 1971; Vierra 1982). Class construction is an iterative processes whereby we define classes based on criteria that are related to a particular problem and if our classes do not apportion phenomena in a way that makes sense to our explanatory theory we may retool the classes (Lewontin 1974:6-12). To begin class construction we are best served by proceeding systematically, so that potentially confounding errors in our classes can be more easily identified and mitigated.

One of the most powerful means for constructing readily comparable classes is through the use of a paradigmatic classification. Paradigmatic classes can be conceived of as definitions built from the mutually exclusive modes of dimensions. Paradigmatic classes are defined by modes and (Dunnell 1971:155-156; Rouse 1939). modes are attribute classes that may be observed on an artifact. Modes are ideational classes (like the color blue), not empirical observations. All of the modes defining a class must be observed on the object for that object to be identified as a member of the class. For the purposes of the classification the meaning of an object identified as a member of a class comes from the classification and nowhere else. Items identified with a class are stipulated to be redundant for the purpose of classification. Of course, any object has an infinite number of modes that can be used to describe it. However, these modes have no bearing on its placement in the class as they are not part of the class definitions.

For paradigmatic classes modes are mutually exclusive attribute classes arranged in dimensions. A dimension, for example, may be "color" of which there could be the modes red, blue, and yellow. A classification of hair may be built from the dimension color with the attributes classes red and not-red and the dimension texture with the attribute classes curly and not curly to produce four mutually exclusive paradigmatic classes that may be used to group all hair observations.

Dimensions are ideational units in classifications that define classes along kinds of variation (e.g., color, texture). Dimensions identify realms of potential variation that will be measured in the empirical world. This makes dimensions critical to our discussion since the measurement of variation is a fundamental requirement of a theoretical system that employs transmission, selection, and innovation to account for change. Dimensions order the variation between classes in a classification in a consistent way. Thus we can unambiguously relate the empirical distributions of these classes to particular kinds of variation that is explicable via our explanatory processes. For example, in investigating ceramic vessel tempers we may be interested in the possible effects of selection on temper density. To construct a sound argument about the effects of selection on temper density we should consider the dimension as a whole (i.e., temper density) with the alternate modes we devise (see Cochrane 2001). If temper density appears unimportant we can remove this dimension from class definitions and, if needed, add a different dimension and re-evaluate class distributions.

3.1.2 Cultural Transmission

The effects of cultural transmission as measured by ceramic classes define the archaeological populations examined in this research. Cultural transmission, or simply transmission, is the passage of information from one individual to another. Each passage of information constitutes a single transmission generation. Transmission implies contact between individuals and could be of a direct nature, such as a mother teaching her daughter to make pottery, or indirect, by an individual creating a spouted vessel after observing one at a market. As transmission implies contact, many archaeologists would likely place transmission as related to, but more exclusive than, the concept interaction. The concept interaction has been employed in many ways by archaeologists (e.g., Caldwell 1964; see Hegmon [1992] and Plog [1983]), but all uses of the concept contain the central idea of individuals acting upon each other, whether this is through communication of ideas, movement of materials, exchange of mates, warfare, power relationships, or some other action.

To summarize, the process of transmission is a form of interaction, the transference of information between individuals. Here, however, the concept transmission is not something to be explained. Rather, it is a theoretical concept in the sense outlined at the beginning of this chapter that can be used to generate meaningful observations that are subject to explanations. While we might want to explain why there is variation in the intensity of transmission over space or time among different populations, the question "why transmission?" does not make sense in this framework.

This idea of transmission as an ideational concept, as opposed to something that is explained, is summarized in Lyman and O'Brien's (1998:624,628) treatment of immanent and configurational processes and properties (first discussed by Simpson 1963, 1970). Cultural transmission is immanent in the material world. It is an ideational process we assume to occur, thus we can use it to explain the configuration of the world at particular times and places. This is the same as our notions of "gravity," an ideational concept we use to account for observations in the world.

Configurational properties or processes, on the other hand, are the condition of the world at any given time. In short, immanent properties or processes—like cultural transmission—are used to explain configurational properties—like a configuration of interaction across populations defined by some material culture difference.

Although the concept of cultural transmission in archaeology has been implicit since the late 19th century (Lyman and O'Brien 2003), detailed investigation of cultural transmission, in both immanent and configurational domains, has begun only in the last several decades. Cultural transmission as a primary component of explanatory system has been developed by anthropologists and archaeologist (e.g., Bentley and Shennan 2003; Boyd and Richerson 1985; Dunnell 1978; Durham 1992; Jordan and Shennan 2003; Kohler, et al. 2004; Lipo 2001b; Lipo, et al. 1997; MacDonald 1998; Richerson and Boyd 1992; Shennan 1989; Teltser 1995), but perhaps more work has been produced by those trained in biology and non-human populations (the biological literature on cultural transmission is vast but see Cavalli-Sforza and Feldman [1981], Dawkins [1982], Pocklington and Best [1997], and Sober [1992]; for very accessible case studies see Grant and Grant [1996], Mesoudi, et al. [2004], Payne [1996], and numerous articles in *Theoretical Population Biology*, *Journal of Theoretical Biology*, *Animal Behaviour*, *Evolution and Human Behavior*, and *Trends in Ecology and Evolution*). Within this large body of transmission research one arena of work will be discussed here: research on the unit of transmission.

3.1.2.1 The Units of Transmission

Up to this point, the entity that is transmitted between individuals has been only referred to generally as a class, in keeping with the discussion of ideational and empirical categories mentioned above, or as traits and variants as these are the terms used in much of the cultural transmission literature. Most discussions of culture as a transmission system refer to the entities transmitted as traits, sometimes empirical and sometimes ideational (Lyman and O'Brien 2003). In the last 30 years, biologists and anthropologists have given increasing attention to the identification, scale, and other properties of cultural traits (e.g., Blackmore 1999; Boone and Smith 1998; Cullen 1996; Dawkins 1982Williams, 2002 #977; Dunnell 1995; Hull 1988b; Lyman and O'Brien 1998; Lyman and O'Brien 2003; Lynch 1996; Pocklington and Best 1997; Shennan 2003). Cultural traits are the units transferred between individuals in transmission and thus are mainly ideas or ideational units. In this chapter they will be referred to as cultural trait classes, to emphasize their ideational character.

When applied to the empirical world, cultural trait classes generate variation explicable by processes such as transmission, selection, and innovation. To be explicable by these processes, cultural trait classes must exhibit certain properties (Shennan 2003:46). First, cultural trait classes must exhibit fidelity during transmission. More specifically, the empirical frequencies generated by cultural trait classes, must change slowly enough so that frequency change is detectable. If entirely new cultural trait classes appear in each cultural generation, it is difficult to invoke any of our explanatory mechanisms. Second, cultural trait classes must be characterized by fecundity. That is, cultural trait classes must be reproduced, so that multiple copies are made during each cultural generation. If the cultural trait classes we construct are too complex (i.e., too many dimensions) we may not be arranging phenomena by classes whose frequencies are affected by transmission. Third, cultural trait classes must be constructed so that they measure variability that is characteristically long-lived. Cultural trait classes should be constructed to measure variability that is persistent enough through time and across space that sample sizes are robust and the likelihood of chance similarity is minimized.

3.1.3 Natural Selection

For natural selection to be useful as an explanation of variation measured by cultural trait classes, these classes must measure phenomena along dimensions where some modes may manifest selective advantage over other modes. Possible selective advantage connotes differing fitnesses. Archaeologists in recent years have begun to measure selective advantage in the cultural portion of the human phenotype through the differing performance characteristics of artifact classes (e.g., Bronitsky 1986; Feathers 1990; O'Brien, et al. 1994; Pierce 1998; Schiffer 1992; Schiffer and Skibo 1987; Schiffer, et al. 1994). Measured performance differences among modes may track the variation that explains the differential reproduction of cultural trait classes we associate with selection (Neff 2001).

When particular cultural trait classes define lineages and the frequency of these classes is influenced by the relative selective differences measured on their empirical members, we can explain the empirical members of these classes as adaptations (O'Brien and Holland 1990; 1992). Such adaptive similarity can be homologous similarity, meaning they denote relatedness among individuals within a transmission system. Adaptive similarities may also arise in separate lineages through convergence or parallelism. These similarities are considered analogous and do not represent relatedness. Because of the confounding effects of analogous similarity on studies of relatedness we must employ methods that separate homologous from analogous similarity.

If artifacts can be measured along dimensions that indicate performance differences and possible selective advantage, the we might expect that artifacts can also be measured along dimensions that show no performance differences and no relative selective advantage. When the different modes of a dimension used to define classes confer no selective advantage, these cultural trait classes are considered neutral with respect to selection and their distribution in time and space will be structured solely by the properties of the transmission system and population structure (Figure 3.1) (Dunnell 1978; Lipo and Madsen 2001; Lipo, et al. 1997; Neiman 1995; Shennan and Wilkinson 2001). The empirical distributions of so-called neutral classes in transmission systems characterized by unbiased transmission will be stochastic in nature. In other words, class frequencies in these particular instances will fluctuate depending on prior frequencies and the sampling vagaries inherent in transmission to produce unimodal distributions (Neiman 1995). It is the unimodal distribution of particular classes that culture historians used to array non-superimposed artifact assemblages in temporal sequences (Dunnell 1978; Lyman, et al. 1997).

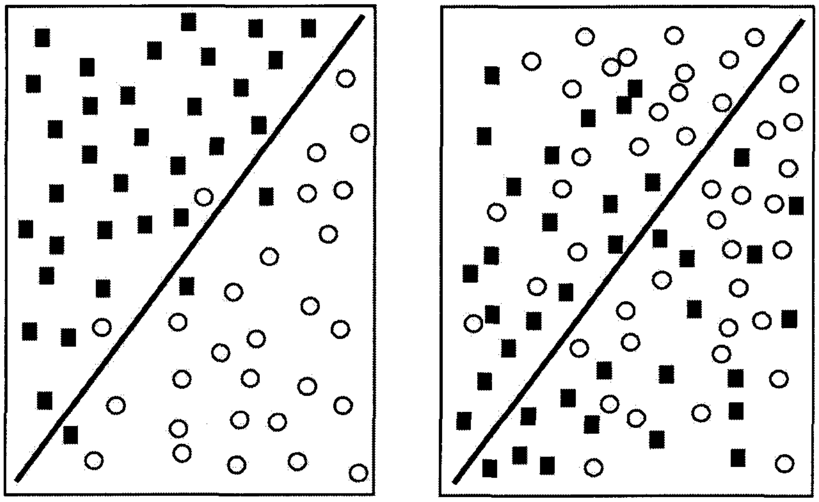

Figure 3.1. In the right hand panel the distribution of two neutral classes (■ and ○) in a single population is random with respect to an environmental gradient (diagonal line). In the left panel the distribution of the two classes is strongly patterned by the environmental gradient suggesting selective differences. If traits in the left panel are used to determine transmission lineages we may incorrectly define two distinct populations (after Lipo, et al. 1997:Figure 5).

Like the distribution of non-neutral classes that define homologous similarity amongst artifacts, the empirical distribution of neutral cultural trait classes can therefore be used to identify the spatial and temporal boundaries of transmission systems. Boundaries are defined by transmission frequencies and are not necessarily categorical demarcations, but rather reflect the scale of analysis and the artifacts examined. It is this possibility of defining transmission systems with neutral classes that has revived the use of seriation in the archaeological study of cultural lineages (Lipo 2001b; O'Brien and Lyman 2000a; Shennan 2003).

3.1.4 Other Sorting Mechanisms

Besides selection, at least two other sorting mechanisms may be identified as the causes of cultural trait class frequencies: hierarchical sorting and hitchhiking.

Hierarchical sorting is the process whereby selection at one scale affects the distribution of nested classes at a smaller scale (Hurt, et al. 2001; O'Brien and Lyman 2000a:382-383; Vrba and Gould 1986). Selection *for* a particular artifact class will necessarily generate selection *of* attribute classes on those artifacts as attribute classes are at a smaller scale than artifact classes. Note, however, that the reverse is not true. Selection for cultural trait classes at a particular scale does not necessarily imply selection of classes at a higher scale.

Hitchhiking occurs when two or more traits are linked so that selection for one of the traits includes selection of the other (Sober 1984:97-102). The scale of the traits does not matter. The distribution of clay raw materials and color of earthenware pottery can serve as an example of hitchhiking. There may be selection *for* a particular raw material source based on the physical characteristics that source imparts to the vessel. The particular clay source may produce vessels of a particular color and thus selection *of* color is a result of hitchhiking. Hurt and colleagues (2001) suggest the difference between selection of and selection for may sometimes be understood in terms of proximate and ultimate causes (see Dunnell 1992; Winterhalder and Smith 1992). Where selection for a particular cultural trait class may be attributable to ultimate, that is evolutionary, cause, while selection of a linked cultural trait class may occur for a variety of proximate causes, and these may change over time or be different across human groups.

The presence of sorting mechanisms is not detrimental to our identification of homologous similarity. Once homologous similarity is identified across assemblages with a particular set of paradigmatic classes, these classes can be systematically changed in level to determine if hierarchical sorting has occurred, that is selection may be occurring at different scales. At some scales this will likely be the case much of the time. One can imagine, for example, that the presence or absence of ceramic vessels in a population will almost always be explained as a result of selection, but that diversity in vessel forms, decorations, and other particulars of manufacture may or may not be explained by selection. Also, if we are confounded in our identification of homologous similarity at a particular scale, we may find that homologous similarity may be identified at a smaller scale by making our paradigmatic classes more precise (see Cochrane [2001] for an example).

Hitchhiking may be identified by examining trait correlations, regardless of scale. Like hierarchical sorting, hitchhiking should not be detrimental to the identification of homologous similarity. Hitchhiking among cultural trait classes may be linked to particular environments and available cultural trait class variation and therefore helpful in delimiting lineage boundaries.

3.1.5 Innovation

If the transference of information between individuals occurred with absolute fidelity cultural variation would be extremely limited. Several processes, however, ensure that in populations of sufficient size, variation will continuously be added to the transmission system. The processes of transmission error and innovation create novel cultural traits.

Novelties are easy to conceive in terms of the definitions of particular cultural trait classes. For example a classification describing a diachronic set of assemblages may include paste classes defined by the dimension clay source with the modes northern clay and southern clay, the dimension temper type with the modes terrigenous and calcareous, and the dimension temper volume with the dimensions greater than 30% and less than 30%. While eight paste classes (i.e., cultural trait classes) are included in this classification, perhaps only two, for example northern clay-terrigenous temper-less than 30% and southern clay-calcareous temper-less than 30% have members over some time period. The appearance of sherds grouped by the class southern clay-terrigenous temper-less than 30% is a novelty or a new cultural trait class if it appears in this sequence.

Novel traits can arise through unintended errors in transmission, where, for example, southern and northern clays are accidentally switched. These changes could be intentional and thus an innovation in the intentional sense, but it is impossible to unambiguously identify intention in the archaeological record (cf., Fitzhugh 2001; Lyman and O'Brien 2000; Schiffer 1996). Novel traits can also be introduced into a transmission system through contact with another transmission system and the introduction of new cultural traits. This, of course, is diffusion and migration, as understood by culture historians (e.g., Meggers 1955:117-118).

Without the generation of novel cultural traits, variation in cultural trait class frequencies will eventually be eroded so that one class dominates a population. When this occurs with a collection of cultural trait classes that measure selectively neutral homologous variation, the phenomenon is labeled drift. The operation of drift is simple. In a finite population of cultural transmitters, the frequency of different selectively neutral cultural trait classes in a transmission generation is a function of population characteristics and the frequencies of classes in the prior generation. In each transmission generation some classes will be transmitted more often than others as a result of chance (akin to sampling error). Because the frequencies of classes in one generation are a product of frequencies in the prior generation, over successive generations one or a few classes will dominate the population. The domination of one or a few classes is mitigated if new cultural trait classes are constantly introduced into the transmission system. Neiman (1995) and others (e.g., Bentley and Shennan 2003; Lipo, et al. 1997) have simulated the cultural transmission of selectively neutral classes and demonstrated that drift will always occur in finite populations where the generation of novel traits is limited.

3.2 DEFINING MATERIAL CULTURE LINEAGES

A primary goal of this research is the definition of material culture lineages, or sequences of entities related through a single line of ancestry. To do this, we must construct a series of classes that arrange the infinite kinds of artifact similarity to identify a set of artifacts whose similarity is explained by cultural transmission within a population. Particular empirical distributions of selectively neutral classes map patterns of cultural transmission after the effect of other processes have been determined and controlled (e.g., archaeological sampling, sample sizes). When homologous similarity is identified with selectively neutral cultural trait classes this is called stylistic similarity in the evolutionary archaeology literature (Cochrane 2001; Dunnell 1978; Lipo and Madsen 2001; Neiman 1995; Shennan and Wilkinson 2001).

Homologous similarity may also be a product of shared non-neutral or adaptive classes. In evolutionary archaeology, classes that measure adaptive or non-neutral variation are called functional classes (Dunnell 1978) and generally functional classes are defined by modes that demonstrate some interaction with the environment (e.g., wear classes on tools, see Meltzer 1981). The distribution of functional classes may also be explained by transmission and when this is the case functional similarity is homologous similarity.

The first step in defining material culture lineages is to construct classifications that arrange variation into cultural trait classes that exhibit the characteristics of fidelity, fecundity, and longevity. Classification is perhaps the most important aspect of tracking historical relatedness. Constructing useful classifications involves a process of trial and error where dimensions and modes are added, removed, and modified as the empirical distributions of resultant classes are examined (see Chapter 5). The second step in defining material culture lineages is to demonstrate that our hypothesized cultural trait classes track homologous similarity. This second step may be accomplished by two methods, seriation (e.g., Lipo, et al. 1997), and comparison of empirical distributions with population biology models (e.g., Neiman 1995). This is done by comparing the distribution of the members of putative homologous classes with the expectations of the models to determine whether the conditions of the model are met. Population biology models are not used in this dissertation as small sample sizes preclude valid measurements. Finally, classes that track homologous similarity need to be arranged in a series of historical relationships demonstrating hypothesized ancestors, descendents, and sister-groups among archaeological materials. Cladistics is the primary method used for this task.

3.2.1 Using Seriation to Measure Homologous Similarity

The term “seriation” is applied by archaeologists to several different methods of ordering archaeological materials (O'Brien and Lyman 2000b). Here, seriation is used in a restricted sense to mean the method of ordering archaeological materials only by classes that define the characteristic of the materials. External relationships such as superposition or bonding and abutting patterns are not formal ordering criteria. As classes are the primary tool for ordering empirical groups with seriation, the classes should be theoretically informed; dimensions and modes should track attributes whose distributions are primarily influenced by cultural transmission.

Other methods often called seriation have been used in Fiji and elsewhere. One method, percentage stratigraphy (Lyman, et al. 1998) involves charting the relative frequencies of groups in a stratigraphic sequence (e.g., Best 1984:Figs. 3.54, 3.55, 4.2). With another method, interdigitation (Lyman, et al. 1998), the relative frequencies of artifact groups from surface assemblages are analytically placed within stratigraphic sequences so the relative frequencies of groups follows the popularity principle and all assemblages can be given relative dates. These methods are ostensibly like seriation as it is described here in that they attempt to track change over time. These methods, however, do not usually employ classes purposely built to track homologous similarity. Indeed in Fiji percentage stratigraphy has been conducted using the empirically-based observational units discussed in Chapter 2. Thus when these groups have been used to track frequency changes across a stratigraphic sequence, we do not necessarily know what the frequency change means in terms of cultural transmission within a lineage.

An important difference between seriation as it is used here and other apparently similar methods is summed up in the difference between heritable and historical continuity (O'Brien and Lyman 2000a:274). Historical continuity refers to any chronological sequence of forms such as displayed in a percentage stratigraphy diagram where one form follows another in a chronological sequence. Historical continuity among forms does not necessarily indicate a transmission relationship. Heritable continuity, on the other hand, refers to continuity of forms that is a direct result of cultural transmission. The seriation method as described here tracks heritable continuity by using theoretically constructed classes to arrange empirical groups. The order of these groups must match a set of expectations for phenomena that share heritable similarities.

These expectations include the distribution and frequency laws outlined by Dunnell (1970). The distribution law is applied to occurrence seriations and states that the distributions of modes' occurrences must be continuous. The frequency law is applied to frequency seriations and states that class frequencies across assemblages must conform to lenticular distributions or some portion of a lenticular distribution within the limits of sampling error. Dunnell (1978) first recognized that lenticular or battleship-shaped distributions of frequency seriations were similar to randomly generated biological clade distributions. Random clade distributions are a product of biological trait transmission and stochastic processes and Dunnell argued that, in a similar fashion, seriation arrays track cultural transmission of heritable, homologous similarity (Teltser 1995). More recently, Neiman (1995) and Lipo et al. (1997) have modeled processes of drift and innovation in finite populations of transmitters and receivers. Their models demonstrate how drift and innovation act upon selectively neutral and culturally transmitted variation to create the lenticular distributions of frequency seriations.

Successful frequency seriations are those that arrange assemblages so that the frequencies of classes across assemblages are lenticular or some portion of a lenticular curve. For occurrence seriations, successful orderings are those where class distributions are continuous and overlapping (Dunnell 1970, 1981; Lipo 2001b; O'Brien and Lyman 2000b). If these conditions are met and chance orderings can be discounted, a successful seriation order indicates that the classes used to describe assemblages or objects in the order largely track selectively neutral variation. Thus by creating successful seriations we are creating those classes that measure both heritable and homologous similarity within a particular set of phenomena.

In this dissertation both occurrence and frequency seriations are used to assess the ability of classes to track homologous similarity. Successful seriations are created by arranging classes so that empirical instances are distributed in accordance with the frequency or occurrence laws (see O'Brien and Lyman 2000b for particulars of technique). Occurrence seriations of cultural trait classes are constructed by arranging classes so that the modes defining each class are continuously distributed across the arrangement. Frequency seriations of ceramic assemblages are created by translating the abundance of each class in an assemblage into relative frequencies and then arranging assemblages so that the frequency of each class displays a lenticular distribution across assemblages.

3.2.2 Cladistics: Method for Constructing Transmission Lineages

Cladistics is a method for arranging classes where class similarities are homologous or a result of inheritance. The ultimate product of cladistic analysis is a phylogenetic tree. Phylogenetic trees arranges sets of classes, or taxa in cladistic terminology, each related through a hypothetical common ancestor. Phylogenetic trees are hierarchical so that at each level in the hierarchy more taxa are included in an ancestor-descendent relationship. There is a single fundamental difference between cladistics and other similarity measures that arrange taxa into hierarchical sets. In cladistics, all similarities, including all homologous similarities, are not equally used to characterize relationships between taxa. Taxa relationships are determined through the distribution of ancestral and derived character states across taxa. Character states, a term used in cladistics, are equivalent to modes of class definitions. Both ancestral and derived character states represent homologies, but derived character states represent those character states that have changed or evolved from earlier, ancestral, character states. Thus taxa relationships that are based on derived character states will more accurately depict the recency of common origins across a set of phenomena.

Cladistic method can be used to arrange any set of phenomena that are related through transmission. The method was initially developed by Hennig (1950; 1966) as a response to perceived ambiguities in biological evolutionary classification and has since enjoyed considerable use. The application of cladistics to cultural phenomena has increased in recent years (e.g., Collard and Shennan 2000; Gray and Jordan 2000; Jordan and Shennan 2003; Lipo, et al. 2005; Mace and Pagel 1994; O'Brien, et al. 2001; Tehrani and Collard 2002). The following review of cladistics is based upon O'Brien and

Lyman's (2003) recent discussion of the method and its application to cultural phenomena as well as the abundant biological literature on cladistics from both a theoretical and practical standpoint (e.g., Forey, et al. 1992; Kitching, et al. 1998; Ridley 1986; Sober 1988).

3.2.2.1 Basics of Cladistic Analysis

Figure 3.2 is a simple phylogenetic tree arranging four taxa based on the distribution of character states in five dimensions. The cladistic term for dimension is character. For each of the five characters there are two possible character states, prime and not prime. Taxa 1-4 are shown in Figure 3.2 with their character state definitions in parentheses.

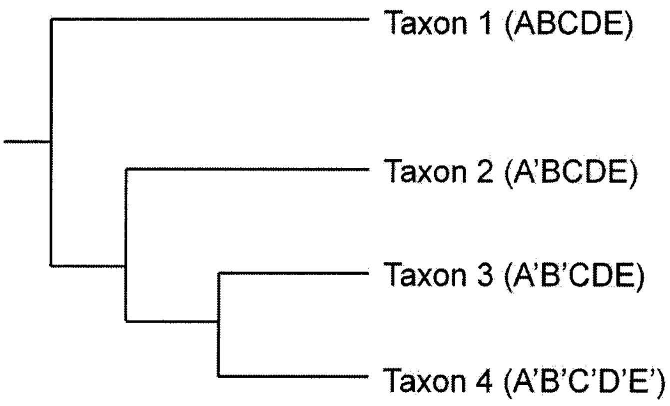

Figure 3.2. Phylogenetic tree showing relationships between taxa based on the distribution of shared derived character states.

In Figure 3.2 non-prime character states are ancestral and prime character states represent evolved novelties. Each bifurcation in the tree represents a character state change found in all the taxa to the right of that bifurcation or node. The split between Taxon 1 and Taxa 2-4 is defined by a change in character states from A to A'. Similarly the bifurcation separating Taxon 2 from Taxa 3 and 4 is defined by the change from character state B to B'. In this phylogenetic tree Taxon 3 is considered more closely related to Taxon 4 than it is to Taxon 2.

The notion of a character state's ancestral or derived nature is relative (O'Brien and Lyman 2003:59-62). The common ancestor of Taxa 3 and 4 exhibited character states A' and B' while the common ancestor of Taxa 2, 3, and 4 also exhibited character state A'. When comparing only Taxa 3 and 4, character state A' is ancestral as this character does not differentiate Taxa 3 and 4 from Taxon 2. However, when comparing Taxa 2-4, character state A' is derived as this character state now differentiates those taxa from Taxon 1.

In the generation of phylogenetic trees cladistic techniques attempt to group taxa in a series of bifurcating relationships such that the number of character state changes in a tree required to account for all the taxa is minimized (O'Brien and Lyman 2003:63). The number of character state changes in Figure 3.2 is five and this is considered the tree length. One character state change for the ancestor of Taxa 2-4, one for the ancestor of Taxa 3 and 4, and there are three character state changes that occur only in Taxon 4. We can create an alternate hypothesis regarding the phylogenetic relationships among these taxa by switching the positions of Taxa 2 and 3. This tree, however, contains six character state changes. An additional character state change is required for Taxon 3 now (B to B') giving this tree a length of six. Using the rule of parsimony, the best tree is the one with the shortest length as it includes the fewest evolutionary events to account for taxa similarities. Thus the first tree (Figure 3.2) is considered the better hypothesis.

Given the simple set of data in Figure 3.2 it is also easy to determine how these taxa would be grouped based on phenetic similarity where there is no differentiation between ancestral and derived homology (see O'Brien and Lyman 2003:75-81). In Figure 3.2, Taxon 3 is more closely related to Taxon 4 than to Taxon 2 based on shared derived characters, in this case, character state B' shared by Taxa 3 and 4. However if we group the taxa in Figure 3.2 based solely on phenetic similarity, Taxon 3 shows a closer affinity to Taxon 2 (four shared character states) and Taxon 1 (three shared character states), than it does to Taxon 4 (two shared character states). Cladistics produces arrangements of taxa that rely solely on the distribution of shared derived characters.

Figure 3.2 displays an additional important quality of cladistically derived trees. Phylogenetic trees group taxa into clades at various hierarchical levels (O'Brien and Lyman 2003:44-46). A clade (also termed a monophyletic group) includes all of the taxa that are related through a single common ancestor, that is they are all related through transmission. In Figure 3.2, Taxa 3 and 4 form a clade as do Taxa 2-4. In contrast, Taxa 1, 3, and 4 do not form a clade as *all* the taxa related to the common ancestor of Taxa 1, 3 and 4 and are not included in the group. Taxa 1, 3, and 4 form what is called a paraphyletic group. In cladistics, paraphyletic groups are not useful for constructing parsimonious hypotheses of transmission-generated relatedness. If we are using our phylogenetic tree in Figure 3.2 and we hypothesize that Taxa 1, 3, and 4 are more closely related to each other than they are to Taxon 2, we need to justify why Taxon 2 is not also included as it shares a common ancestor with Taxa 1, 3, and 4. By using paraphyletic groups within phylogenetic trees we are circumventing the arrangement created by the tree and thus one of the primary reasons for using cladistics. In short, the use of paraphyletic groups to demonstrate relatedness requires us to craft additional arguments not based on the distribution of character states in the tree and thus questions our original application of the method to the problem of relatedness.

We can craft hypotheses of relatedness based on heritable continuity using the clades produced through cladistic analysis and we can also track particular routes or lineages of transmission within a phylogenetic tree (O'Brien and Lyman 2003:121). The lines of descent in a phylogenetic tree from the base of the tree, through various nodes (i.e., hypothetical ancestors) to the terminal taxa are transmission lineages (Figure 3.3).

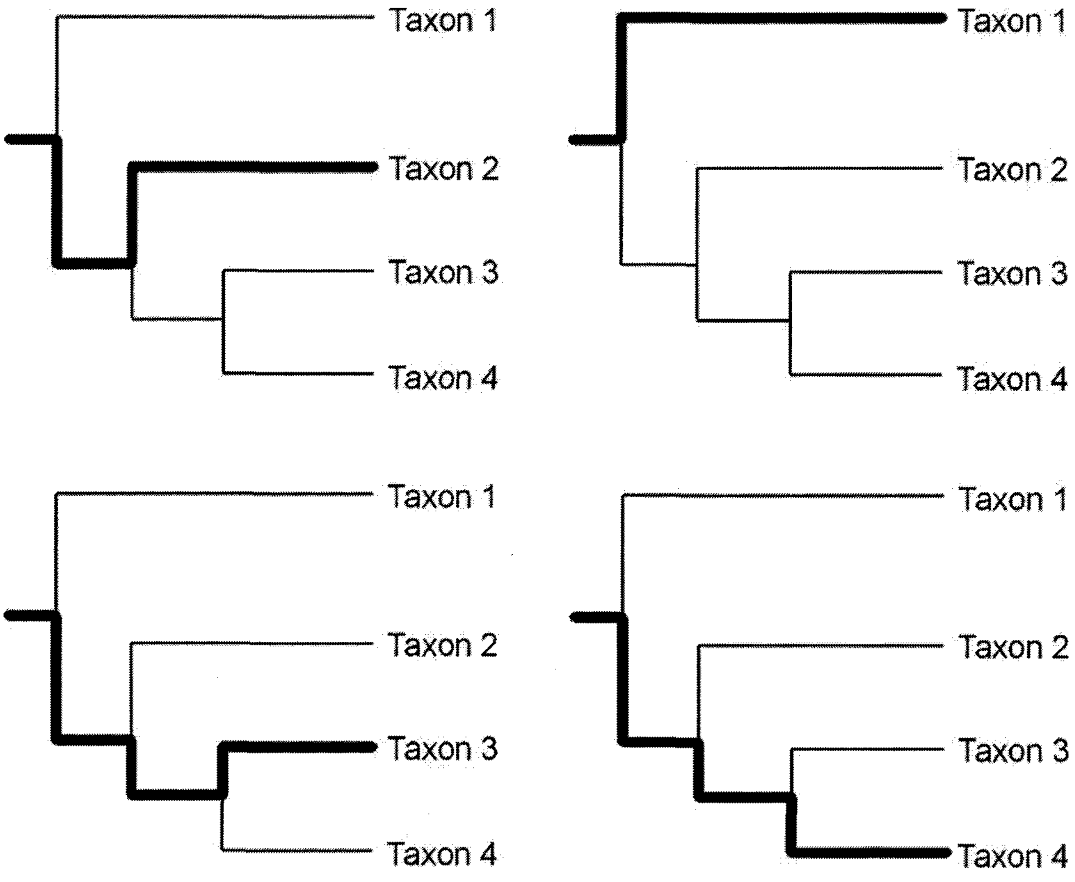

Figure 3.3. Four transmission lineages (bold lines) within the Figure 3.2 phylogenetic tree. See O'Brien and Lyman (2003:Figure 4.7)

Clades and transmission lineages exhibit a somewhat counterintuitive relationship to each other. Clades are groups of hierarchically related taxa. The terminal taxa of a clade are related through a series of common hypothetical ancestor at various levels in the hierarchy represented by the nodes of the tree. These terminal taxa also define transmission lineages and the application of these taxa (i.e., homologous classes) to the empirical world creates temporal and spatial distributions that map the temporal and spatial characteristics of a transmission lineage. The transmission lineages defined by the terminal taxa of a clade are then also related hierarchically. For example, in Figure 3.3 the lineages defined by taxa 3 and 4 share a more exclusive relationship than those lineages together share with the lineage defined by taxon 2.

O'Brien and Lyman (O'Brien and Lyman 2003:120) argue that clades as described in phylogenetic terms are similar to what culture historians had in mind when speaking of traditions. Willey (1945:53) defined a tradition as "a line, or number of lines, of pottery development within the confines of a certain technique or decorative constraint." That the culture historians created a concept similar to clade is not surprising. Culture historians' primary theoretical units used to measure archaeological phenomena were types that had passed Krieger's (1944) test of historical significance. These historical types arranged phenomena in time and space based on the distribution of homologous modes, although culture historians justified their classes with the popularity principle (Lyman, et al. 1997). Thus the distribution of a culture historical type through space and time may roughly track some portion of the same similarity captured in a transmission lineage.

3.2.2.2 The Mechanics of Creating Phylogenetic Trees

The phylogenetic tree in Figure 3.2 is a simplified example that we would never find in an analysis of real data. In Figure 3.2 no character states revert to an ancestral state, and similar character state changes do not occur across separate lineages. With real world data, however, these events often transpire. In the cultural realm we might expect character states to sometimes revert to ancestral states (e.g., reinvention), and similar sequences of character state change may occur in separate lineages. When this happens it is difficult for cladistic techniques to produce trees consisting only of bifurcating splits.

When similar sequences of character states occur in separate lineages a scenario such as depicted in Figure 3.4 may be produced. The phylogenetic trees in (a) and (b) are the most parsimonious arrangements for these taxa and each are of length 6. Black boxes indicate character state changes with the new character state beneath the box. Taxon 2 is different from the previous tree (Figure 3.2) as it now exhibits the character state E', similar to Taxon 4. With this new definition of Taxon 2, each of the most parsimonious arrangements contains an instance of convergence or parallelism (O'Brien and Lyman 2003:63) where the same character state change appears in separate transmission lineages; in (a) the character state is E', and in (b) it is B'.

Without making assumptions about the cost of particular character state transformations (see Kitching 1992b; Scotland 1992), cladistic techniques can not decide upon a better hypothesis of phylogenetic change given the two trees in Figure 3.4 (a) and (b). One solution is shown in Figure 3.4 (c) with what is called a consensus tree. Since we can not unambiguously decide between the two trees, the consensus tree displays the relationships between taxa that are shown in both (a) and (b). Since in both (a) and (b)

Taxa 2-4 form a clade, the consensus tree joins all three taxa in a single undifferentiated group. There are several techniques for constructing consensus trees (Figure 3.4 shows a strict consensus tree) (see O'Brien and Lyman 2003:68-72). In Chapter Six 50% majority-rule consensus trees are produced. These consensus trees display the taxa relationships present in at least 50% of all the equally parsimonious trees for a set of taxa.

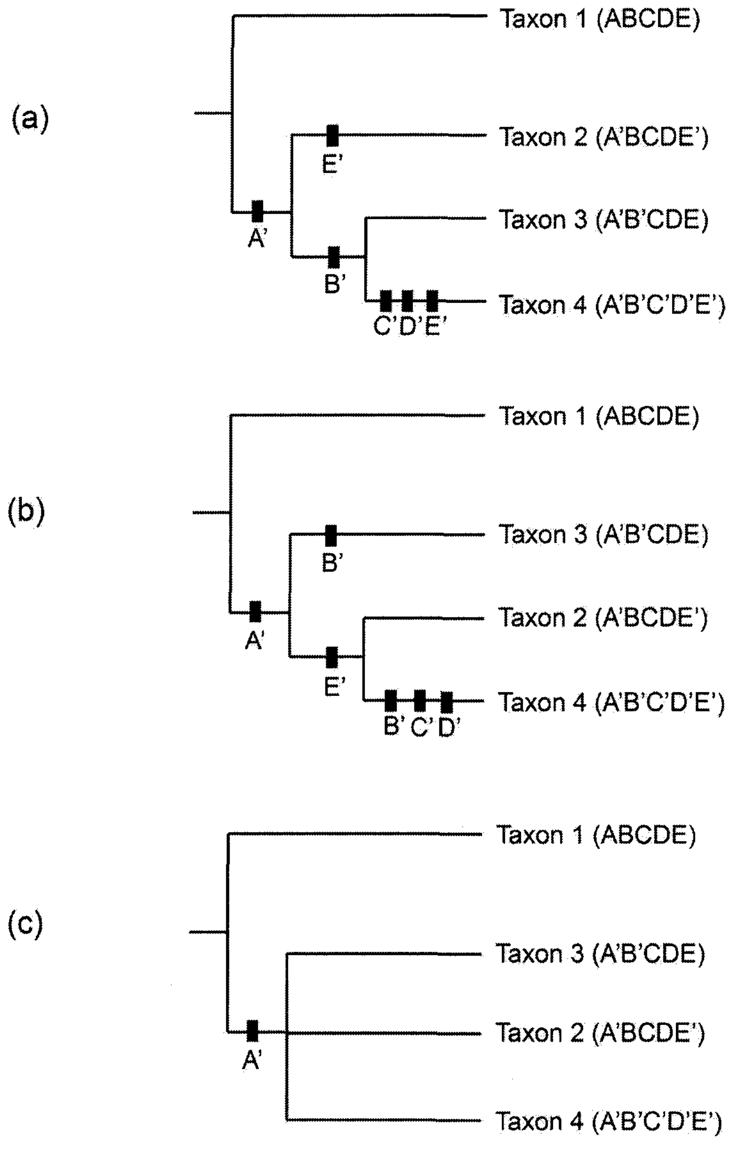

Figure 3.4. Two possible cladistic trees (a, b) for Taxa 1-4, each of length 6, and the consensus tree (c) showing the homoplasious relationship of Taxa 2-4.

The parallelism or convergence depicted in Figure 3.4 along with character state reversals are generally referred to as homoplasy (see O'Brien and Lyman 2003:62-63). This condition hinders our ability to construct phylogenetic trees consisting of only bifurcations for a given set of taxa. With real world data, however, phylogenetic orders often have multiple instances of homoplasy across numerous (thousands and hundreds of thousands) equally parsimonious trees.

As we add taxa, characters, and come across instances of homoplasy the chore of constructing the most parsimonious tree or consensus tree is beyond our computational capabilities. There are many cladistics programs to choose from[11] that will produce phylogenetic trees and perform other operations on a series of taxa and character state definitions. The program PAUP* 4.0 (beta version 10) by Swofford (2001) was used for the analyses presented in Chapter 6.

Cladistics software takes care of the computational work of creating parsimonious trees given a set of data and there are several algorithms that can be followed to create trees. The method of Maximum Parsimony has been described here. Prior to the computational work, however, the analyst must construct a classification that describes phenomena by homologous character states (O'Brien, et al. 2002; Scotland 1992) and determine for the taxa under consideration which character states are ancestral and which are derived. This is referred to as determining character polarity and is accomplished through the choice of an outgroup.

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[11] http://evolution.genetics.washington.edu/phylip/software.html is a popular archive of available cladistics software.

An outgroup is a taxon that diverged from all the taxa in a phylogenetic tree before they diverged from themselves. Thus an outgroup determines which character states are ancestral and which are derived. Different outgroups, of course, will produce different phylogenetic trees given the same set of taxa, thus the choice of outgroup greatly influences the resulting analysis.

There are different methods for determining an outgroup (Kitching 1992a; O'Brien and Lyman 2003:59-62, 159-164), but in general one should choose an outgroup taxon that is closely enough related to the taxa being ordered (the ingroup taxa), so that the ancestral and derived nature of character states is correctly determined. Any group can serve as a possible outgroup, but we want to choose a group that is close enough to the ingroup taxa to serve as an informative guide to character polarity. In this research outgroups are chosen based on the chronological relationships of taxa in single archaeological deposits, as well as comparison with earlier assemblages from other areas of Fiji.

3.2.2.3 Debates in the Use of Cladistics to Track Material Culture Change

Phylogenetic trees create groups of sister-taxa related through a common ancestor. The notion that nodes in the phylogenetic tree represent ancestors is, however, problematic in the analysis of both biological (Ridley 1986:138-149) and cultural (O'Brien and Lyman 2003:81-83) change. Consider, for example, Figure 3.2 where Taxa 2-4 are related through a common ancestor. If these taxa (e.g., rim classes) had appropriate dates of origin and extinction we could possibly say that Taxon 2 was the ancestor of Taxa 3 and 4. Phylogenetic trees do not, however, distinguish between sister-taxa and ancestor-descendent taxa.

The solution to this problem is to consider the nodes of a phylogenetic tree to represent hypothetical ancestors or more appropriately as collections of ancestral character states from which later sets of character states (our terminal taxa) emerged. Thus in Figure 3.2, Taxon 2 might be the ancestor of Taxa 3 and 4, but it also might another descendant from the pool of ancestral character states represented by the node that joins these three taxa. One ramification of this position is that phylogenetic trees do not track the phylogenetic relationships of taxa per se, but rather they track the changing configurations of sets of character states. Only some of these sets of character states are represented by the terminal taxa in our phylogenetic trees (Ridley 1986:138-149). This position on ancestors also refutes arguments such as Moore's (1994:928) that anthropological cladistic analyses intend to reconstruct "real antecedent populations [at the nodes of a cladogram], not representations created only for comparative purposes."

A variety of arguments against applying phylogenetic and cladistic methods to cultural phenomena have been made over the years (see O'Brien and Lyman 2003:97-121), but here I briefly address only one here: role of phylogenetic trees in explanation.

Phylogenetic trees are not explanations regarding the transmission relationships among a set of taxa. A phylogenetic tree is one possible hypotheses of these relationships. Different phylogenetic trees can be generated from the same set of taxa and each of these hypotheses can be evaluated by means internal to the cladistic method (e.g., various tree statistics such as length and tree construction algorithms) and through external data such as the chronological and spatial relationships of taxa.

A phylogenetic tree presents a set of relationships that must be explained (O'Brien and Lyman 2003:111-113). The configurational aspects of a human groups and the natural and cultural environment, along with properties of cultural transmission, selection and sorting mechanisms, and innovation may explain the pattern presented by a phylogenetic tree. Conflating the pattern of a phylogeny with the processes that explain it is systematic empiricism, where observation and explanation become one and the same (Cochrane 2001; Willer and Willer 1974).

3.3 COMPONENTS THAT MUST BE CONSIDERED WHEN EXPLAINING THE DISTRIBUTION OF HOMOLOGOUS SIMILARITY

Several different processes influence our measurement and thus explanation of homologous similarity. Some of these processes are stipulated by theory and thus should be considered in the construction of homologous classes. Other processes involve the formation of archaeological deposits and archaeological sampling techniques, both of which influence the counts of phenomena generated with our classes.

To help us in our construction of classifications and explanation homologous similarity—or the degree to which entities are related via cultural transmission—can be conceived as a function of transmission continuity, the technology of transmission, the duration of transmission, the configuration of the population, the configuration of geographic space, and archaeological formation processes. Each of these components is considered below (see Lipo [2001a] for more complete exposition).

3.3.1 Trait Continuity

Transmission is an important component affecting our measurement of homologous similarity. In the phenomenological world, if transmission between individuals does not occur at a sufficient frequency, homologous similarity may not be defined at a particular analytical level.

A continuous empirical distribution of cultural trait classes across time and space may occur, if the transmission frequency between individuals is sufficiently high. If the distribution of multiple cultural trait classes is not continuous and overlapping then we can not be sure we are examining transmission defining a lineage (Dunnell 1981). Figure 3.5 displays the presence and absence of seven cultural trait classes that track homologous and selectively neutral similarity across several assemblages. In Figure 3.5 (a) all of the assemblages are part of the same transmission lineage defined by cultural trait classes 3 and 4. Other trait classes or combinations of trait classes are not continuous and overlapping across all assemblages. Figure 3.5 (b) suggests a different scenario in which trait continuity and overlap across assemblages is not present. Here Assemblages 1, 2, and 5 do not necessarily constitute the empirical manifestation of a transmission lineage. Instead Assemblage 5 may be better identified as a member of a lineage separate from Assemblages 1 and 2 as cultural trait class continuity and overlap are not expressed in these assemblages.

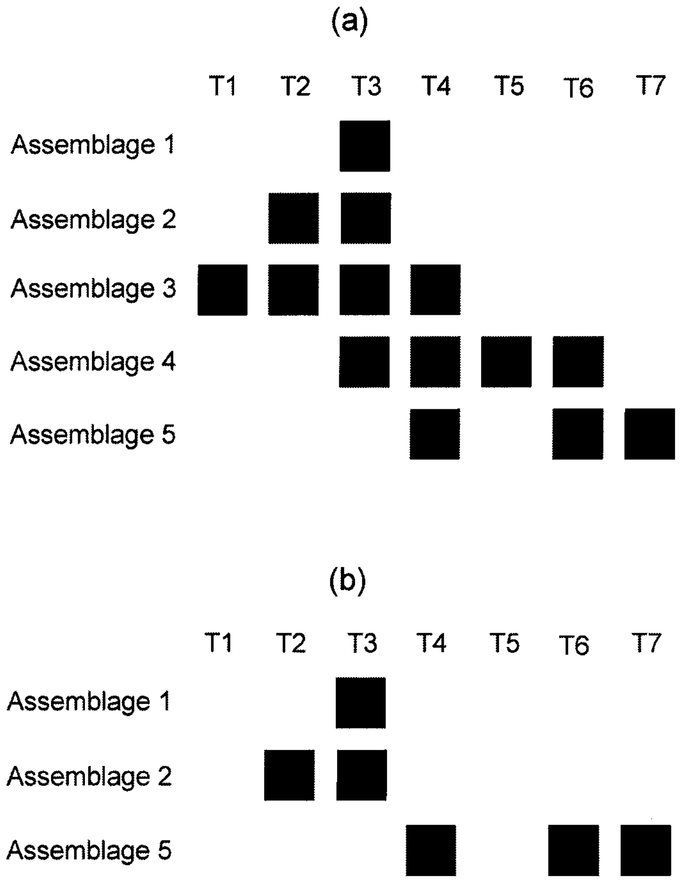


Figure 3.5. The empirical distribution of trait classes (T1-T7) across several assemblages with black boxes noting the presence of artifacts in that class. In (a), the overlapping distribution of classes across assemblages suggests that these assemblages, when described by classes T1-T7, constitute a transmission lineage. In (b), without Assemblages 3 or 4, the remaining assemblages do not necessarily constitute the empirical manifestation of a transmission lineage.

In the scenario depicted in Figure 3.5 (b) we may be examining two unrelated transmission lineages that share spatial or temporal proximity, or both. It is easy to envision the historical contingencies that might create this situation. For example, physical replacement of one population by another in an area may create a discontinuity in the temporal and spatial distribution of the transmission lineage. Transmission lineages may also be contemporaneous, but separated by geographic or population boundaries. Lipo (2001b; 1997) identified frequency-defined boundaries between transmission lineages in the lower Mississippi Valley that appear to be a product of both geography and population structure.

Discontinuities in transmission lineages may also be a product of analytical sampling processes and not representative of actual terminations of transmission lineages. If the archaeological record has not been adequately sampled then discontinuities in transmission lineages may be a product of inadequate sampling. Indeed this is another possible explanation for the scenario depicted in Figure3.5 (b).

Discontinuities may also be due to the diminishing frequencies of cultural traits as these cultural trait classes become increasingly rare in group of cultural transmitters. These frequency discontinuities are therefore a product of the difficulty in identifying increasingly rare classes in a sample population (Leonard and Jones 1989). The confounding effect of sampling induced discontinuities can be lessened by defining cultural transmission lineages with multiple cultural trait classes, assuming that these kinds of discontinuities have far less chance of occurring across multiple classes at once.

3.3.2 Technology of Transmission

The technology of transmission influences the probability of transmission by the choice of materials and the organization of technology. Material choice can affect transmission probabilities if, for example, different materials are employed to produce similar looking objects (e.g., hooks made of both shell and bone, or designs executed on both pottery and mats). The distribution of modes on such materials must first be examined to determine if their occurrence is controlled by technological characteristics (see e.g., Allen 1996). As the research presented examines only earthenware pottery, the possible correlations of materials and transmission are obviated.

The organization of technology refers to the manner in which individuals and energy are organized to produce different kinds of artifacts. For complex artifacts, those in which the design of the artifact is separated from its manufacture, cultural transmission lineages may refer to the ways in which designers transmit with each other (designer transmission lineages) and with respect to consumers (designer-consumer transmission lineages). In this dissertation it is assumed that the earthenware pottery analyzed was almost certainly produced and designed by the same individuals. No previous researchers have identified any evidence suggesting that pottery production in Fiji was so complex as to include separated design and manufacturing systems. Thus the organization of technology is largely held constant for the materials examined here. The organization of technology in Fiji may have changed after European contact, particularly with the increasing movement of goods and individuals on European ships (Derrick 1968).

3.3.3 Duration of Transmission

The duration of transmission can also have a direct impact on the measurement of homologous similarity because duration represents the time it took either for the set of attributes to come together as a unit of archaeological observation (when individual artifacts are the focus of analysis) or the time it took for the set of objects to come together as a recognizable depositional unit within the archaeological record (when assemblages are the focus of analysis). Also if the rate of deposition of objects differs markedly within the duration represented that this too can affect measurement of homologous similarity (Dunnell 1981; Green 1971). When artifacts are the scale of observation they must be comparable for this same reason. If there are substantial differences in the time it takes for artifacts to be completed, and for cultural traits to be incorporated into their manufacture, then analyses of class distributions may track differences in the duration of transmission represented on artifacts. Similarly, if artifacts undergo repair and remodeling during their use histories and if these events add or subtract attributes on the object, then the duration of transmission may vary.

When assemblages are the focus of analysis, that is when the frequencies of cultural trait classes across a set of artifacts is the scale of observation, differences in duration refer to the time within which transmission occurred on all artifacts included. This relationship is complicated by the fact that the duration of transmission may only be estimated in these instances by the duration over which deposition occurred for some assemblages. Thus, duration may estimate the temporal interval after artifacts were manufactured and during which the objects came to be represented in the archaeological record. This latter aspect of duration represents a formation process affecting archaeological field units. Archaeologists apply a number of conventions to the record by defining and recognizing empirical units (e.g., stratigraphic layers, arbitrary levels, surface remains), or by developing analytical units (e.g., temporal units) through which assemblages of objects are generated.

Some culture historians (e.g., Ford 1938, 1949; Philips, et al. 1951; Rouse 1939) understood that groups in which the duration represented was either relatively short in time or of nearly equivalent duration were necessary for seriation, a method they used to track homologous similarity. Dunnell (1970) clarified this condition (i.e., he identified equivalent duration as the controlling factor) for the successful application of seriation and later (Dunnell 1981) explored some of the implications of using groups of substantially different duration. In the research presented here, the duration of transmission will be monitored by comparing assemblages depositional histories and through radiometric dating analyses, and seriation.

3.3.4 Population Configuration

Archaeologists and anthropologists have long appreciated that the distribution of individuals across space will affect the probability of transmission between them. Early in the 20th century this idea was crystallized in the culture-area and age-area concepts (see Kroeber 1931). New archaeologists later used similar ideas, albeit more explicitly formulated as gravity equations, to analyze artifact similarity and identify the level of interaction between communities (e.g. Deetz 1965; Hill 1970; Hodder and Orton 1976; Longacre 1970; Plog 1976). Population configuration can be decomposed into spatial and size variables, each of which may affect our measurement of homologous similarity (Lipo 2001a).

Population distribution can be measured with the X and Y coordinates of analyzed assemblages. By examining the spatial distribution of classes representing a transmission lineage across assemblages we can examine the relationship between population distribution and lineage formation.

The population size directly involved in transmission is the effective population and that unit is less than the total population for the transmission of cultural trait classes.

The effective population in most biological studies is generally the number of adults available for mating. For cultural transmission, the effective population may be some other subset of the population, for example females or adult females.

One effect of increasing the effective population, all things being equal, is to increase the number of potential transmissions, and thereby the probability of transmission and innovation. As the effective population decreases, the number of transmissions may diminish and with this, there can be a corresponding erosion of variability, first in terms of the frequencies of cultural trait classes and then in the occurrence and abundance of classes. Neiman (1995) has simulated this for cultural traits that confer no adaptive benefit as the equivalent to genetic drift. In general, then, the relationship between effective population size on measurement of homologous similarity is the potential correlation between changes in effective population size and the frequency or presence and absence of cultural trait classes The larger the effective population the longer trait classes may persist. With substantial or catastrophic decreases in the effective population (e.g., through founder's effects in island colonization or epidemic diseases spread among unprotected populations), loss of both variation and number of cultural trait classes will likely occur (Vayda and Rappaport 1963). The research presented here examines populations approximately 200 years after the earliest colonization of Fiji and just up to the population losses associated with European contact (Derrick 1968; Kirkendall 1998). We can assume Fiji's population grew steadily over these 2800 years. Dramatic changes in population size over this time may influence the distribution of homologous variation. Such changes could include rapid population growth as might be experienced with invention of new technologies or the exploitation of new environments (Boserup 1965; Shennan 2003:113-123) and rapid population decline such as that which occurred throughout the Pacific with the introduction of Old World diseases by Europeans (Stannard 1989).

3.3.5 Geographic Space

The role of space in the transmission of cultural traits is reflected not only in the distribution of the population on a landscape, but is also represented by the role that the physical nature of that landscape plays in structuring population distribution. Geographic paths for cultural transmission are not all of equal cost, even when linear distance is the same. Thus the configuration of geographic space may affect the distribution of homologous similarity by increasing or decreasing the probability of contact between individuals, and hence transmission, in particular directions. The direction of watercourses, ocean currents, and wind patterns can increase chances for transmission whereas the location of mountains, swamps, and other geographic barriers may decrease chances for transmission (Irwin 1990, 1992; Lipo 2001b; Renfrew 1977). Barriers interact with the configuration of the population to produce differences in the size and density of human groups across the landscape. The effects of geographic structure, however, depend heavily upon available communication and transport technology (Hodder and Orton 1976). Analyses that suggest changes in cultural transmission frequency must therefore be evaluated against possible changes in technology that may foster transmission.

Increases in population density resulting from changing population configurations or their location will increase the probability of transmission events. Decreases in population density will reduce the probability of transmission. The geometry of variable population densities also plays a role. Populations are not usually randomly or uniformly distributed over the landscape but are to some extent clustered. Increases and decreases in clustering distributions for human populations does not change the mean rate of cultural transmission, but may have non-linear effects due to critical thresholds in the network configurations (Clark and Anderson 2001; Green 1994; Hunt 1988).

We can track the effects of geography on cultural transmission through linear distance between assemblages and different transmission probabilities according to direction and increased or decreased connectivity between assemblages due to physical geography. Differences in connectivity can be measured in other ways as well; two examples include geographic information systems taking into account least-cost travel surfaces (e.g., Field 1998) and geography-specific models such as riverine systems (e.g., McCutcheon 1996).

3.3.6 Formation Processes

Before we can define homologous similarity among ceramic assemblages we must assess the effects of formation processes, broadly construed, upon cultural trait class frequencies. These formation processes include archaeological sampling, sample representativeness, and assemblage formation.

3.3.6.1 Archaeological Sampling

Processes of archaeological sampling used to generate ceramic data must be known, so inter-assemblage variation that is a product of different sampling regimes can be identified. Furthermore, each archaeological sampling event introduces random and systematic error into the generation of class counts and frequencies. Systematic errors should be known and minimized when possible (e.g., by using randomized sub-sampling procedures). Archaeological sampling regimes include field procedures associated with excavation (e.g., screen sizes for recovering artifacts), and analytical procedures. Analytical procedures include instrument-based measures and classification. Error terms can be computed for all measures by making repeated measurements and observations. Measurement error associated with metric assemblage characteristics can be compared to the degree of similarity between different assemblages based on those characteristics. If the degree of similarity can be encompassed within measurement error ranges, then that similarity may be a result of measurement error. Classifications of sherds in different assemblages should also be comparable (i.e., have similar class definitions), so that inter-assemblage variation is not a product of variation in the classifications.

3.3.6.2 Sample Representativeness

Sample representativeness must be considered in any analysis of homologous similarity. If samples do not accurately represent an underlying population, similarity between samples may not be explained by cultural transmission, but to equally poor representations of diversity. The occurrence of such chance similarities can be lessened through two complementary procedures. First, the possibility of poor sample representativeness decreases with increasing sample sizes as larger sample sizes are more likely to accurately represent the underlying ceramic population of interest (Rhode 1988). Bootstrapping techniques can determine if a sample adequately represents an underlying population (Efron and Tibshirani 1993; Lipo, et al. 1997) and samples that poorly represent underlying variation can be segregated or be analyzed using other methods less sensitive to richness and evenness problems (see Welsch, et al. 1992).

Second, class precision can be modified to lessen the possibility of chance similarities based on poor sample representativeness. Objects are similar based on their membership in a class defined by modes. If the number of modes that define a class is increased, the class is a more exclusive grouping device. More precise classes, however, require larger sample sizes to adequately represent the richness and evenness of the underlying population. Sample representativeness can be monitored by noting sample size effects through boot-strapping techniques and by careful construction of classifications.

3.3.6.3 Assemblage Formation

The similarity between assemblages is also a function of formation processes affecting the ceramic deposits (Schiffer 1987). To accurately measure similarity, ceramic deposits should be a product of comparable depositional regimes so that at least three characteristics of the assemblages are alike. First, the temporal duration represented by assemblages should be similar so that variation resulting from differing amounts of change is not mistaken for variation of analytical interest. Second, the possible post-depositional alteration of ceramic abundance (e.g., through erosion) should be minimal. Third, the post-depositional alteration of ceramic composition (e.g., leaching) should be minimal or comparable.

3.4 CHAPTER SUMMARY

This chapter develops the theoretical framework by which prehistoric ceramic variation in the Yasawas Islands is explained. The framework is founded upon the immanent processes of cultural transmission, selection along with other sorting mechanisms, and innovation. These processes explain the distribution of homologous variation. By integrating explanatory theory and classification, observational classes can be constructed with defining criteria that track variation explicable within the theoretical framework.

The choice of theoretical framework does not simply represent a new jargon applied to old analyses, but is instead an attempt to explicitly link empirically observable classes to a set of universal processes that explain variation and change in cultural inheritance systems. As we saw in Chapters 1 and 2, questions of variation and change in cultural inheritance systems, including questions about cultural diversity, are important in Fiji, the Pacific, and the world.

The primary task of the theoretical framework and resulting classifications is to arrange ceramic variation into transmission lineages. Methods that are direct corollaries of the theoretical framework are available for this task. With seriation and cladistics we can order cultural trait classes or into hypothesized transmission lineages.

Once transmission lineages and groups of related lineages are defined, variation between them can be explained. Possible explanations will rely on the processes that structure homologous variation: components of transmission processes, innovation, selection and sorting, population configuration, and geography.

CHAPTER 4. ARCHAEOLOGICAL OVERVIEW OF THE YASAWA ISLANDS

> The Yasawa Group comprises six large islands and many smaller ones, having a total area of fifty-two square miles. From a point twenty-five miles north-northwest of Lautoka, they stretch for over fifty miles in a NNE direction, forming a broken ribbon of land, rarely more than three miles wide, and generally much less, and except at the south end, so straight that their line might have been drawn on a map with a ruler . . . and when seen from points of vantage on Viti Levu, they suggest a string of blue beads lying along the horizon.
>
> R. A. Derrick (1957:212-214)
> *The Fiji Islands*

4.1 NATURAL ENVIRONMENT OF THE YASAWA ISLANDS

The Yasawa Islands (Figure 4.1) are the westernmost outpost of the Fijian archipelago (excepting Rotuma, 600 km north of Viti Levu). The islands comprise dramatic peaks, rolling grasslands, and sheltered bays. The islands are graced with rich marine resources including numerous near-shore and fringing reefs. The Yasawa Islands are some of the driest in Fiji receiving approximately 190 cm of rain each year. Vegetation in the islands is dominated by *talasiga* or "fern-shrub savanna-grasslands," the distribution of which represents an unknown proportion of both anthropogenic and non-human environmental change since the mid-Holocene (Nunn 1997:448; 2000a). The other major vegetation type in the Yasawas is a broadleaved dry forest found at higher elevations and in the small valleys leading to the coast. Coastal terraces contain mixed shrub flora along with screwpine (*Pandanus* sp.) coconut (*Cocos* sp.), and other trees.

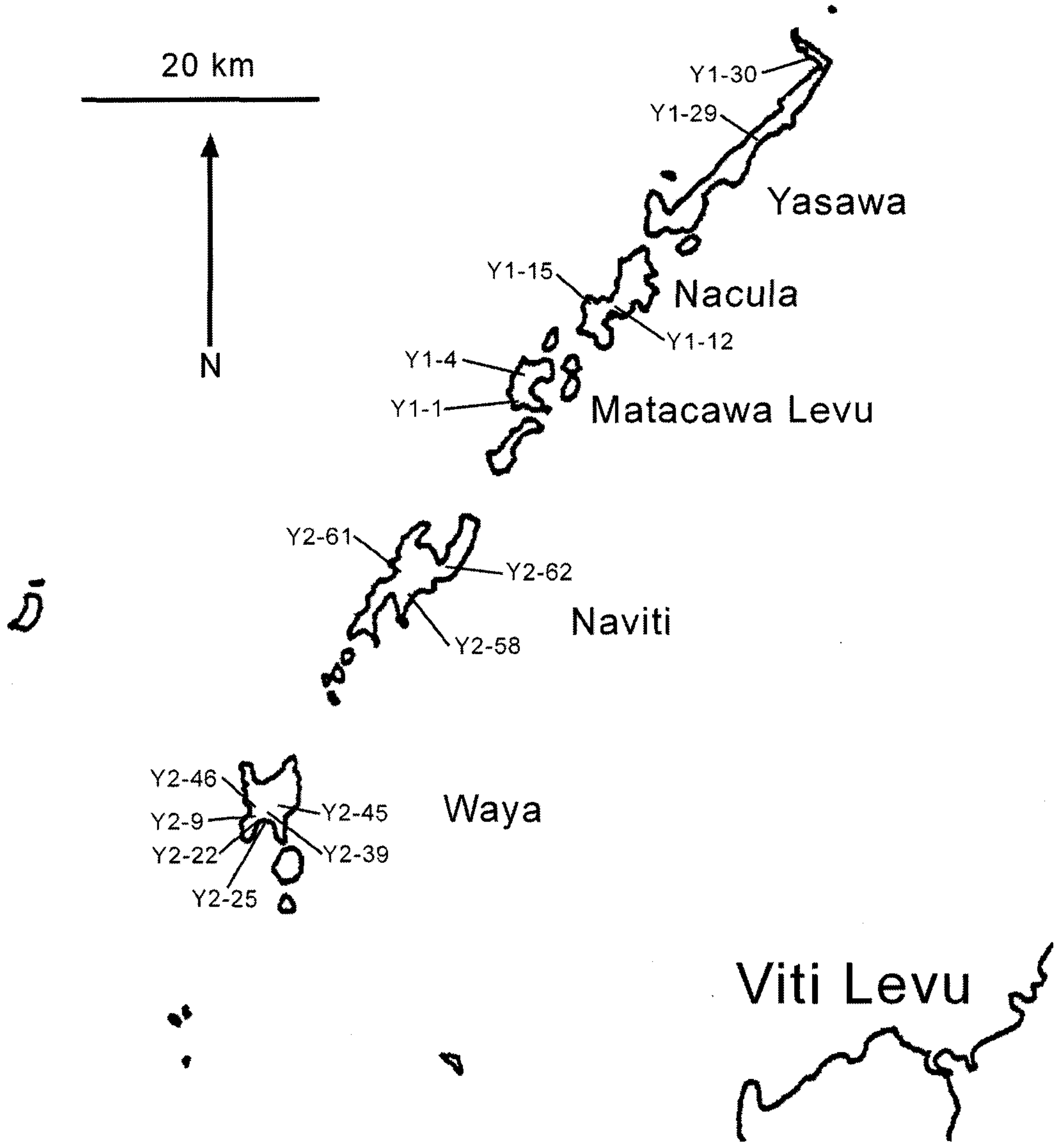


Figure 4.1. The Yasawa Islands showing locations of archaeological sites discussed in text.

Since human colonization of the islands, the Yasawas have been affected by sea-level changes that have both altered the relative position of the coastline and influenced the progradation of coastal terraces. No paleosea-level work has been conducted in the Yasawa Islands and the complex tectonic environment of Fiji creates localized emergence and subsidence (Nunn, et al. 2002). Despite this, general conclusions regarding sea-level change in the Yasawas can be made.

Sea-levels have changed several times during the human history of Fiji. At the time of colonization, approximately 3000 BP, a high-stand raised sea-levels 1-2 m above current levels in Fiji with sea-level subsequently falling to present levels at an average rate of 0.5 m every 1000 years (Nunn 1998). Over the 3,000 years of human occupation, however, the rate and direction of sea-level change has not been constant. Nunn (1998; 2000b; 2001) has correlated variation in sea-level with global climatic patterns. During the Little Climatic Optimum (LCO), an essentially world-wide event of increased temperatures (c. 1050-690 BP), sea-level may have rose again to within 0.9 m of its present position. In a transition period following the LCO (c. 690-575), sea-level may have quickly dropped 0.5 m as a result of global temperature fall that ushered in the Little Ice Age (LIA). At the start of the LIA (c. 575-150 BP), sea levels may have again risen to their present position, only to gradually fall to almost a meter below present position by c. 200 BP. The last two hundred years have seen sea-levels rise again to present levels.

In the Yasawas, evidence of these sea-level changes are seen in both archaeological deposits and coastal geology. Paleobeach deposits in several archaeological sites (see below) confirm that at the time of initial occupation of the Yasawas sea-level was at least 1 m higher than present. Wave-cut notches on much of the Yasawan Islands coastline bedrock are the result of storm surge, high-stands, or both. However, geological core and excavation unit data from several coastal terraces in the islands show a prograding sequence of terrace formation associated with sea-level fall from the mid-Holocene high-stand.

4.2 ARCHAEOLOGICAL FIELD WORK IN THE YASAWA ISLANDS

There are over 230 archaeological sites in the Yasawa Islands recorded by Simon Best and Geoff Irwin during reconnaissance surveys in 1978 and by University of Hawai'i teams during the 1990s and early 2000s (Hunt, et al. 1999). Best and Irwin also made surface collections of ceramics, but their surface collection methods are not recorded. In some instances plain body sherds were counted, but not collected. Subsequent excavation of a few sites has been conducted on Waya and Nacula islands confirming the colonization of the Yasawas approximately 2,700 years ago, perhaps 200 years later than other areas of Fiji. These excavations have also revealed a prehistoric sequence of ceramic, subsistence, and settlement change throughout the islands.

The present analysis focuses on ceramic collections from five excavated sites and 11 surface assemblages throughout the islands (Figure 4.1 and Table 4.1). The remainder of this chapter describes these 16 sites and their artifact assemblages. The excavated sites in the analysis were chosen because their deposits represent particular points along the Fijian cultural chronology. The 11 surface assemblages were chosen, out of the several hundred in the islands, because preliminary analysis of their ceramic inventories (Cochrane and Hunt 2004) indicates that they provide the most representative samples in terms of decorative diversity. The ceramics recovered from each site are described using the standard decorative categories developed by previous researchers (e.g., Best 1984; Clark 1999; Frost 1974; Shaw 1967). These categories are described in Table 4.2. In

Chapter 5 a classification of surface modification tailored to the problems addressed in this research will be presented.

Table 4.1. Summary descriptions of Yasawas archaeological sites discussed in text.

Site	Name	Elevation (m)	Landform, Primary Use Category	Collection Strategy
Y1-1	-	-	-	surface collection
Y1-4	Vatialele	182	hilltop, ceramic scatter	surface collection
Y1-12	Druidrui	225	hilltop, defended habitation with earthworks	surface collection, 1 excavation unit
Y1-15	Natia	15	coastal flat, occupation with shell midden	surface collection, 5 excavation units
Y1-29	-	15	coastal terrace, ceramic scatter	surface collection
Y1-30	Yasawairara/ Namuanai	30	ceramic scatter	surface collection
Y2-9	Lakala	350	hilltop, occupation with midden and surface architecture	surface collection
Y2-22	Korowaiwai	2	coastal/alluvial flat, defended habitation with annular earthworks	surface collection, core samples
Y2-25	Olo	3	coastal/alluvial flat, occupation with dense midden	surface collection, 11 excavation units
Y2-39	Qaranicagi	130	cave, occupation with dense midden	surface collection, 3 excavation units
Y2-45	Nasau	160	upland slopes, occupation with midden and surface architecture	surface collection
Y2-46	Natavosa	274	ridgeline, occupation with midden and earthworks	surface collection, 1 excavation unit
Y2-58	-	-	ceramic scatter	surface collection
Y2-61	-	-	ceramic scatter	surface collection
Y2-62	-	2	coastal flat, defended habitation with annular earthworks, ceramic scatter with shell midden	surface collection

Table 4.2. Description of standard Fijian ceramic decorative categories.

Decorative Category	Description
Wiping	Close and parallel striations in the vessel body caused by wiping a fibrous material across the wet or leather-hard vessel.
Slip	Clay slurry applied to vessel before firing.
Paddle-Impressed, Cross-hatch (PICH)†	Recessed checkerboard indentations applied to the unfired vessel by a carved paddle and anvil.
Paddle-Impressed, Parallel Rib (PIPR) †	Recessed parallel rib indentations applied to the unfired vessel by a carved paddle and anvil. Also identified as Parallel Bar.
End-tool Impression	Punctates produced on an unfired vessel by pressing a tool into the surface so that the length of the tool is roughly perpendicular to the vessel surface. Includes single finger punctates and the late-Lapita "shell arcs" confine to vessel lips.
Side-tool Impression	Punctates produced on an unfired vessel by pressing a tool into the surface so that the length of the tool is roughly parallel to the vessel surface at the point of the punctation. Includes the typically early side-tool rim notches and parallel dents similar to PIPR.
Appliqué	Clay pieces added to the surface of the vessel before firing. Appliqué is present in a variety of forms including round "buttons" and fillets.
Molding	The wet surface of the vessel is manipulated to create relief, typically rows on the vessel body or scallops along a rim. Molding may be difficult to distinguish from appliqué.
Finger-pinching	Thumb and finger are used to pinch wet clay creating a raised hour-glass shape between the oval finger indentations. Also referred to as molding.
Incising	Shallow lines are created by cutting the wet vessel surface with a sharp or toothed tool. Includes symmetric incising where narrow incisions are created by holding the tool roughly perpendicular to the surface and asymmetric incising where the tool is held at a highly acute angle creating wider incision that whose border is sloped on one edge.

† Throughout Fiji Paddle-Impressed ceramics exhibit greater variation in the particular carved design then displayed in this table.

4.2.1 Archaeological Sites of Waya Island

Forty-seven archaeological sites have been identified on Waya, including defended habitation sites on hilltops and coastal flats, open coastal flat habitations, cave shelters, artifact scatters, and fish-traps. Of these sites, six contain assemblages analyzed here.

4.2.1.1 Site Y2-9: Lakala

Lakala is a small habitation site located on a flat section between two rock outcrops forming the peaks of Vatu Nareba (Figures 4.2). At approximately 350 m in elevation with limited level surface for planting and no permanent water source, Lakala was almost certainly a place of refuge and not sustained occupation.

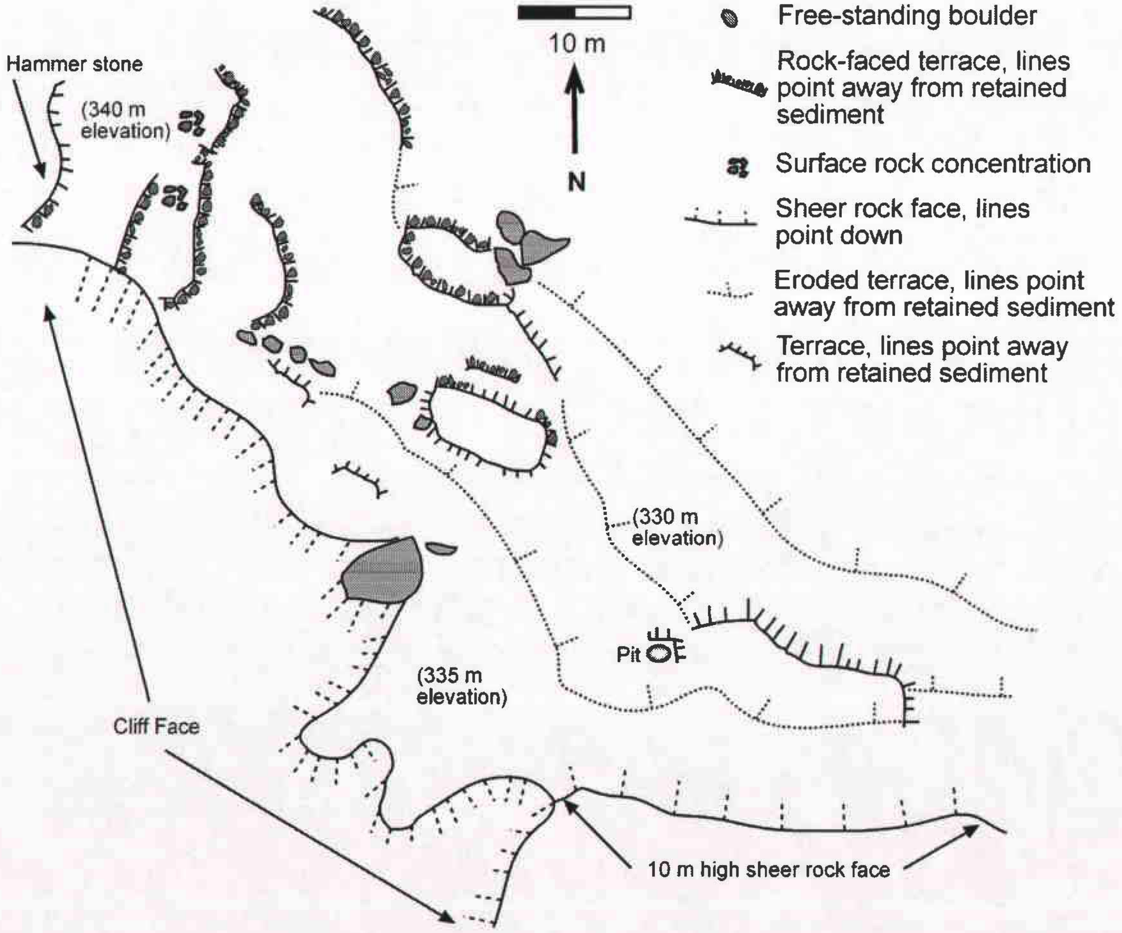


Figure 4.2. Plan map of Lakala (Y2-9).

Lakala consists of ten small terraces, many stone-faced with 2-5 courses of cobbles and small boulders, and one free-standing earthen platform. These structures are all likely house mounds (*yavu*) and are situated on three terraces that span the 160 m length of the site (Figure 4.2). To the northwest, Lakala rises in elevation, so that the *yavu* here are approximately 10 m higher in elevation than the site-center. The surface of the site is sparsely covered with marine shell midden including *Trochus* sp., *Strombus* sp., *Anadara* sp. and others. Most midden was likely thrown over the cliff face that forms the southwest border of the site. Additional surface features include two rock concentrations arranged in circles at the northwest corner of the site, and a stone-lined pit.

Portable artifacts were found by crawling along transects spaced 1 m apart through the leaf-litter covering the site. A rounded cobble hammer stone, basalt flake, and a piece of branch coral were recovered from the *yavu* in the northwest corner. Pottery sherds were found across Lakala with the highest density from the northwest half of the site These sherds were added to the Best and Irwin collection and are recorded in Table 4.3. Pottery sherds from the site surface exhibit decorations that are typically late, c. 200 BP. Rim and neck sherds also suggest a suite of late vessel forms were used at Lakala, including shouldered everted-rim pots and flat-lipped bowls.

Table 4.3. Lakala (Y2-9) sherd types and decoration.

Provenience	**Body**	**Neck**	**Rim**	**Total**	**Symmetric Incised**	**Side-tool Impression**
surface	120	10	8	138	3	1

4.2.1.2 Site Y2-22: Korowaiwai

Korowaiwai is a fortified settlement immediately west of Yalobi village. The site consists of an annular ditch approximately 110 m in diameter with a single causeway on the northern side (Figure 4.3). A small creek runs to the west of the site and drains the small valley behind. The interior of the site contains abundant *Pandanus* sp. and no architecture save for a number of modern graves; the residents of Yalobi village use Korowaiwai as a cemetery today and the *Pandanus* is cultivated for raw material in mat-making and other crafts. Inside the ditch boundary there are abundant ceramics (including historics), marine shell midden, and at least one, small red chert core.

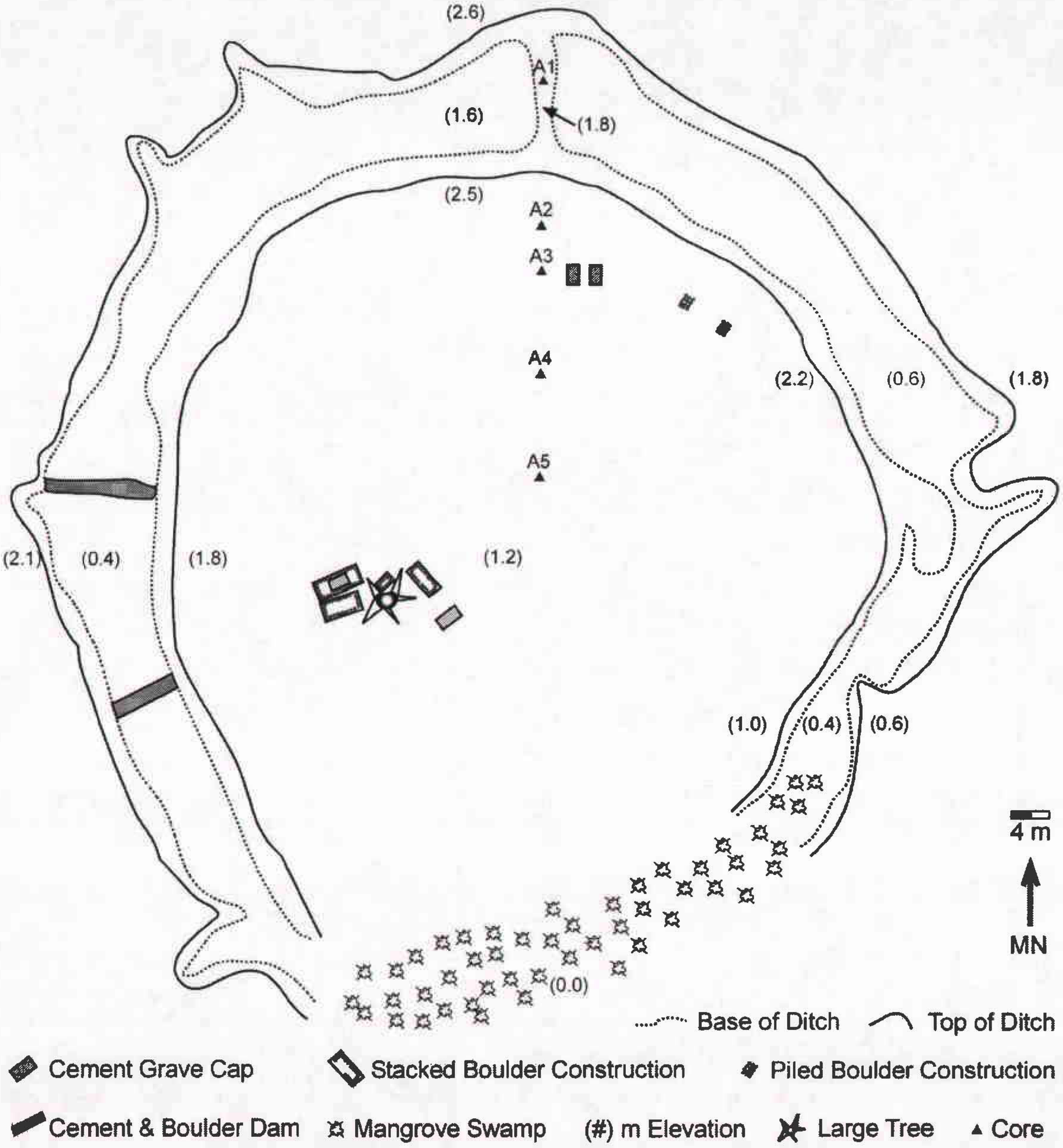


Figure 4.3. Plan map of Korowaiwai (Y2-22) generated in 1994. Additional cement graves have since been added.

Oral historical accounts from Yalobi suggest that Korowaiwai was built and occupied in late prehistoric or historic times (Hunt, et al. 1999). Combined evidence from sea-level changes, other dated ring-ditch sites, oral history, and marine shell dating also suggest a late occupation for Korowaiwai. First, the southern portion of Korowaiwai is inundated by a coastal mangrove swamp and much of the ring-ditch contains standing water. The mangroves and water table depth are related to current sea-level, thus assuming that the site was constructed without the swamp trespassing on its southern border, Korowaiwai was probably built sometime after 690 BP, the time when sea-level likely dropped at the onset of the Little Ice Age (LIA). Lowered sea-level would reduce both the presence of ground water and water salinity at the southern edge of the site making a less-favorable environment for mangroves. The second piece of evidence pertaining to the construction of Korowaiwai is the onset of ring-ditch construction in other areas of Fiji. Field (Field 2004:93)notes that ring-ditches, as a particular type of defensive site, are not constructed until after the LIA in the Sigatoka Valley, possibly as late as c. 260 BP. Third, there are no named lineages associating Yalobi villagers with inhabitants of Korowaiwai, suggesting the ring-ditch site is at least several hundred years old. Finally, a sample of marine shell midden was collected from a few centimeters beneath the ground surface in the middle of the site. A large *Trochus* sp. (73.6 g) was submitted for standard radiocarbon dating. The sample (Wk-6482) returned a date range of 650-460 BP at 2σ (Table 4.14). Although it not unambiguously associated with the construction and occupation of Korowaiwai, the *Trochus* sp. sample, in conjunction with the evidence discussed above suggest the site was occupied over some period of time between c. 650 BP to c. 300 BP.

A large surface ceramic collection from the interior of the ring-ditch has been generated over several field seasons (Table 4.4). Surface collections were generally conducted by walking along closely spaced transects (approximately 1 m apart) and recovering all visible sherds. Ground visibility inside Korowaiwai is good with no leaf litter, but copious stands of *Pandanus* sp. make movement over the surface difficult. Vessel forms at Korowaiwai include the shouldered cooking pot with everted and thinned rim (i.e., the *kuro*), as well as expanded rims (both abrupt and gradual), everted bowls with flat lips, and inverted rim pots (Figures 4.17 and 4.18).

Table 4.4. Korowaiwai (Y2-22) sherd types and decoration.

Provenience	**Body**	**Neck**	**Rim**	**Total**	**Appliqué**	**Appliqué/ Sym. Incising**	**PIPR**	**Symmetric Incision**	**End-tool Impression**	**Side-tool Impression**	**Symmetric Incision/ End-tool Impression**
surface	476	31	65	572	3	1	13	20	7	11	2

A series of core samples (A1-A5) were recovered from Korowaiwai during the 2001 field season using a 12 cm diameter bucket auger. All of the core samples contained artifacts and cores A2-A5 reached the top of the water table between approximately 50 cm (A2) and 23 cm (A5) below the ground surface. All of the core samples also contained ceramics and marine shell, while only some contained charcoal, fish and medium mammal bone (with cut marks). Artifacts were recovered up to a depth of 2.9 m in core A2 in a sandy clay matrix. Sediment descriptions of the matrix recovered from each core were generated using field consistency tests and Munsell color charts. Sediment descriptions suggest that artifacts in the upper portion of the top layer may be associated with the occupation of Korowaiwai. In cores A2-A5 this top layer was described as a reddish black (10YR 2.5/1) to very dark grey (10YR 3/1) clay to silty clay loam that continued to approximately 80 cm below the surface in cores A2-A4 and to approximately 50 cm below the surface in core A5. The characteristics of the top layer appears to result from soil formation processes, human deposition, and low-energy flood transport mechanisms. The layers beneath this increase in gravel, pebble, and cobble content with depth until the basal layer is reached at approximately 2.1 m below surface. In the basal layer sand size particles increase in abundance, with silt and clay particles also present. This sequence likely represents a depositional history similar to the Olo site (Y2-25) located 750 m to the east. The basal cultural layer is comprised of anthropogenic beach sand and artifacts with upper layers containing a mix of colluvial and alluvial sediments and artifacts. Many of these artifacts, save for those in the top portion of the first layer, may be transported from their location of initial deposition. This transportation is evident in the several water-worn sherds recovered.

4.2.1.3 Site Y2-25: Olo

Olo is the name given to the coastal flat situated between Yalobi village and the Ratu Naivalu Memorial School on the shores of Yalobi bay. Olo is slightly higher in elevation than surrounding areas and thus was not completely inundated during sea level high-stands over the last 3,000 years. The ancient shoreline is preserved in subsurface paleobeach deposits toward the back of the coastal flat.

Presently, Olo consists of a small dune fronting the coastal flat that is drained by a creek to the west (Figure 4.4). Excavations conducted since 1994 have sampled the earliest habitation deposits occurring in the paleobeach sand. Excavations have concentrated on these deposits within a small area (Figures 4.5 and 4.6) that is far enough from the shoreline so that the paleobeach deposit is both above the water-table and capped by only a small amount of colluvial and alluvial sediments.

As discussed by Hunt et al. (1999:22-24), all excavation units reveal a broadly similar stratigraphic profile (Figure 4.6). The topmost Layer I is a colluvial terrigenous deposit of poorly sorted muddy, sandy, gravel (terminology follows Folk [1974]) with a few artifacts. Layer I has some internal variation: greater concentrations of cobbles and beds of clay-silt with fewer gravel and cobble inclusions. Below Layer I, Layer II is a mixed sand and clay-silt deposit with abundant artifacts. The basal Layer III is calcareous beach sand with beach rock, branch coral, and very few artifacts.

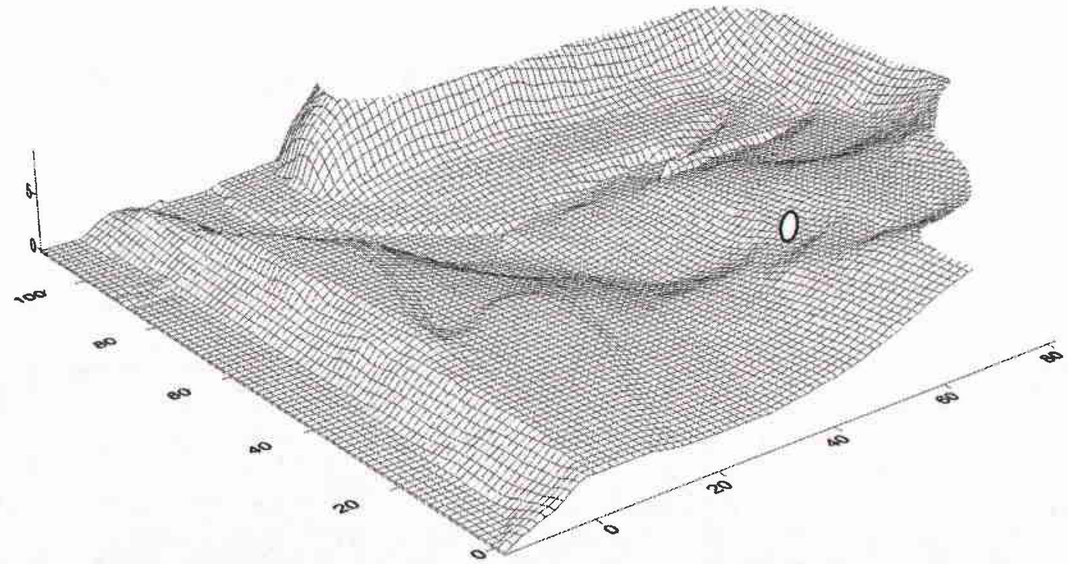


Figure 4.4. Perspective view of Olo coastal flat (Y2-25) looking northwest. Circle denotes excavation area. Scale in meters with elevation exaggerated 3.5X.

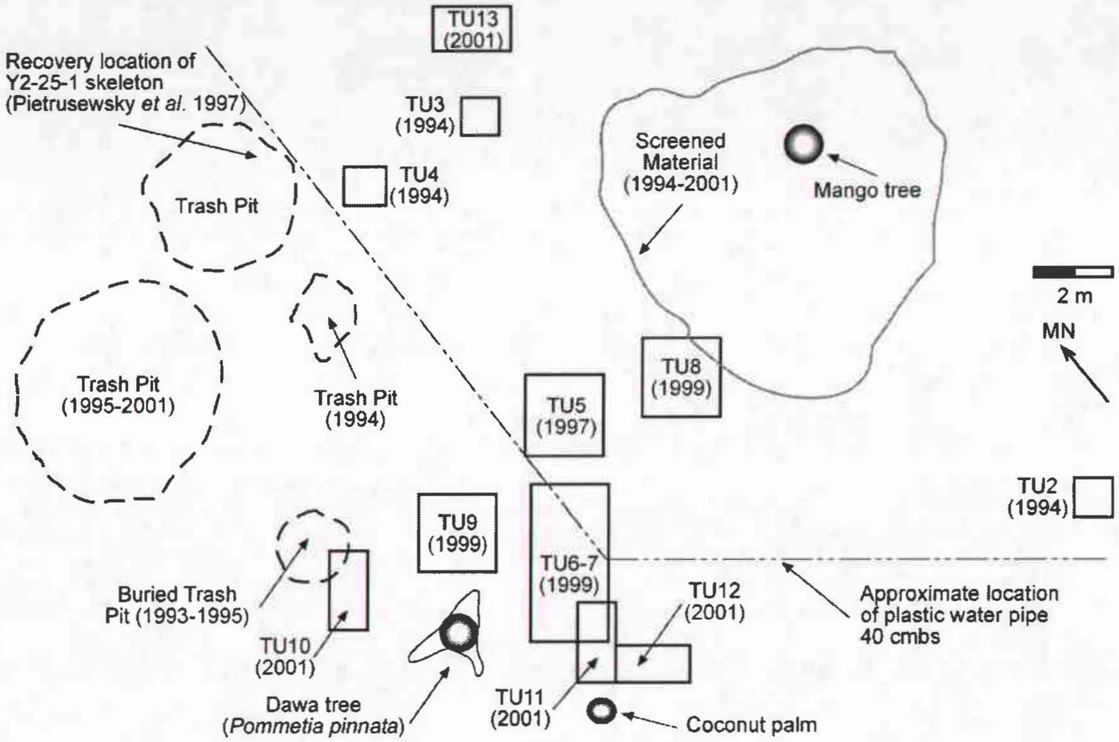
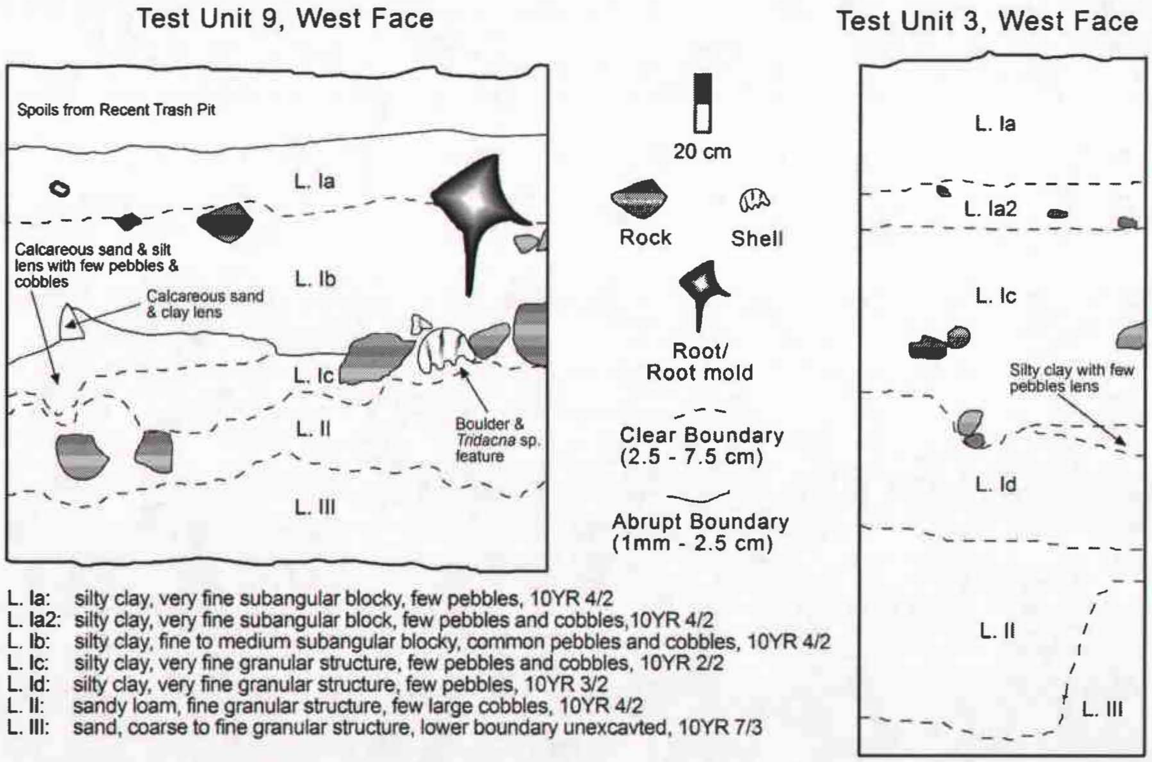


Figure 4.5. Plan map of Olo (Y2-25) excavations. TU 1 is outside the boundaries of this map.

Hunt et al. (1999:22-24) suggest a hypothetical reconstruction for the deposition of sediments at Olo. The calcareous sand beach (Layer III) was present during initial habitation of Olo and was likely protected from the surf by a low dune ridge. Occupation took place on this surface and included the construction of features such as post holes, midden dumps, the interment of burials, as well as the deposition of portable artifacts. Layer II is the primary result of this occupation and is an accretionary deposit composed of anthropogenic sediments. The top surface of Layer II appears to be truncated by a high-energy depositional event as evidenced by channels and pockets cut into Layer II, many then filled with a finely sorted clayey sediment of terrigenous origin. Above this Layer I-II interface larger, poorly sorted sediments were deposited likely through mass wasting from the slopes surrounding Olo. The Layer 1-II interface is occasionally altered by crab burrows and root disturbances.

The depositional history of Layers III and II suggest that the positions of artifacts within these layers are a product of their initial depositional events. An unknown number of artifacts in Layer I, however, have been re-deposited from their primary depositional environment through mass wasting events and subsequently mixed through pedoturbation. The lack of clearly demarcated soil horizons in Layer I also suggests that this deposit is undergoing continuing sedimentation and pedoturbation (Holliday 1992).



L. Ia: silty clay, very fine subangular blocky, few pebbles, 10YR 4/2
L. Ia2: silty clay, very fine subangular block, few pebbles and cobbles,10YR 4/2
L. Ib: silty clay, fine to medium subangular blocky, common pebbles and cobbles, 10YR 4/2
L. Ic: silty clay, very fine granular structure, few pebbles and cobbles, 10YR 2/2
L. Id: silty clay, very fine granular structure, few pebbles, 10YR 3/2
L. II: sandy loam, fine granular structure, few large cobbles, 10YR 4/2
L. III: sand, coarse to fine granular structure, lower boundary unexcavted, 10YR 7/3

Figure 4.6. Representative Olo (Y2-25) profiles, west faces of Test Units 3 and 9.

4.2.1.3.1 Cultural Material Recovered from Y2-25

A variety of materials have been recovered from all depositional layers at Olo. This section summarizes primarily those materials from Layers II and III as these units represent sustained occupation of the site with artifacts representing *in situ* deposition..

The earliest human occupation of Olo occurred sometime after about 2760 BP based on two radiometric dates on charcoal from the base of Layer II in Test Unit (TU) 3 and one date on human skeletal material recovered from a trash pit exposing Layers II and III. One of the samples (Beta-86839) from TU3 consists of dispersed wood charcoal collected from the undulating base of Layer II (179-238 cm below surface)and is dated c. 2760-2360 cal. BP at 2σ (Table 4.14). The second sample (Beta-86840) from TU3 consists of dispersed wood charcoal pieces recovered from the fill of a pit cut into the Layer III calcareous beach sand (pit base at 196 cm below surface). The pit fill is a sand-silt-clay mix containing large quantities of charcoal, internal ash lenses, and abundant fish bone and marine shell. Extended counting of the pit fill sample returned a date range of c. 2850-2350 cal. BP at 2σ (Table4.14). The third date derives from a sample of human bone recovered from a trash pit adjacent to TU3 (see Figure 4.5). The burial was placed in a pit dug into the paleobeach deposit (Layer III) and the pit contained fill from Layer II including pottery sherds and midden (Pietrusewsky 1997). The sample (CAMS-24946) returned a date range of c. 2760-2360 cal. BP at 2σ (Table 4.14). Using Bayesian rules for combinations of probabilities (Doran and Hodson 1975), the combined 2σ age range for the three dated samples is 2760-2470 cal. BP.

The large artifact assemblage from Layers II and III at Olo includes ceramics, formal lithic tools (e.g., adzes, hammer-stones), flakes, and cores, shell tools (e.g., "peelers") and ornaments (e.g., *Trochus* sp. bands and shell pendants), coral abraders and "net-weights," shellfish remains and midden material of fish, bird, mammal, reptile or amphibian, and human bone (shellfish and faunal materials from 2001 excavations not yet analyzed). The fish assemblage suggests most marine procurement took place in the nearshore reef ecosystem. The low diversity and abundance of non-fish vertebrate remains is represented by human, rat (*Rattus* sp.), turtle, and fruit bat (Hunt, et al. 1999). A single specimen of *Gallus gallus* was recovered from Layer II, otherwise no additional domesticates such as dog or pig have been identified in the Layer II and III assemblage.

Ceramics from the Olo habitation deposits (Table 4.5, Figure 4.7) are broadly similar in rim forms and decoration compared to terminal Lapita assemblages found throughout Fiji (e.g., Best 1984; Birks 1973; Burley and Dickinson 2004). Rim sherds suggest that shouldered pots with everted and expanded rims were prevalent. Many of these shouldered pots also exhibit either notched rims designated in Table 4.6 as both End-tool and Side-tool impression, or wiping around the neck. Inverted and everted bowls are also present along with a few slightly carinated body sherds, pot stands, and handles.

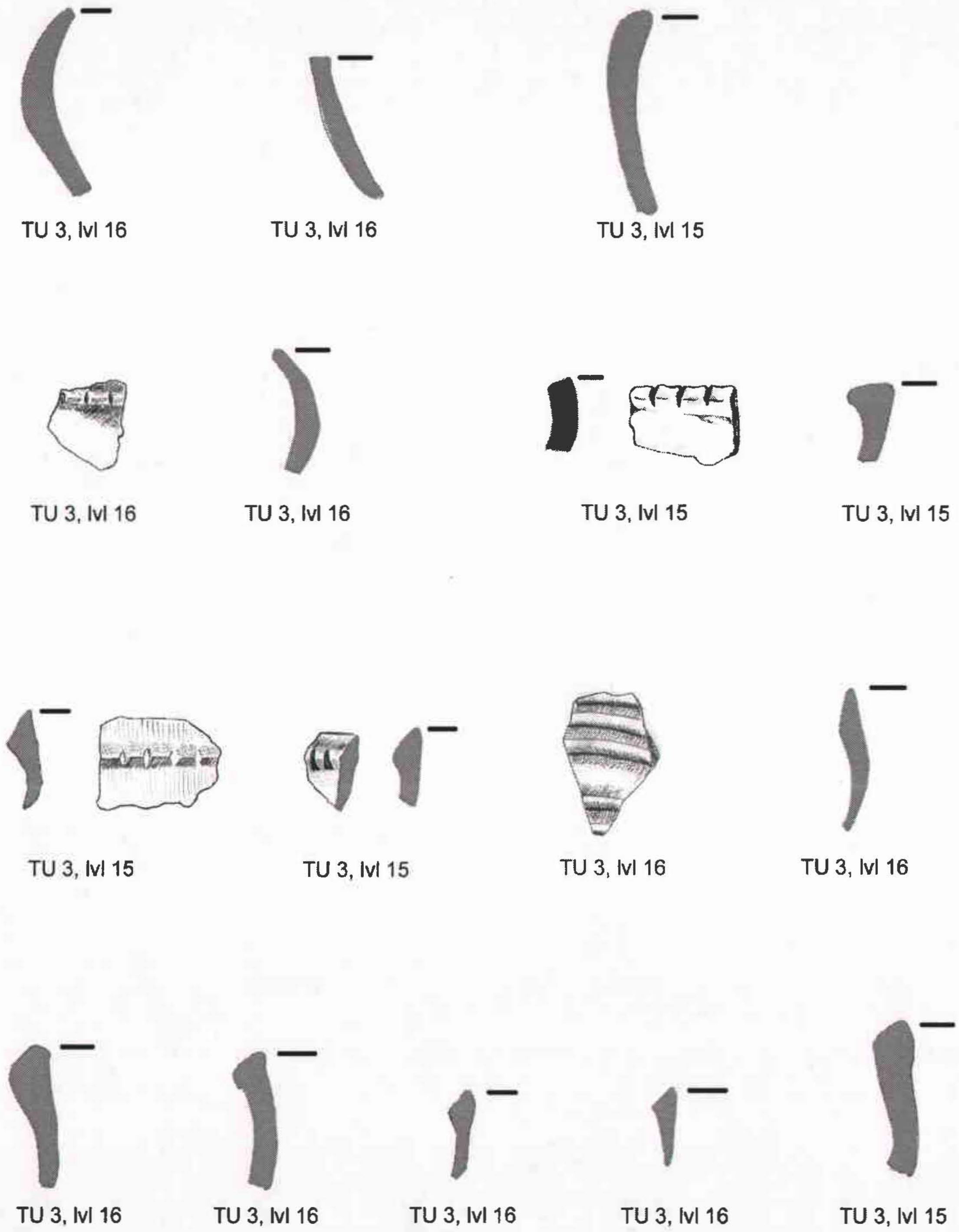


Figure 4.7. Examples of surface modification and rim cross-section variation from Olo (Y2-25). Number below each sherd refers to Test Unit and level. Black bars next to rim cross-sections designate vessel interior.

Table 4.5. Olo (Y2-25) ceramic assemblage characteristics: Layers II and II, Test Units 3 (1x1 m), 5 (2x2 m), and 9 (2x2 m).

Provenience	Body	Neck	Rim	Total	Appliqué fillet & End-tool	Appliqué	PIPR	PICH	PI-various	Asymmetric Incision	Symmetric Incision	End-tool Impression	Side-tool Impression	Molding	Carinated	Wiping	Pot stand/leg	Handle	Slip
TU3 L.II, lvl. 15	893	40	116	1049			12	3			1	2	1			9			
TU3 L.II, lvl. 16	1706	72	119	1897			4	1	2	1		1	1	2		18	1		
TU3 L.II, lvl. 17	289	7	12	308												4			
TU5 L.II, lvl. 8	738	36	45	861			1	3								18		1	
TU5 L.II, lvl. 9	941	47	85	1074			2		1			5				23			
TU5 L.II, lvl. 10	1227	59	102	1388	1							1	6		1	25	1		3
TU9 L.II, lvl. 2	1064	39	49	1152		1	9		1		1	4			1	20			
TU9 L.II, lvl. 3	825	22	34	881			1	1				1				9			
TU9 L.II, lvl. 4	921	28	42	991			2	6	1	1	1	4	2			9			2
TU9 L.II, lvl. 5	823	35	44	902									4		1	7			

Table 4.5 (continued). Olo (Y2-25) ceramic assemblage characteristics.

Provenience	Body	Neck	Rim	Total	Appliqué fillet & End-tool	Appliqué	PIPR	PICH	PI-various	Asymmetric Incision	Symmetric Incision	End-tool Impression	Side-tool Impression	Molding	Carinated	Wiping	Pot stand/leg	Handle	Slip
TU9 L.II, lvl. 6	715	26	32	773								4				15	2		
TU9 L.II, lvl. 7	556	20	44	620			3	1			1	2				13			
TU9 L.II, lvl. 8	268	12	24	304	2				2		1		1			7		1	
TU9 L.II, lvl. 9	156	7	11	173			1		1						1	1			
TU9 L.II, lvl. 10	93	8	10	111								2				4			
TU9 L.II, lvl. 11	70	7	9	86					4			1				3			1
TU9 L.III lvl. 12	9	1	1	11								1							
TU9 L.III lvl. 13	22	2	1	24												1	1		
TU9 L.III lvl. 14	10	2	1	13												2			

4.2.1.4 Site Y2-39: Qaranicagi

Qaranicagi means "cave of the winds," the name give to this location as the cave was used in recent times as a refuge during cyclones. Qaranicagi sits approximately 100 m above sea level overlooking Yalobi bay on Waya Island's southern coast. The cave comprises approximately 255 m^2 behind the drip-line and contains 2.6 m of cultural deposits examined by three test units (Figure 4.8). Today, the area surrounding Qaranicagi and the slope down to Yalobi village is used mostly for gardening. Abundant ceramics and other artifacts are found throughout these gardens.

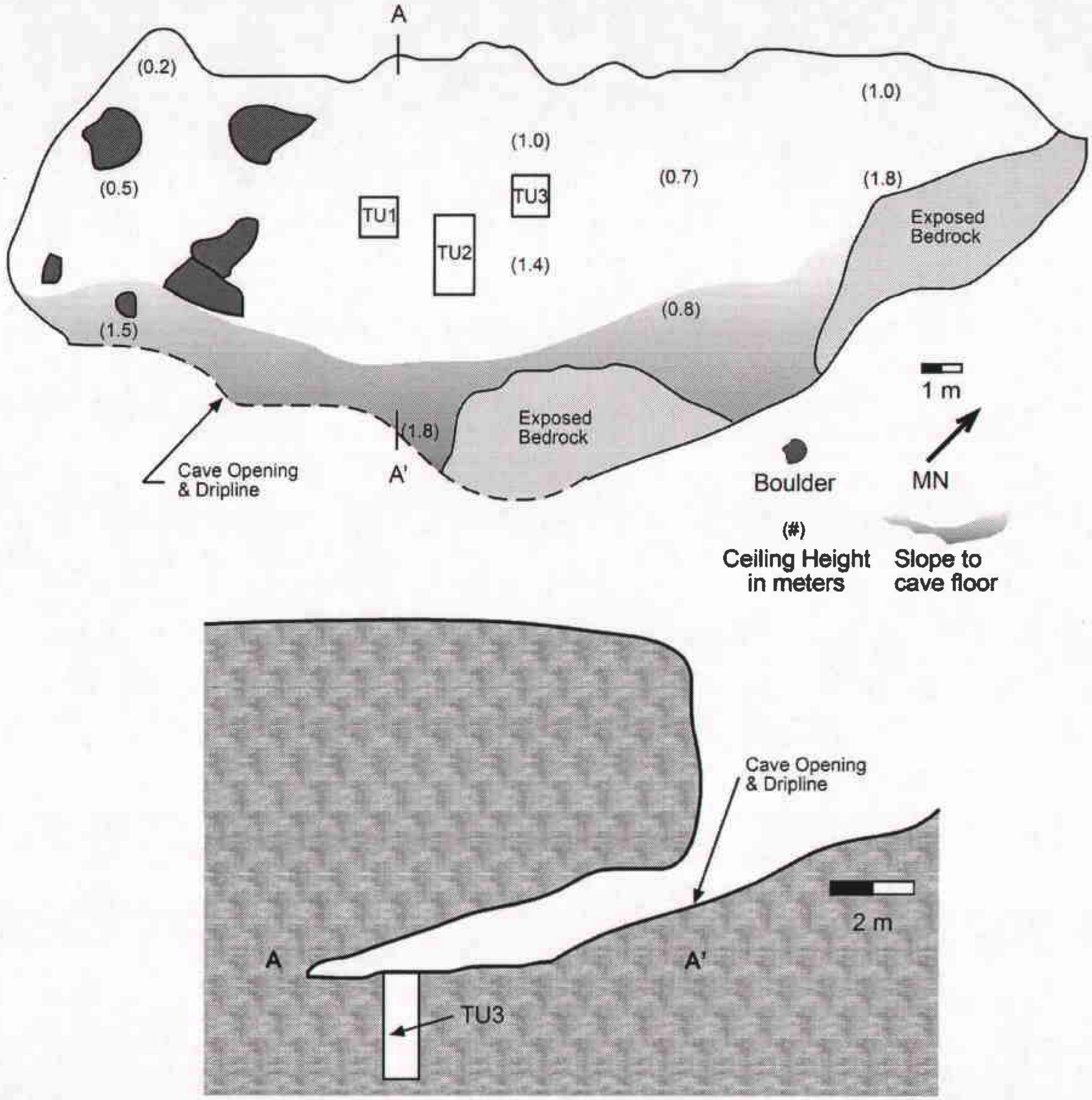
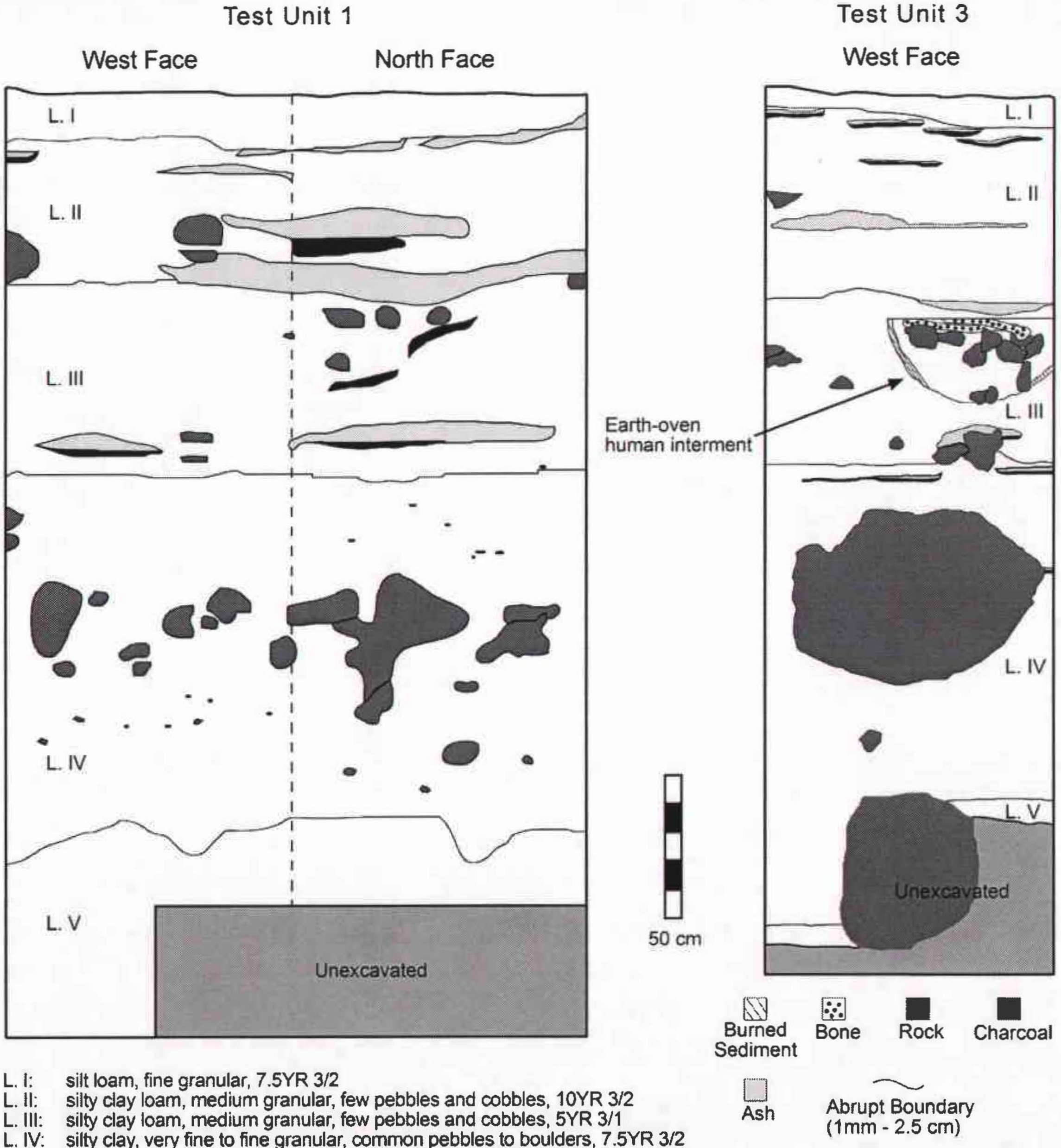


Figure 4.8. Plan map and cross-section of Qaranicagi (Y2-39).

4.2.1.5.1 Cultural Material Recovered from Y2-39

The three test units excavated at Qaranicagi revealed a stratified deposit with abundant fire features, ceramic, lithic, and faunal material (Cochrane 2002a; Cochrane, et al. 2004; Hunt, et al. 1999). The identifiable human history at Qaranicagi begins with the deposition of ceramics and charcoal on the original cave floor, approximately 2.6 m below the present surface (Figure 4.9).



L. I: silt loam, fine granular, 7.5YR 3/2
L. II: silty clay loam, medium granular, few pebbles and cobbles, 10YR 3/2
L. III: silty clay loam, medium granular, few pebbles and cobbles, 5YR 3/1
L. IV: silty clay, very fine to fine granular, common pebbles to boulders, 7.5YR 3/2
L. V: silty clay, very fine granular, few pebbles, 10YR 3/3

Figure 4.9. Qaranicagi profiles from Test Units 1 and 3. The north face of TU 1 is toward the back of the cave.

The excavation units at Qaranicagi all reveal a similar depositional history described by colluvial, gradual slope-wash, and human activity (Hunt, et al. 1999). The deposits in TUs 1 and 3 contain relatively little to no slope-wash sediments from outside the cave as they are near the back of the cave. In contrast, the southern half of TU 2 (toward the cave opening, see Figure 4.8) exhibits deposits interfingered with the primarily colluvial and anthropogenic sediments in the northern half of the unit (Layers I-IV as depicted in Figure 4.9). The interfingered deposits likely represent deposition of sediments from outside the cave primarily resulting from slope-wash. The interfingered deposits occur approximately 120 cm below the ground surface to 10 cm below the ground surface. This includes excavation levels 1-12 in TU 2.

The topmost Layer I is a silt loam with very few 0.5 cm roots. The top 5 cm of Layer I is very soft and represents recent disturbance from surface vines and human activity. Layer II is a slightly hard silty clay loam with no roots and abundant marine shell midden. Layer III is similar to layer II, but is differentiated through a color difference and less abundant shellfish remains, both possibly due to differences in human activity during Layer III deposition relative to other layers. Layer IV is a hard silty clay with a higher clay content and lower overall artifact abundance than the upper layers (although some excavation levels contain many ceramics). An episode of roof-fall is also evident from the cobbles and boulders at similar depths in layer IV in all test units. Layer V is a culturally sterile, hard silty clay.

Geoarchaeological analysis of the Qaranicagi sediments (Bauer 2002; Hunt, et al. 1999) indicates a relatively stable and ongoing low energy depositional history. The pH values of the different layers at Qaranicagi range from 6.0 to 7.4, with a slight decrease in alkalinity with depth. Differential artifact preservation due to variation in pH was likely not a factor at Qaranicagi.

The earliest human occupation at Qaranicagi likely began sometime after 2750 BP, contemporary with the initial human occupation of Olo (Y2-25). The earliest use of Qaranicagi and its continued use is attested by multiple features, a continuous artifact sequence and seven radiocarbon dates distributed across excavation depths (Table 4.14). Six of the radiocarbon dates were obtained from charcoal recovered in excavation by Hunt (first reported in Hunt, et al. 1999) and a seventh date was obtained from a single chunk of wood charcoal from an earth-oven feature in TU 3 containing a dismembered and interred adolescent (Cochrane, et al. 2004). The four radiocarbon date ranges obtained from charcoal in levels 23-21, and level 17 in TU1 overlap at two standard deviations. Additionally, the date obtained from the charcoal in level 21 is out of sequence as analysis returned an older range than the charcoal in level 22. Despite these problems, the oldest deposits at Qaranicagi seem likely to record a human presence by approximately 2750 BP as ceramics found in the lowest levels share decorative characteristics with other Fijian assemblages of this age (e.g., Y2-25 and see Best 1984; Birks 1973; Burley and Dickinson 2004). By joining the probability distributions of the age-ranges obtained for levels 23-21, the combined 2σ age range for these three samples is 2760-2430 cal. BP (88.4%) and 2420-2360 cal. BP (7.0%). The remaining radiocarbon dates from charcoal in levels 17, 12, 8 (earth-oven feature), and 6 decrease in age toward the present cave surface.

Qaranicagi contains a large artifact assemblage of ceramics, lithic flakes, midden comprised of shellfish and faunal remains of fish, turtle, birds, reptiles, and mammals including humans. The Qaranicagi midden includes a similar range of fish taxa as Olo with the earliest specimens (Scaridae and Lethrinidae) occurring in excavation level 21, perhaps a few hundred years after the first use of the cave. Level 23, the deepest cultural deposit (i.e., with ceramics), also contains *Rattus* sp. Other vertebrates recovered from the Qaranicagi deposits include *Rattus exulans* (by level 16), turtle (by level 17), *Pteropus* sp. (by level 18), *Sus scrofa* (by level 15), and six avian species intermittently present in the deposits. Fragmented human bone, some burned, incorporated in the midden occurs sporadically in levels 15 through 5 (Pietrusewsky, et al. 2004). An earth-oven with an adolescent interment was also encountered in level 8. The individual's head, hands, feet, and most of the vertebral column were missing and cut marks were distributed across several elements (Cochrane, et al. 2004; Pietrusewsky, et al. 2004). Lithic flakes and cores were also found throughout the Qaranicagi deposits. No formal tools were recovered.

Ceramics are the most numerous artifacts at Qaranicagi (total for TUs 1-3 is 5,478) found in the deepest cultural levels to the present surface. Thus, the ceramic sequence at Qaranicagi presents an unbroken sequence of ceramic change from initial colonization of Waya Island up to the present (Table 4.6). Like Olo, the earliest ceramics at Qaranicagi include shouldered pots with everted rims and expanded lips, inverted and everted rim bowls, and surface modifications such as wiping, slipping, and side-tool impressions and shell arcs on rims (Figure 4.10). Carved paddle-impressed ceramics appear for the first time in level 17 (2750-2300 cal. BP) and continue until level 9 (760-660 cal. BP date for level 8), with one paddle-impressed ceramic in level 1 of TU 2. After level 19, expanded-rims are no longer present, but shouldered everted-rim pots continue, as well as everted and inverted rim bowls. Rims similar to Best's (2002; 1984) "kuro" are present by level 14. Various kinds of end-tool (e.g., fingernail) and side-tool impression occur in slightly greater frequency across levels 16-12. By the end of the sequence surface modifications include appliqué, and various incised and impressed designs on shouldered everted-rim pots and everted and inverted bowls.

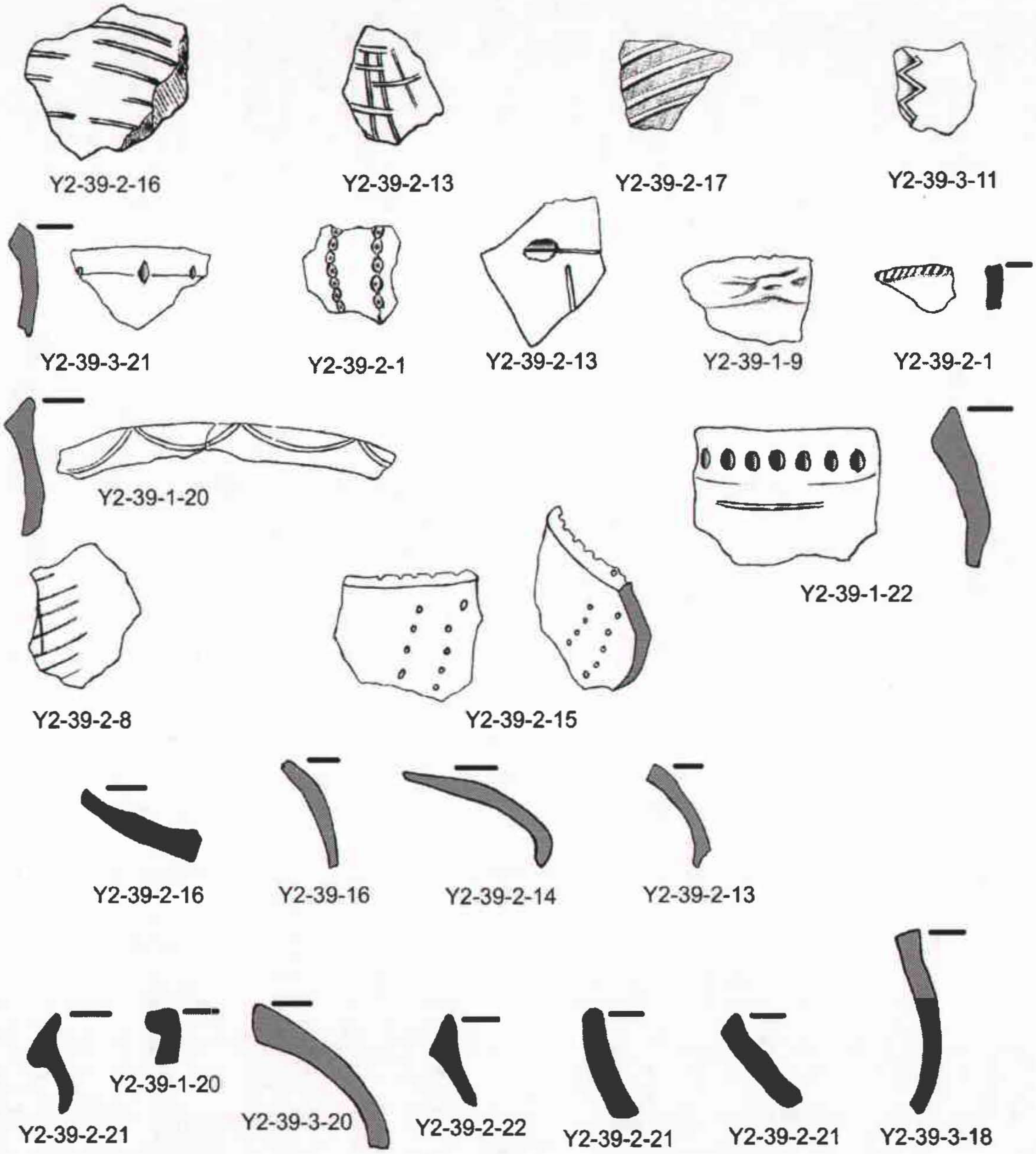


Figure 4.10. Examples of surface modification and rim cross-section variation from Qaranicagi (Y2-39). Last number below each sherd refers to excavation level. Number to the left designates Test Unit. Various kinds of paddle-impressing on sherds in top row. Black bars next to rim cross-sections designate vessel interior.

Table 4.6. Qaranicagi (Y2-39) ceramic assemblage characteristics: Test Units 1 (1x1 m), 2 (2x1 m), and 3 (1x1 m)

Provenience	Body	Neck	Rim	Total	Appliqué fillet & End-tool	Appliqué	PIPR	PICH	PI-various	Asymmetric Incision	Symmetric Incision	End-tool Impression	Side-tool Impression	End-tool Imp. & Sym. Incision	Molding	Carinated	Wiping	End-tool, rim arc	Slip
TU1, lvl.1	84	1	3	80							1								
TU1, lvl.2	139	2	3	134							2								
TU1, lvl.3	65	2		63		2													
TU1, lvl.4	89			89															
TU1, lvl.5	118	2	1	115															
TU1, lvl.6	140	1		139															
TU1, lvl.7	39	2	3	34															
TU1, lvl.8	9			9															
TU1, lvl.9	8	1	1	6		1		1											
TU1, lvl.10	0			0															
TU1, lvl.11	78	1	3	74			1	1											
TU1, lvl.12	112	1	2	109			1	2						1					
TU1, lvl.13	44	2		42			2	3			1	1							
TU1, lvl.14	47	2	3	42			4												
TU1, lvl.15	280	21	15	244			3						3		1				

Table 4.6 (continued). Qaranicagi (Y2-39) ceramic assemblage characteristics

Provenience	**Body**	**Neck**	**Rim**	**Total**	**Appliqué fillet & End-tool**	**Appliqué**	**PIPR**	**PICH**	**PI-various**	**Asymmetric Incision**	**Symmetric Incision**	**End-tool Impression**	**Side-tool Impression**	**End-tool Imp. & Sym. Incision**	**Molding**	**Carinated**	**Wiping**	**End-tool, rim arc**	**Slip**
TU1, lvl.16	302	20	28	254			4						4						
TU1, lvl.17	68	2	5	61															
TU1, lvl.18	11			11															
TU1, lvl.19	24			24															
TU1, lvl.20	195	17	5	173											1			1	
TU1, lvl.21	141	7		134															
TU1, lvl.22	72	4	5	63									2				4		
TU1, lvl.23	1			1															
TU1, lvl.24	0			0															
TU1, lvl.25	0			0															

Table 4.6 (continued). Qaranicagi (Y2-39) ceramic assemblage characteristics.

Provenience	Body	Neck	Rim	Total	Appliqué fillet & End-tool	Appliqué	PIPR	PICH	PI-various	Asymmetric Incision	Symmetric Incision	End-tool Impression	Side-tool Impression	End-tool Imp. & Sym. Incision	Molding	Carinated	Wiping	End-tool, rim arc	Slip
TU1, lvl.26	1			1															
TU2,lvl.1	209		2	211	7		1					1	1						
TU2,lvl.2	137		3	140	2							11							
TU2,lvl.3	58		1	59								1							
TU2,lvl.4	304	2		306															
TU2,lvl.5	143			143															
TU2,lvl.6	111	2		113								1							
TU2,lvl.7	24			24															
TU2,lvl.8	137	8	5	150							1								
TU2,lvl.9	2			2															
TU2,lvl.10	1			1			1												
TU2,lvl.11	32	2	3	38			1												
TU2,lvl.12	239	10	13	262			14						1						
TU2,lvl.13	274	5	5	284			7	24				1	1						
TU2,lvl.14	28	3	1	32			1	2											
TU2,lvl.15	142	4	8	154			6					2	1						
TU2,lvl.16	178		5	183			7						1						
TU2,lvl.17	73	15	18	106			1					1							

Table 4.6 (continued). Qaranicagi (Y2-39) ceramic assemblage characteristics.

Provenience	Body	Neck	Rim	Total	Appliqué fillet & End-tool	Appliqué	PIPR	PICH	PI-various	Asymmetric Incision	Symmetric Incision	End-tool Impression	Side-tool Impression	End-tool Imp. & Sym. Incision	Molding	Carinated	Wiping	End-tool, rim arc	Slip
TU2,lvl.18	93	1	4	98												1			
TU2,lvl.19	38		1	39															
TU2,lvl.20	137		1	138															
TU2,lvl.21	135	5	7	147															
TU2,lvl.22	45	1	3	49									2						1
TU2,lvl.23	29		2	31															
TU2,lvl.24	2			2															
TU3,lvl.1	81	1		82	1														
TU3,lvl.2	15		1	16															
TU3,lvl.3	47			47															
TU3,lvl.4	23			23															
TU3,lvl.5	21			21															
TU3,lvl.6	17	2		19															
TU3,lvl.7	7	1		8															
TU3,lvl.8	139	8	5	152															
TU3,lvl.9	0			0															
TU3,lvl.10	25			25															
TU3,lvl.11	133	2	1	136			3	1											
TU3,lvl.12	51			51			8		3										

Table 4.6 (continued). Qaranicagi (Y2-39) ceramic assemblage characteristics.

Provenience	Body	Neck	Rim	Total	Appliqué fillet & End-tool	Appliqué	PIPR	PICH	PI-various	Asymmetric Incision	Symmetric Incision	End-tool Impression	Side-tool Impression	End-tool Imp. & Sym. Incision	Molding	Carinated	Wiping	End-tool, rim arc	Slip
TU3,lvl.13	10			10			1		3										
TU3,lvl.14	11	1		12			1												
TU3,lvl.15	30	6	2	38			3												
TU3,lvl.16	26		1	27			2												
TU3,lvl.17	8			8															
TU3,lvl.18	2			2															
TU3,lvl.19	27	1	3	31															
TU3,lvl.20	37		8	45															
TU3,lvl.21	8		1	9									1						
TU3,lvl.22	12			12															
TU3,lvl.23	3			3															

4.2.1.6 Site Y2-45: Nasau

Nasau is an area on the upland slopes of eastern Waya with surface architecture and surface ceramic deposits underneath a canopy of banana, coconut, and breadfruit trees. A series of cobble and boulder faced terraces are constructed on the gentle slope (east-west) and run north-south for approximately 50 m. At least 12 rectilinear platforms (*yavu*) are constructed atop these terrace. Each platform is approximately 1 m higher and faced with three to four course of cobbles and boulders. In 1997 the platforms were under cassava (*Manihot* sp) cultivation. Ceramic sherds, as well as shell and bone midden are scattered across the surface. A single, large *Trochus* sp. shell was removed from just below the ground surface on one of the terraces. Radiocarbon analysis of the shell (Wk-6485) returned a date range of c. 630-330 cal. BP (Table 4.14).

Ceramic surface collections were made at Nasau by Best and Irwin in 1978 and by University of Hawai'i teams in 1990 and 1997. Collection strategies used by Best and Irwin and the 1990 team are unknown. These efforts may have concentrated on decorated sherds influencing the high percentage of such sherds in the assemblage. In 1997 surface collection proceeded along transects spaced approximately 3 m apart. The small amount of leaf-litter was removed from transect lines to increase surface visibility. Ceramic variation at Nasau is recorded in Table 4.7 and Figures 4.17 and 4.18 and includes many paddle-impressed sherds with fine parallel ribs. Vessel forms include strongly everted *kuro*, slightly everted-rim shouldered pots, and parallel rim bowls.

Table 4.7. Nasau (Y2-45) sherd types and decoration.

Provenience	Body	Neck	Rim	Total	Appliqué	PIPR	PICH	Symmetric Incision	End-tool Impression	Side-tool Impression
surface	121	10	24	155		43		11	-	-

4.2.1.7 Site Y2-46: Natavosa

Natavosa (Figure 4.11) comprises a ridgeline above Yalobi village with a single eroded rectilinear earthen platform (*yavu*) and surface scatter of ceramics and lithics. The site likely served a defensive purpose. A series of eroded terraces (one section with rock facing) descends the eastern slope from the ridge line. In 1994, a University of Hawaiʻi team collected ceramics and lithics from the site surface and excavated a small test unit (1x1 m) in the earthen platform (Hunt, et al. 1999). Surface ceramics were collected by walking along the narrow ridge-line (approximately 4 m wide) with many ceramics exposed in a series of eroded surfaces at the northern end of the site. In addition to the ceramics, two adzes and one adze fragment were recovered (two quadrangular and one of lenticular cross-section).

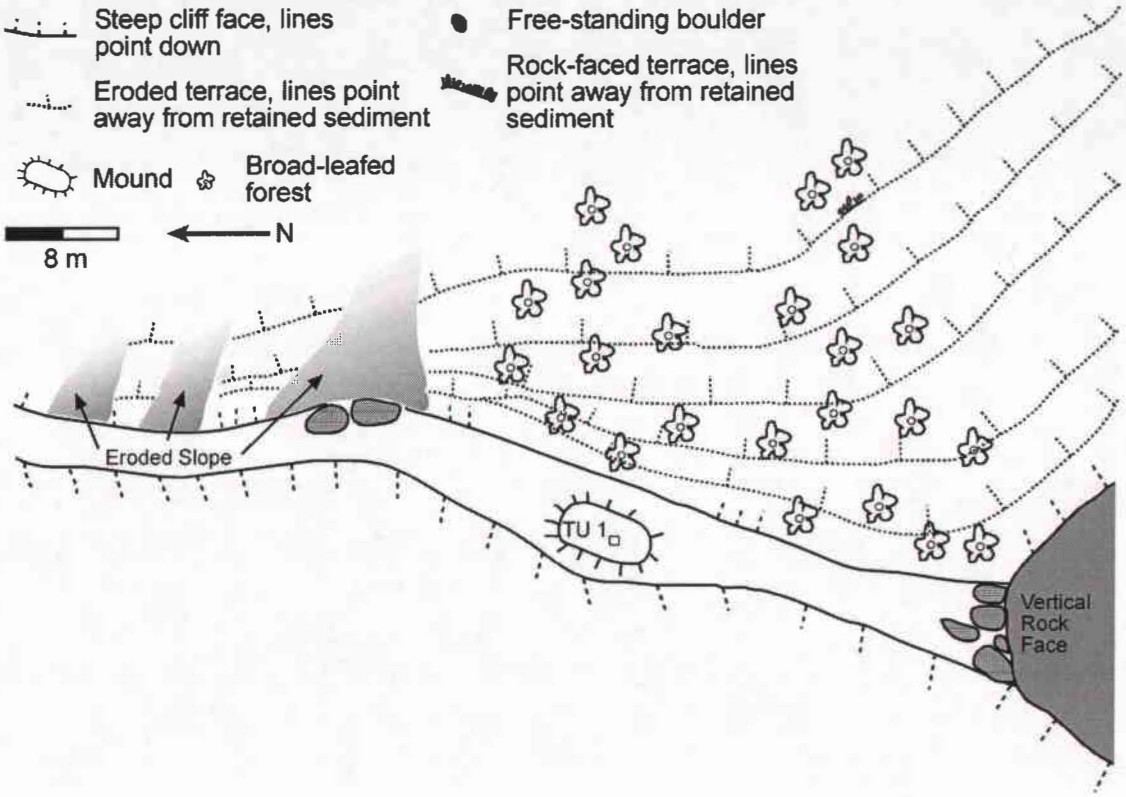


Figure 4.11. Plan map of Natavosa (Y2-46).

The excavated test unit revealed a shallow deposit with a few sherds and 1 shell fragment in the top 10 cm of the clay-loam matrix (see Hunt, et al. 1999). Below this the deposit turned increasingly to a larger-grained decomposing bedrock. Charcoal pieces were collected from a clayey pocket at 12 cm below the ground surface. Radiocarbon analysis on these materials (Beta-93971) returned a date range of 550-100 cal. BP (Table 4.14).

Ceramic surface collection and excavation at Natavosa recovered *kuro* rim forms, parallel rim bowls, and ceramics with end-tool impressed rims, molding, and incising (Table 4.8 and Figures 4.17 and 4.18)

Table 4.8. Natavosa (Y2-46) sherd types and decoration.

Provenience	Body	Neck	Rim	Total	Appliqué	Molding	PIPR	PICH	Symmetric Incision	End-tool Impression	Side-tool Impression
surface	36	1	7	44	-	1	-	-	3	1	-

4.2.2 Archaeological Sites of Naviti Island

Eighty-eight archaeological sites have been identified on Naviti Island and include isolated ceramic scatters, defended mountain tops, beach flat sites, and ridgeline occupations. Ceramics from the surfaces of these sites were collected by Best and Irwin in 1978 and during a single additional field season by the University of Hawaiʻi in 1990. Three sites are summarized in this section.

4.2.2.1 Sites Y2-58, 61, and 62

Sites Y2-58 and 61 were visited by Best and Irwin in 1978 and have since not been re-examined. There is no additional information available for these sites. Site Y2-62 was revisited by University of Hawaiʻi teams in 1990. Site Y2-62 is a ceramic scatter on a prograding coastal flat. Surface collection at this site proceeded along equally spaced transects (approximately 3 m) and augmented the earlier Best and Irwin work. Ceramics from all these Naviti sites reported are listed in Table 4.9.

Ceramic variation across the Naviti surface assemblages includes a wide-range of decoration with various forms of paddle-impressing, molded scallop-shapes on rims and molded ribs on necks, appliqué, incising, and tool impressions (Figures 4.17 and 4.18). Vessel forms, as indicated by rim sherds, consist of *kuro*, bowls, both inverted and everted, with parallel rims and rims that are expanded in a variety of ways. Based on decorative and formal characteristics, the Naviti assemblages may have been deposited over the last 600 – 500 years.

Table 4.9. Ceramic assemblage characteristics from Naviti Island surface sites (Y2-58, 61, and 62)

	Body	**Neck**	**Handle**	**Rim**	**Total**	**Molding**	**Appliqué**	**Molding, End-tool, & Symm. Incision**	**Appliqué & Side-tool Impression**	**Appliqué & End-tool Impression**	**PIPR**	**PICH**	**PI - Various**	**Asymmetric Incision**	**Symmetric Incision**	**End-tool Impression**	**Side-tool Impression**	**Wiped**	**Symmetric Incision & End-tool**
Y2-58, surface	389	87	1	70	547	3		1	2	1	20	18	3	-	27	33	3	-	-
Y2-61, surface	93	58	-	70	221	2	-	-	-	-	5	4	-	-	12	27	-	-	-
Y2-62, surface	216	17	-	60	293	1	-	-	-	-	3	-	-	2	12	17	4	-	1

4.2.3 Archaeological Sites of Matacawa Levu Island

Best and Irwin identified eighteen archaeological sites on Matacawa Levu Island, one of several small islands in a group between Nacula Island and Naviti Island. University of Hawai'i teams have not visited Matacawa Levu and information about these sites is limited.

4.2.3.1 Sites Y1-1 and Y1-4

Site Y1-1 is a ceramic scatter on a prograding coastal flat at the southern end of Matacawa Levu and site Y1-4 is a hilltop occupation at the opposite end of the island. The ceramic inventories include paddle-impressed, incised, and end-tool impressed ceramics (Table 4.10 and Figures 4.17 and 4.18) and suggest late occupations perhaps extending back several hundred years. Rim sherds include shouldered, everted-rim pots and everted rim bowls.

Table 4.10. Ceramic assemblage characteristics for sites Y1-1 and Y1-4

Provenience	**Body**	**Neck**	**Rim**	**Total**	**Appliqué**	**PIPR**	**PICH**	**Symmetric Incision**	**End-tool Impression**	**Side-tool Impression**
Y1-1, surface	59	9	6	74		6	3	2	2	-
Y1-4, surface	87	-	3	90	1	-	-	8	3	-

4.2.4 Archaeological Sites of Nacula Island

Seventeen archaeological sites have been identified on Nacula Island, including defended habitation sites on hilltops, open coastal flat habitations, and artifact scatters,.

Of these sites, two have been examined by University of Hawai'i teams and contain assemblages analyzed here.

4.2.4.1 Site Y1-15: Natia

Natia is a large prograding coastal flat just east of Nacula village. Natia is dominated by modern garden vegetation including cassava, banana, and papaya. Prior to the establishment of Nacula village, a small population lived at Natia approximately 50 years ago (elder residents of Nacula village were children at this time) and the remnants of this seaside village are seen in various *yavu* and the deteriorating remains of a concrete-walled church.

In 2002 a series of elevation profiles running perpendicular from the beach to approximately 360 m inland were generated. Seventeen cores were excavated along these transects between 76 and 300 m from the beach in an effort to locate buried cultural deposits. Paleobeach and shell midden deposits were identified approximately 160 m from the present shoreline. Two test units were excavated in 2002 and three in 2003 to explore these deposits (Figure 4.12).

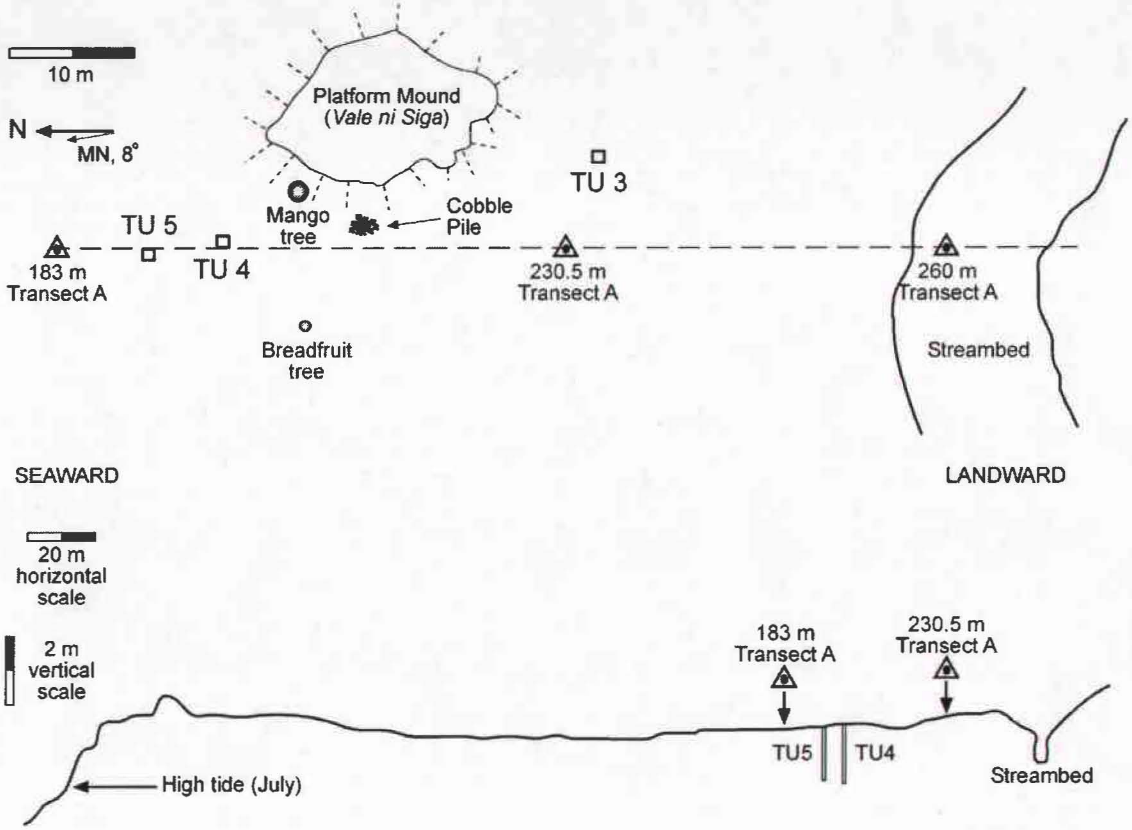


Figure 4.12. Natia (Y1-15) excavations. Plan-view of 2003 excavations at top, with 2002 excavations (not shown) approximately 20 m seaward. Profile of Transect A at bottom.

The five Natia test units (Figure 4.13) reveal a sequence of low-energy alluvial and anthropogenic deposits, shell midden deposits, and paleobeach sediments[12]. The basal Layer IV in each test unit consists of structureless calcareous beach sand with natural shell, coral, and very few artifacts. The basal layer of test unit 5 also contains beachrock (concreted calcareous sand). A structureless loamy sand of Layer III tops the basal layer in all test units. Anthropogenic shell is common in Layer III, as are micro to fine roots. In test units 4 and 5, Layer III is capped by a relatively thin structureless

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[12] TU3 was excavated to a depth of 50 cm and abandoned after a core placed 4 m away encountered several meters of alluvial deposit and no paleobeach sediments.

sandy clay loam, with few micro to fine roots, some charcoal flecking, and abundant anthropogenic shell (25%-40% of inclusions in TU 4). The sandy clay loam Layer II is not present in test units 1 and 2, both placed approximately 20 m seaward of test units 4 and 5. Layer I is the topmost deposit in all units and consists of a columnar structure silty clay with common micro roots and some charcoal flecking. An A horizon has formed in the top 30-40 cm of Layer I. This clay loam horizon exhibits a columnar and blocky structure containing common micro to very fine roots, less than 5% subangular pebbles, and some charcoal flecking. Crab burrows were found in the top layers of several units. Sediment from these disturbances was removed and not included in the screened or analyzed layer matrix.

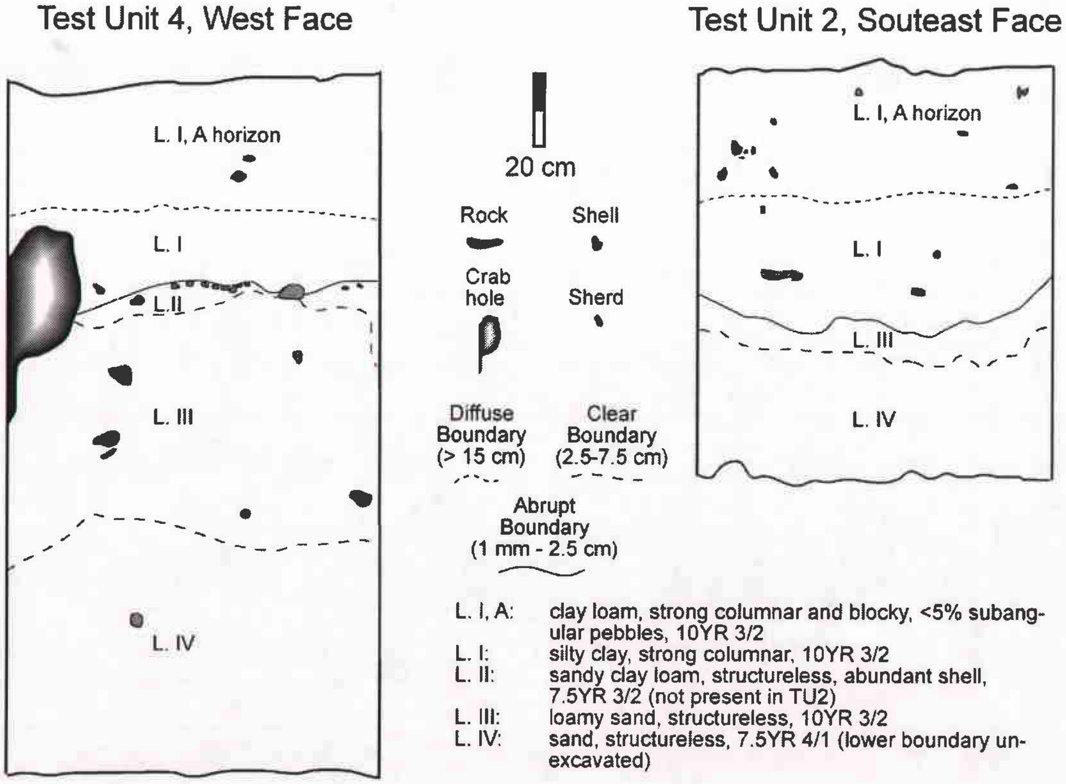


Figure 4.13. Representative Natia (Y1-15) profiles from test units 2 and 4.

The likely depositional sequence for Natia begins with a calcareous sand beach (Layer IV) similar to that described for Olo (section 4.2.1.3). The present land surface at Natia is extensive with slowly increasing elevation from the beach to the inland slopes (see Figure 4.12). And shallow water continues off the beach for approximately 100 m. Thus, the Natia beach inhabited by colonizing populations was probably wider than Olo and may have fronted a more extensive reef flat as well. Artifacts within the basal sandy layers at Natia reflect human use of the area at this time. With sea-level fall over the last several thousand years, alluvial sediment load from two ephemeral (above current water table) streams on the beach flat likely influenced the prograding sequence. Layer III is a combination of anthropogenic and low-energy alluvial deposition (overbank flow) from the ephemeral streams. Layer II appears to be a less-expansive depositional unit (not present in Test Unit 2) perhaps associated with a spatially restricted occupation that included increased marine shell deposition. Layer I represent continued human use of Natia, but with less abundant shell deposition. A relatively sudden change in the depositional environment from Layer II (Layer III in Test Unit 2) to Layer I is indicated by the abrupt stratigraphic boundary separating these layers. The depth of the Layer I A horizon suggest it is a product of current gardening activities. The top 30-40 cm of the ground surface is routinely hand-tilled with heavy-duty pitchforks to create small earthen cassava mounds.

In addition to the calcareous sand grains, sediments in TUs 1-5 contain silts and clays with only very occasional water-worn pebbles and cobbles. This suggests that depositional regimes throughout the human occupation of Natia were primarily low-energy, probably with occasional overbank flood deposits. Populations inhabited Natia during coastal progradation as artifacts and shell midden occur in the upper layers. Unlike Olo, colluvial sedimentation or mass wasting events are not part of the Natia sequence as elevation changes at the back of the coastal flat are too gradual.

4.2.4.1.1 Cultural Material Recovered from Y1-15

The earliest human occupation at Natia was generally contemporaneous with the first occupations at Olo and Qaranicagi on Waya Island. Both ceramics and anthropogenic shell were recovered from the deepest excavation levels (180-190 cmbs). Carbon residue on a sherd from level 15 in Test Unit 5 (AA-60255) returned an AMS-derived date range of 2380-2170 cal. BP at 2 σ (Table 4.14). Thus the early occupations associated with levels 16-19 are likely several hundred years older.

A second AMS derived date (AA-60256) from level 7 in Test Unit 5 identifies the final deposition of materials associated with the Layer II shell midden (see Figure 4.13). This date is 710-590 cal. BP at 2 σ (Table 4.14). The end of the shell midden deposition and the beginning of Layer I may signify a change in the prehistoric use of Natia as Layer I sherd abundances are dramatically higher than deeper layers at the site.

Test units 4 and 5 contain the greatest abundance of cultural material. Coarse-grained basalt flakes, jasper and tan chert flakes (one with worked edges) and cores are found in small amounts throughout Layers I through III. A small (4.5 x 2.5 cm) rectilinear cross-section adze was recovered from Layer I in test unit 4, level 4, while a broken *Trochus* sp. shell pendant was found at the interface between Layers II and III in test unit 4. A small shell bead was recovered from test unit 5 in Layer II, level 9.

The abundance of shellfish food remains varies both across test units and depositional layers. Shell from test units 4 and 5 is unanalyzed but the abundance of shell is greatest in Layers II and III and slowly decreases in abundance toward the base of the deposit. Shell from Test Unit 2 displays a similar pattern, although the greatest abundance of shell remains occur in level 1 and decrease steadily toward the base of the deposit (Morrison 2003). The taxonomic diversity of recovered bivalves and gastropods also generally decreases with depth suggesting that the inhabitants of Natia relied on more varied shellfish over time (barring sample-size effects). The distribution of shellfish remains in Test Unit 1 is bimodal with abundance peaks at levels 4 and 10. Test Unit 1 may suffer from post-depositional mixing as evident in the excavation unit stratigraphy.

Ceramics are the most numerous artifacts recovered at Natia and are found throughout all excavation levels of test units 1-5 (Table 4.11). The earliest deposits at Natia contain very few sherds, but sherd deposition increases in the upper layers, with dramatically higher sherd abundances in the levels of Layer I. Test units 4 and 5 have the greatest abundance of decorated sherds. None of the terminal Lapita shell arc impressed rims or slipped sherds are found at Natia (as at Qaranicagi and Olo), although various forms of wiping do occur in deposits that are quite late. Several different forms of paddle-impressing as well as impressing and incising are present in the Natia assemblage (Figure 4.14).

The earliest rim forms are simple shouldered vessels with slightly everted rims. Later rim forms include inverted bowls of various sizes, some with expanded rims. The *kuro* rim of Best (Best 1984) is first recovered in level 7 and is found throughout the upper levels.

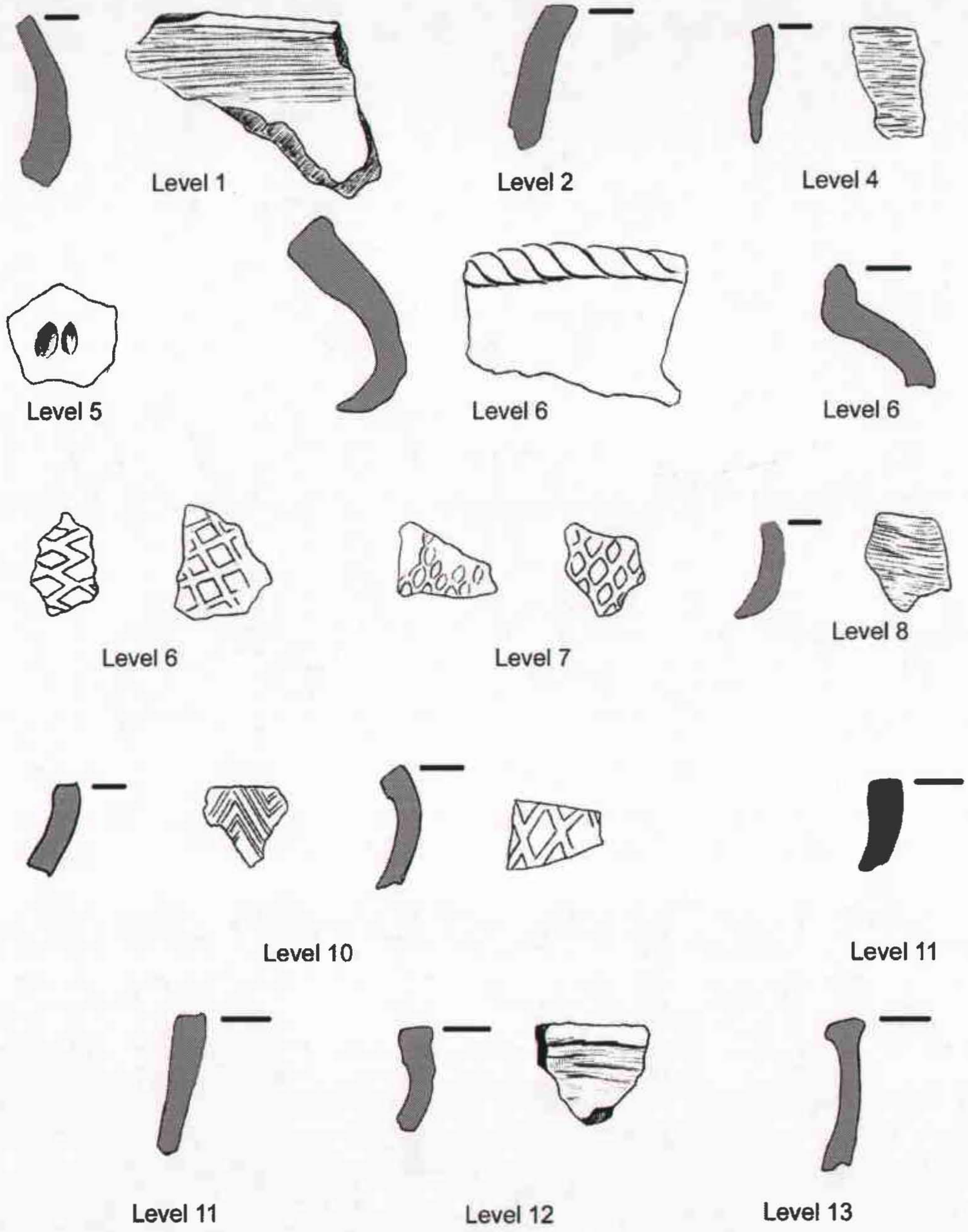


Figure 4.14. Examples of surface modification and rim cross-section variation from Natia (Y1-15). Numbers below sherds indicate test unit and level. Black bars next to rim cross-sections designate vessel interior.

Table 4.11. Natia (Y1-15) ceramic assemblage characteristics: TUs 1, 2, 4 and 5 (all 1x1 m).

Provenience	**Body**	**Neck**	**Spout**	**Rim**	**Total**	**Symmetric Incision & End-tool Impression**	**Appliqué & Molding**	**PIPR**	**PICH**	**PI-various**	**Symmetric Incision**	**End-tool Impression**	**Side-tool Impression**	**Molding**	**Wiped**	**Appliqué**
Surface	41	16	1	27	85	11	1	3			44	9	4			1
TU1, lvl.1	118	3		5	126						1					
TU1, lvl.2	12			1	13											
TU1, lvl.3	168	4		5	177			1	1		1					
TU1, lvl.4	136	1		3	140			2	2							
TU1, lvl.5	53			3	56				1							
TU1, lvl.6	34	2			36				1							
TU1, lvl.7	26				26			1								
TU1, lvl.8	20	1			21											
TU1, lvl.9	11				11				2							
TU1, lvl.10	4	1			5			1								
TU1, lvl.11	9	1			10											
TU1, lvl.12	6				6											
TU1, lvl.13	18				18											
TU1, lvl.14	9				9											
TU2, lvl. 1	746	13		14	773			4			10	7				
TU2, lvl. 2	410	3		2	415		1	1	1		5					
TU2, lvl. 3	376	4		2	382						5					
TU2, lvl. 4	455	5		5	465											

Table 4.11 (continued). Natia (Y1-15) ceramic assemblage characteristics: TUs 1, 2, 4 and 5 (all 1x1 m).

Provenience	Body	Neck	Spout	Rim	Total	Symmetric Incision & End-tool Impression	Appliqué & Molding	PIPR	PICH	PI-various	Symmetric Incision	End-tool Impression	Side-tool Impression	Molding	Wiped	Appliqué
TU2, lvl. 5	205	3	1	5	214											
TU2, lvl. 6	112			2	114											
TU2, lvl. 7	32				32											
TU2, lvl. 8	5				5											
TU2, lvl. 9	14				14			1								
TU2, lvl. 10	23				23											
TU2, lvl. 11	3	1			4				1						1	
TU2, lvl. 12	1				1											
TU2, lvl. 13					0											
TU2, lvl. 14	3				3											
TU4, lvl. 1	135	2		2	139						1	1				
TU4, lvl. 2	107	2		3	112											
TU4, lvl. 3	195	4		2	201			4								
TU4, lvl. 4	251	17		5	273		2	6							1	
TU4, lvl. 5	305	8		2	315	1		9		2	1				2	
TU4, lvl. 6	161	2		3	166			10	1		1					
TU4, lvl. 7	82	2		1	85			3		1						
TU4, lvl. 8	101	3	1	5	110			9		3		1	3	1	1	
TU4, lvl. 9	72	3		1	76			5	1	2	1				1	

Table 4.11 (continued). Natia (Y1-15) ceramic assemblage characteristics: TUs 1, 2, 4 and 5 (all 1x1 m).

Provenience	Body	Neck	Spout	Rim	Total	Symmetric Incision & End-tool Impression	Appliqué & Molding	PIPR	PICH	PI-various	Symmetric Incision	End-tool Impression	Side-tool Impression	Molding	Wiped	Appliqué
TU4, lvl. 10	87	3		7	97			6			1					
TU4, lvl. 11	67	1		7	75								1			
TU4, lvl. 12	54	9		1	64											
TU4, lvl. 13	23	3		3	29			2							1	
TU4, lvl. 14	27	3		2	32											
TU4, lvl. 15	7			1	8											
TU4, lvl. 16	10	1			11											
TU4, lvl. 17	4				4											
TU4, lvl. 18	3				3											
TU4, lvl. 19	1				1											
TU5, lvl. 1	86	3		1	90				1		1					
TU5, lvl. 2	86	1		1	88						1	1				
TU5, lvl. 3	55	3			58											
TU5, lvl. 4	86	2		2	90			3	1							
TU5, lvl. 5	201	2		3	206					1	2					
TU5, lvl. 6	342	15		10	367		1	4	4		3			3		
TU5, lvl. 7	182	11		13	206			3	2	2	1					
TU5, lvl. 8	76	2		3	81											
TU5, lvl. 9	13	1			14											

Table 4.11 (continued). Natia (Y1-15) ceramic assemblage characteristics: TUs 1, 2, 4 and 5 (all 1x1 m).

Provenience	Body	Neck	Spout	Rim	Total	Symmetric Incision & End-tool Impression	Appliqué & Molding	PIPR	PICH	PI-various	Symmetric Incision	End-tool Impression	Side-tool Impression	Molding	Wiped	Appliqué
TU5, lvl. 10	4			1	5											
TU5, lvl. 11	5	1			6											
TU5, lvl. 12	3				3											
TU5, lvl. 13	4			1	5											
TU5, lvl. 14	12				12											
TU5, lvl. 15	4				4											
TU5, lvl. 16	4				4											
TU5, lvl. 17	3				3											
TU5, lvl. 18	3				3											
TU5, lvl. 19	2				2											

4.2.4.2 Site Y1-12: Druidrui

Druidrui is a fortified hilltop occupation including ditch and bank earth-works, stacked rock walls, and other surface features. Situated on one of the highest peaks on Nacula (200 m), Druidrui is readily accessible only from the north (Figure 4.15) as cliffs border the site in other directions. Surface artifacts including ceramics (collected by Best and Irwin in 1978), shell midden, and rock features attest to human occupation of the site. Abundant shell midden covers the slope beneath the 15-20 m cliff at the western boundary of the site. Approximately 75% of the site is covered in tall (1 m) grasses with the remainder sheltered by broad-leafed dry forest.

The northern end of Druidrui consist of a level area with excavated ditches and embankments on its west, north, and east sides. The only unimpeded access is from the northwest up a narrow slope or chute on which four terraces have been constructed. These terraces are placed at approximately 20 m intervals down the slope.

The northern section is separated from the rest of the site by an approximately 8 m embankment. This embankment has an attached ditch to the south and sections of a stacked-rock retaining wall are visible in the ditch. This ditch and bank comprise the northern boundary of the upper level of the site. Free-standing rock walls are built upon a rock outcrop to the west of this large ditch and bank complex. There is no unimpeded access to the upper level of the site; cliffs comprise the east and west boundaries and a large rock pinnacle and cliff form the southern boundary (not shown in Figure 4.15).

A 3 x 4 m section of exposed bedrock at the western edge exhibits 17 groups of long and narrow grinding surface and eight basin-shaped grinding surfaces. Each group of narrow grinding surfaces comprise approximately five grinding grooves, with each groove approximately 20 cm long, 2 cm wide, and 1 cm deep. The size and shape of the grooves suggest they may have been used to sharpen wooden spears or other such implements (see Clunie 2003:145-155). The eight basin-shaped grinding surfaces, each approximately 30 cm x 10 cm, may have been used to sharpen basalt stone adzes or similar tools.

To the south of the bedrock grinding facets, several surface features suggest possible domestic habitation, including linear rock alignments, circular rock alignments, and a fresh-water spring and catch-basin.

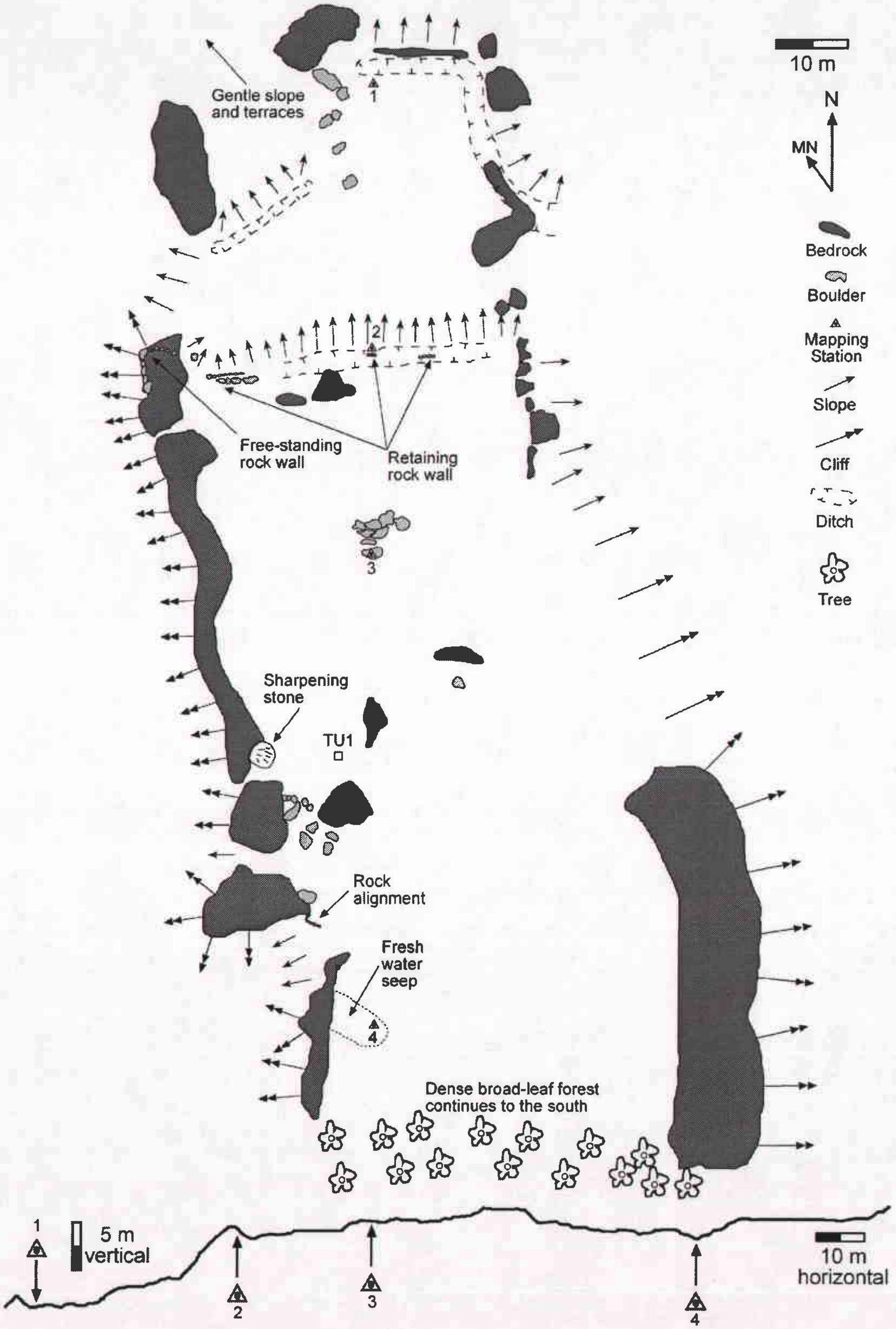
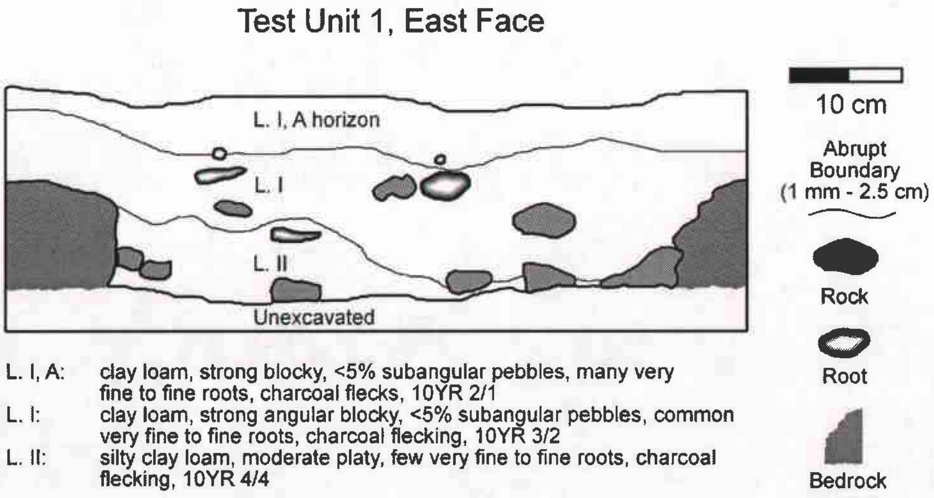


Figure 4.15. Plan map and profile of Druidrui (Y1-12).

A single test unit was excavated at Druidrui during the 2003 field season in a relatively flat area of the site surrounded by bedrock outcrops and surface features (see Figure 4.15). The test unit revealed two cultural layers containing marine shell, faunal remains lithics, charcoal, and ceramics (Figure 4.16). Layer I contains the bulk of the artifactual material, including a small fragment of jasper, fish remains, shell, charcoal chunks, and ceramics. Layer II contained fewer artifacts, including a few marine shells and ceramics. These artifacts were confined to the first 5 cm of Layer II, with the rest of the layer being culturally sterile. Excavation was halted due to the lack of cultural material and the encroachment of bedrock across most of the unit surface area. Layer II probably constitutes the original habitation surface with Layer I resulting from increased intensity of occupation.



L. I, A: clay loam, strong blocky, <5% subangular pebbles, many very fine to fine roots, charcoal flecks, 10YR 2/1
L. I: clay loam, strong angular blocky, <5% subangular pebbles, common very fine to fine roots, charcoal flecking, 10YR 3/2
L. II: silty clay loam, moderate platy, few very fine to fine roots, charcoal flecking, 10YR 4/4

Figure 4.16. Profile of TU 1, east wall, at Druidrui (Y1-12).

4.2.4.2.1 Cultural Material Recovered from Y1-12

Druidrui appears to have been occupied in the recent past. Dispersed charcoal recovered from Layer I, level 2 (10-20 cmbs) returned an AMS determined date range of

340-110 (78.5%) cal. BP and 90-40 cal. BP (16.9%) at 2 σ (Table 4.14).If this charcoal dates human occupation of the site , the earlier date range more likely reflects the initial occupation of Druidrui as the oldest individuals of Nacula today have no recollection of their ancestors living at Druidrui. Druidrui was established during a final phase of fort-building identified in other parts of Fiji that in the Sigatoka Valley included mostly settlements surrounded by annual ditches and palisades (Field 2004:93).

Faunal (primarily fish) and shellfish remains from the test unit suggest that food items were obtained from the coast. The level areas of Druidrui to the north of TU 1 may have been used for agriculture, as may have the down-slope terraces to the northwest of the site.

Ceramics are the most abundant artifact at the site and were recovered from the site surface by Best and Irwin in 1978 and a University of Hawai'i team in 1991, as well as through the excavation levels of TU 1. Collection methods for the surface assemblage are unknown, but were probably focused on rim sherds given the high percentage of these in the collection. Recovered ceramics are listed in Table 4.12 and exhibit a variety of incised and end-tool decorative treatments and various vessel forms including the strongly everted rim kuro, slightly everted-rim shouldered pots, and parallel rim bowls (Figures 4.17 and 4.18). A single large spout broken off the surface of a vessel was found on the site surface.

Table 4.12. Druidrui (Y1-12) ceramic assemblage characteristics: surface and TU 1 (1 x 1 m).

Provenience	Body	Neck	Spout	Rim	Total	Appliqué, Sym. Incision & End-tool	Appliqué	Asymmetric Incision	Symmetric Incision	End-tool Impression	Side-tool Impression	Asymmetric Incision & End-tool	Symmetric Incision & End-tool
Surface	62	4	1	42	109	1		9	8	5		4	1
TU1, L. I, lvl. 1	155	3		4	162		1		22	5			
TU1, L. I, lvl. 2	146			2	148				16	1			
TU1, L.II, lvl. 3	15	4			19				1				

4.2.5 Archaeological Sites of Yasawa Island

Best and Irwin identified 31 archaeological sites on Yasawa Island at the northern extent of the Yasawa chain (and four sites on several offshore islets). Sites Y1-29 is a ceramic scatter in a small drainage basin. Site Y1-30 is a ceramic scatter in the lowland hills. Only site Y1-29 was re-surveyed by University of Hawai'i teams, although information on survey methods is not available.

3.2.5.1 Sites Y1-29 and 30

The ceramic surface assemblages at these sites are decorated with incising, end-tool impressing and molded scallops on rims, while vessel forms are restricted to inverted and everted bowls and a single narrow-mouthed shouldered pot (Table 4.13 and Figures 4.17 and 4.18).

Table 4.13. Ceramic assemblage characteristics for sites Y1-1 and Y1-4

Provenience	**Body**	**Neck**	**Rim**	**Total**	**Molding**	**PIPR**	**PICH**	**Symmetric Incision**	**End-tool Impression**	**Side-tool Impression**
Y1-29, surface	73	3	3	76	1			2	3	
Y1-30, surface	197	19	8	234				27	5	

4.3 OVERVIEW OF YASAWA ISLANDS ARCHAEOLOGY

The Yasawa Islands were first inhabited approximately 2700 BP and have been home to human populations since then to the present (Table 4.14). The initial and sustained colonization of the Yasawas likely occurred several hundred years after the initial habitation of sites in other parts of Fiji, particularly in the east. The earliest identified occupations of Yasawa Islands sites such as Olo (Y2-25) and Qaranicagi (Y2-39) produce radiocarbon dates that are slightly later than those for early sites in the Lau Group and at a few other sites in Fiji (see Anderson and Clark 1999; Best 1984; Clark, et al. 2001; Clark 1999; Nunn, et al. 2004). Important early sites in western Fiji, including Natunuku and Yanuca, may not be reliably dated (see Chapter Two and Clark and Anderson [2001]) and one recently reported group of sites in southwest Viti Levu appears to date between 1200 and 900 BP (Nunn, et al. 2004). The vessel forms and decorative attributes in the early Olo and Qaranicagi deposits are also similar to the so-called terminal Lapita deposits found at other sites (see Figures 4.7 and 4.10). Why were the Yasawa Islands potentially bypassed for 200-300 years until after the colonization of other areas of Fiji? Perhaps populations looked first to the resources available on the large island of Viti Levu, but more archaeological work and precise dating of occupation is necessary to examine this claim (Clark and Anderson 2001).

Table 4.14. Chronometric age determinations for Yasawa Islands materials.

Lab No.	Location	Material	^{14}C Age BP	^{13}C/^{12}C Ratio	^{13}C Adjusted Age BP	Calibrated Age Range BP (2 σ probabilities)*
Wk-6482†	Y2-22, surface	*Trochus* sp.	500 +/- 50	-	-	570-460 (80.1%) 650-580 (15.3%)
Beta-86839‡	Y2-25, TU3, L.II base	wood charcoal	2590 +/- 50	-28.2	2540 +/- 50	2760-2460 (92.3%) 2420-2360 (3.1%)
Beta-86840	Y2-25, TU3, pit feature 1	wood charcoal	2630 +/- 90	-28.7	2570 +/- 90	2810-2350 (93.6%) 2850-2820 (1.8%)
CAMS-24946	Y2-25, L.II, burial pit	human bone	2530 +/50	-	-	2760-2430 (91.5%) 2420-2360 (3.9%)
Beta-53197	Y2-39, TU1, L. II, lvl. 6	wood charcoal	370 +/- 70	-27.4	330 +/- 70	550-250 (93.5%) 200-150 (1.9%)
Beta-174986‡	Y2-39, TU3, L.III, earth-oven feature	wood charcoal	800 +/- 40	-26.4	780 +/- 40	760-660 (95.4%)
Beta-53196	Y2-39, TU1, L.III, lvl. 12	wood charcoal	1160 +/- 80	-26.6	130 +/- 80	1270-920 (95.4%)
Beta-53195	Y2-39, TU1, L.IV, lvl. 17	wood charcoal	2430 +/- 80	-27.2	2400 +/- 80	2750-2300 (95.4%)
Beta-53194	Y2-39, TU1, L.IV, lvl. 21	wood charcoal	2910 +/- 110	-27.2	2870 +/- 110	3350-2750 (95.4%)
Beta-52221	Y2-39,TU1, L.IV, lvl. 22	wood charcoal	2310 +/- 90	-28.2	2260 +/- 90	2750-2650 (2.0%) 2500-2000 (93.5%)
Beta-53193	Y2-39, TU1, L.IV, lvl. 23	wood charcoal	2840 +/- 260	-28.0	2790 +/- 260	3650-2150 (95.4%)
Wk-6485†	Y2-45, surface	*Trochus* sp.	480 +/- 50	-	-	630-590 (6.2%) 570-430 (87.4%) 360-330 (1.8%)
Beta-93971	Y2-46, TU1, L.I, lvl. 1	wood charcoal	370 +/- 90	-25.7	360 +/- 90	550-100 (95.4%)
AA-60255‡	Y1-15, TU 5, L. III, lvl. 14	carbon residue on sherd	2207 +/- 35	-25.6	-	2380-2170 (95.4%)
AA-60256‡	Y1-15, TU 5, L.I, lvl. 7	carbon residue on sherd	607 +/- 33	-27.1	-	710-590 (95.4%)
AA-60257‡	Y1-12, TU1, L.I, lvl. 2	dispersed wood charcoal	156 +/- 33	-24.2	-	340-110 (78.5%) 90-40 (16.9%)

* Calibrations performed with OxCal 3.8 (Ramsey 2003) using atmospheric data from Stuiver et al. (1998) unless otherwise noted.

‡ Accelerator Mass Spectrometry dated.

† Shell samples calibrated using the marine curve data available with OxCal 3.8 and the ΔR correction factor provided for Fiji by Toggweiler et al. (1989).

These earliest inhabitants of the Yasawas produced an artifact inventory and food remains suggesting they relied heavily on marine resources, but they also used chicken and plant resources that were likely grown in gardens; modified shells from Olo may have been used as peelers, while hammer-stones may have been used to extract nut meat. Reliance on marine resources occurs throughout the Yasawa Islands sequence evidenced by fishbone and marine shell in deposits of all ages. Other animal resources appear at different times during the Yasawa sequence: pig, turtle, fruit bat, and a variety of lizards are present in the Olo and Qaranicagi deposits.

Besides Qaranicagi and Natia, there are no identified sites that appear to have been occupied within the c. 2400-700 BP time range. This is likely a reflection of the differential identification and preservation of sites. Many of these sites may be covered by colluvial and alluvial deposits associated with coastal progradation. Additional archaeological work will likely uncover other long-occupied coastal areas similar to Natia.

Fortified habitations such as Korowaiwai (Y2-22) on Waya, Druidrui (Y1-12) on Nacula, and site Y2-62 on Naviti begin to appear after c. 600 BP. These fortified sites attest to increased competition between populations throughout the Yasawas.

Surface and subsurface cultural deposits in the Yasawas contain a variety of artifact types including formal lithic tools and flakes, likely ornamental objects of shell, coral tools, abundant midden, and ceramics. Ceramics are the most abundant artifact recovered in the Yasawas (27,826 sherds in the assemblages described here) and display a great range of decorative and formal variation (surface ceramics shown in Figures 4.17 and 4.18). Many of the Yasawa assemblages display affinities with other ceramic assemblages throughout Fiji. There is also some regional variation within the Yasawas. For example, molded scallops created on rims and symmetric incision of hashed triangles appear only in assemblages of the northern islands in the Yasawa Group. Such comparisons of Yasawas ceramic variation both within the island group and with other assemblages in Fiji are, in part, the topic of the remaining chapters.

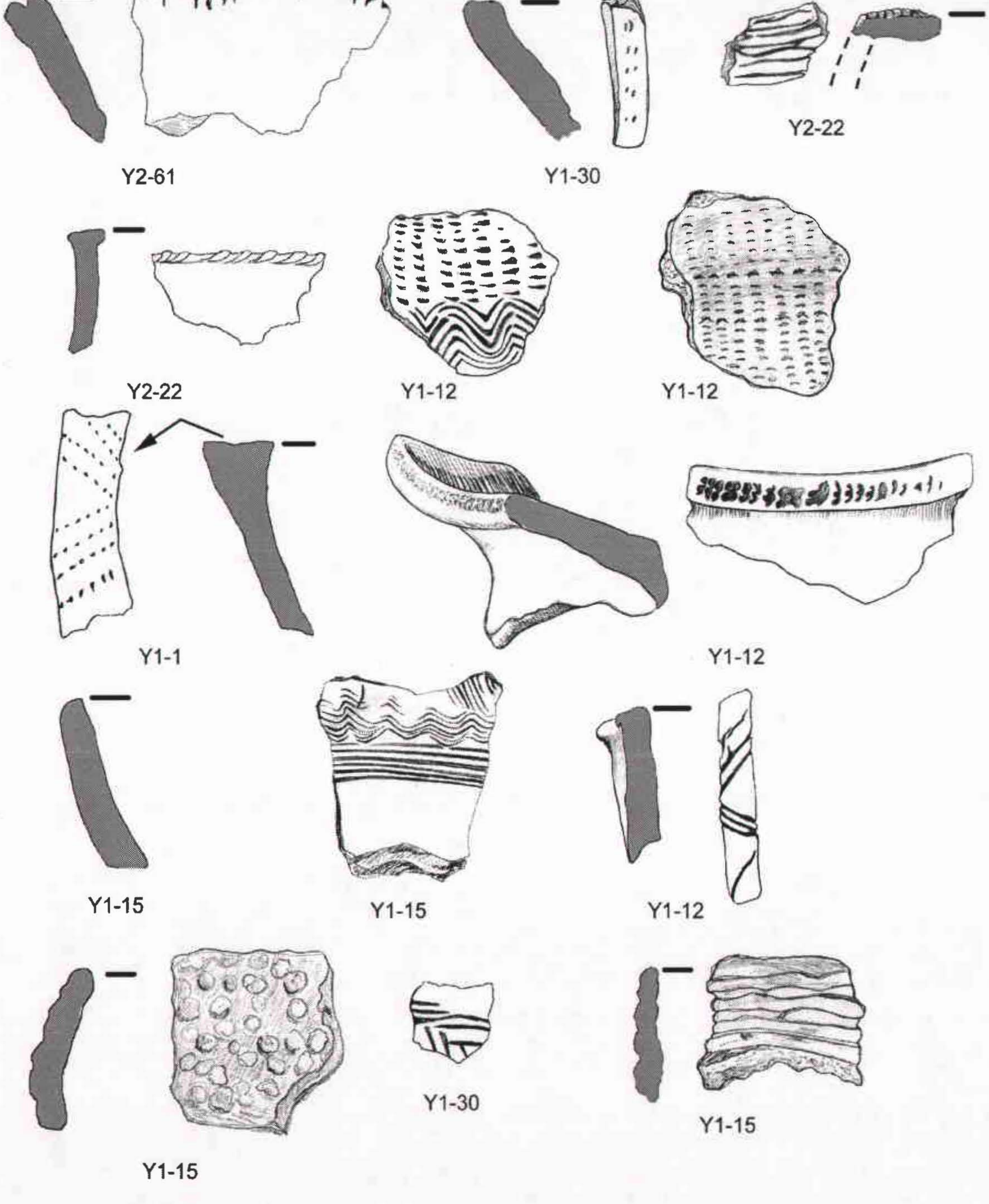


Figure 4.17. Surface modification and rim form variation at surface sites in the Yasawa Islands. Sherds are drawn at 1:2 scale. Site designations given beneath sherds. For rim sherds black bar indicates interior of vessel.

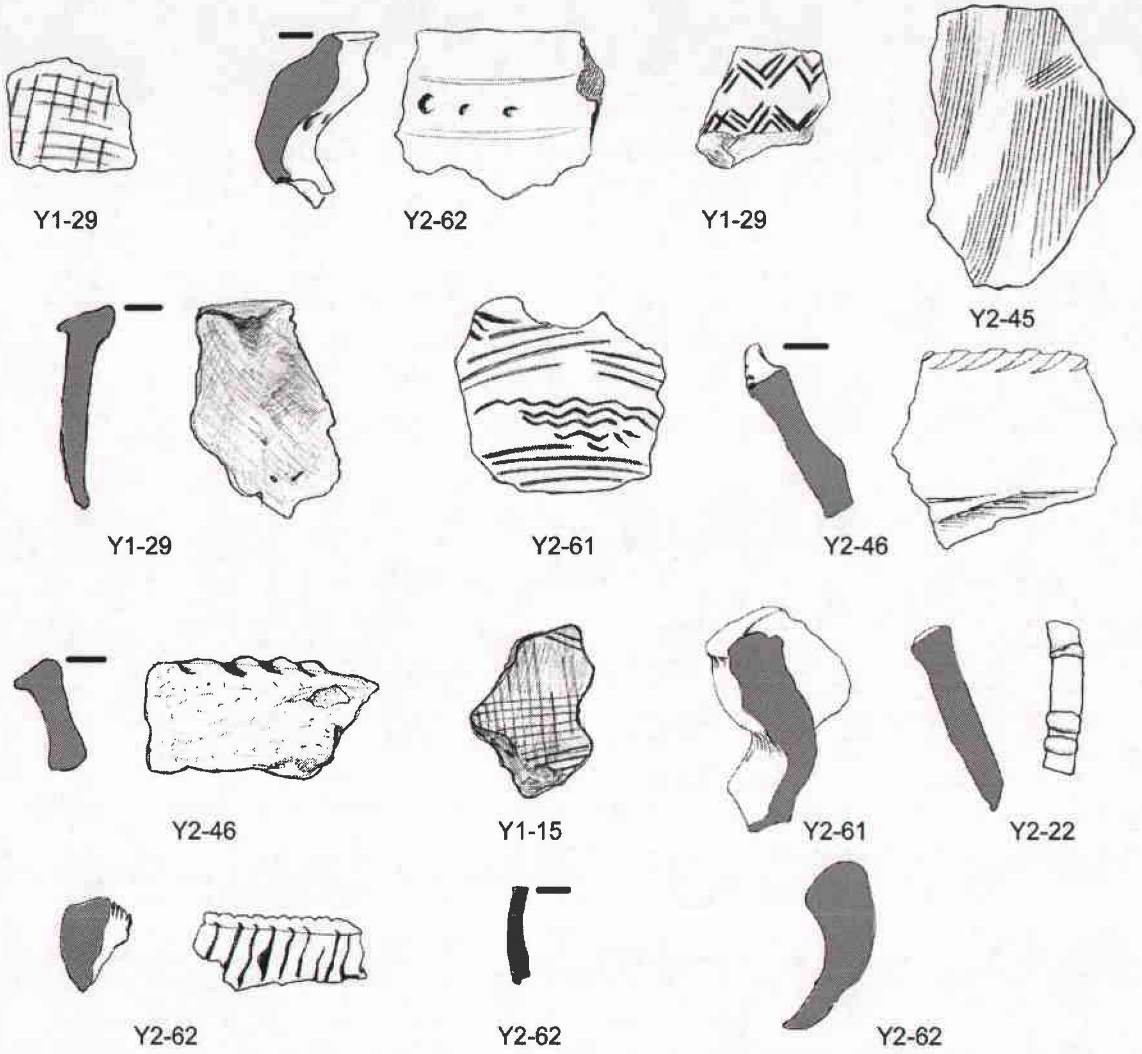


Figure 4.18. Surface modification and rim form variation at surface sites in the Yasawa Islands. Sherds are drawn at 1:2 scale. Site designations given beneath sherds. For rim sherds black bar indicates interior of vessel.

4.4 CHAPTER SUMMARY

This chapter outlines the natural and cultural history of the Yasawa Islands as generated through archaeological field work conducted from 1978 to 2003. Every site thus far identified has not been described, but those sites with the largest and most likely representative artifact inventories are presented.

The Yasawas Islands were first inhabited c. 2700 BP. Throughout prehistory human occupation occurred in a variety of settings including prograding coastal terraces, uplands, caves, fortified ring-ditch villages, and defended hilltop hamlets. Two sites, Qaranicagi (Y2-39) and Natia (Y1-15) represent the majority of the prehistoric sequence in the islands, with other sites representing early and late occupations.

Artifact assemblages from the Yasawa Islands contain a number of artifact types, including lithics, faunal remains, and ceramics. There is also both change over time and intra-Yasawa Group differences within each of these artifact categories. The ceramic sequences identified in the Yasawa Islands display both similarities and differences with other assemblages in Fiji. These ceramics are further examined in Chapters 5 and 6.

CHAPTER 5. CERAMIC CLASSIFICATION AND ANALYSES OF VARIATION

> I have an old belief that a good observer really means a good theorist . . .
>
> Charles Darwin (November 22, 1860)
>
> Letter to H. W. Bates written in Kent, England

The primary reason for examining ceramic variation in this chapter is to develop classes that can be used to track cultural transmission and define lineages within the Yasawa Islands. This is accomplished by using a series of classifications and other analyses to describe individual sherds. To be effective in this task, classes should measure (predominantly) homologous similarity or similarity that is a primarily a result of cultural transmission. Homologous similarity may fit a model of adaptive (functional) similarity, or selectively neutral (stylistic) similarity.

As Darwin's quote above suggests, classification involves both deductive and inductive components. For the ceramic classifications here we can deduce from theory that classes will more likely measure homologous similarity if the modes that define classes do not track functional differences. Modes that describe functional variation, for example variation affecting performance characteristics of vessels, may hinder the ability of classes to track homologous similarity. Functional similarities may arise in separate lineages through convergence or parallelism and if we mistake these similarities as homologous our transmission analyses may produce undetected inaccuracies.

Our theoretical framework may be used to guide our classificatory decisions (Dunnell 1971). In the following classifications dimensions were defined based on expectations about what kinds of variation we can expect to follow a model of selectively-neutral model. We might expect variation in rim forms and surface modification may follow this model, but variation in sherd thickness to be explained by other processes. These expectations are propositions that may be shown incorrect through additional analyses. In Chapter 6, the classes used to track transmission are subjected to initial tests of their ability to track homologous similarity. In this sense, classifications are initial hypotheses about the structure of variation (Cochrane 2002a).

Theory also suggests that the modes used to construct classes that measure homologous similarity should also vary over time and space. More specifically, the presence and absence or frequency of particular modes of a dimension should change regularly, but also be characterized by some level of continuity (fidelity) and abundance (replication). These criteria of variability do not guarantee classes that measure homologous similarity, but if our classes are constructed so that they generate no empirical variation over time and space we will not identify changes in cultural transmission.

Classification for transmission analysis also involves an inductive component whereby previous analyses of ceramic variation indicate what kinds of variation may be appropriately incorporated into class definitions. Temporal and spatial variation in surface modification, rim forms and temper characteristics has been recorded throughout Fiji (Best 1984; Birks 1973; Burley and Dickinson 2004; Clark 1999; Cochrane 2002a; Crosby 1988; Frost 1974; Green 1963; Hunt 1980; Hunt, et al. 1999; Kirkendall 1998;

Palmer 1971a; Rechtman 1992; Rossitto 1989a, b) and suggests that these dimensions may be fruitfully incorporated in classes used to track transmission. The inductive and deductive components of classification give it the "trial and error" characteristics noted by archaeologists and others (e.g., Lewontin 1974; O'Brien and Lyman 2003:144; Teltser 1995).

Classifying phenomena for cladistic and seriation analyses, like any analysis, is the most important step in building explanations. As with other statistical grouping methods, cladistics will produce an answer, a tree, regardless of the data (i.e., ideational classes, empirical groups) that the cladistic algorithm is fed. Biologists may tend to underemphasize the importance of classification in transmission analyses (e.g., Kitching, et al. 1998:19), probably because they have a longer history of exploring issues of systematics and the pathways of transmission they examine are generally well-understood. Simply classifying sherds, however, does not guarantee the definition of accurate transmission lineages.. This chapter and the next present analyses that evaluate the ability of these classes to track homologous similarity.

5.1 TECHNIQUES FOR DESCRIBING CERAMIC VARIATION

The following classifications and analyses examine a subset of the excavation and surface collection sample of 27,826 sherds described in Chapter Three. The total number of analyzed sherds is 1,915, a little more than 6.8% of the collections. This is a stratified random subsample of sherds with sampling strata defined (in order of increasing conclusiveness) by island, site, depositional unit, arbitrary excavation unit (test units and levels), and vessel part (e.g. rim or body).

Classification and analyses proceeded iteratively to arrive at the final abundance of each analyzed sample. The first round of classification was conducted on a set of sherds selected from various excavation provenience units chosen to represent the spatial and temporal variation of occupations in the Yasawas. Sherds from each unit were passed through -4.0 phi (1.6 cm^2) geological screens to remove sherds too small to be easily manipulated for some of the classifications (e.g., creating fresh breaks to observe the fabric). The -4.0 phi and larger sherds were then successively quartered until a small sample was created, usually between 5 and 30 sherds, depending on the initial number of sherds in the unit. In some instances additional rim sherds from the unit were added to the analytical sample to generate the potentially most informative class distributions. Additionally, the order in which samples were classified during the first round was random. Since the ability of the analyst to make measurements may change (e.g., improve in accuracy) over the course of the classification and analysis, randomizing the order of samples classified will randomly distribute "analyst learning error" across the samples.

After the first round of classification, the samples were examined for sample representativeness using both richness vs. sample size plots and bootstrapping techniques. If the first round of classification did not produce a representative sample for a particular classification, additional sherds were drawn from the unit until a representative sample was achieved. This procedure resulted in the analysis of all available rim sherds (n = 799) in the collections, as the rim sherd classification required large sample sizes to approach population representativeness.

The classifications of technological and decorative variation in the Yasawa Islands ceramics are part of an ongoing effort to describe these collections in ways amenable to transmission-related analyses (see Cochrane 2002a; Cochrane and Hunt 2004). Six areas of ceramic variation are examined in this section: sherd size, vessel part, rim form, temper composition, surface modifications, and clay composition.

5.1.1 Sherd Size

Sherd size (surface area) is classified through a series of nominal modes: less than 5 cm^2, 5-16 cm^2, 16-49 cm^2, 49-100 cm^2, 100-225 cm^2, and greater than 225 cm^2. Each sherd is compared to a size template to determine the properly descriptive mode. Sherd size classes are used to track the distribution of other modes (e.g., surface modifications) across sherds of different sizes to determine how different dimensions of sherd variation may be mechanically linked to sherd size.

5.1.2 Vessel Part

The dimension vessel part refers to the location on a vessel from which a sherd originates. Vessel part modes include rim, neck, body, carination, handle, and base. Vessel part is identified by the characteristics in Table 5.1 and a schematic vessel is shown in Figure 5.1. Pot-stands, the only type of non-vessel sherd that have been identified in the assemblages, are considered individually. Vessel part modes are also used to track the distribution of other modes (e.g., surface modifications) across sherds.

Table 5.1. Description of Vessel Part modes.

Vessel Part Mode	Description
Rim	Exhibits upper termination of vessel (or is estimatable); may exhibit neck characteristics
Neck	Exhibits concave vertical curvature and convex horizontal curvature (viewed from exterior); does not exhibit upper termination of vessel (nor is this estimatable)
Body	Exhibits both convex vertical and horizontal curvature
Carination	Exhibits both convex vertical and horizontal curvature; vertical curvature created by the intersection of two planes on exterior surface and the angle between planes is measurable
Handle	Cylindrical, curved, ceramic object

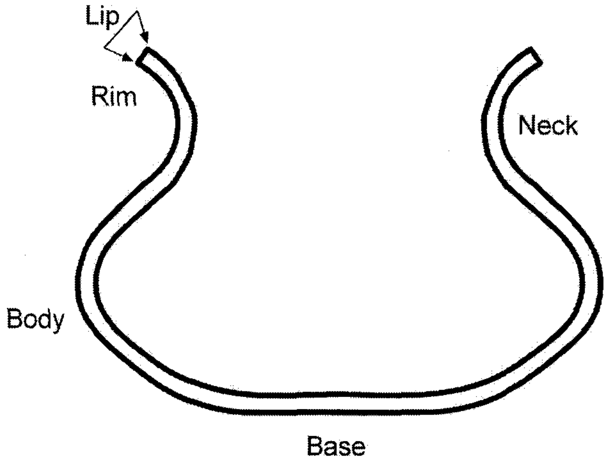


Figure 5.1. Schematic representation of vessel with general areas producing Vessel Part modes listed in Table 5.1. Vessel lips also shown.

5.1.3 Rim Form

Sherds identified as rims are further classified by several dimensions collectively describing rim form. Rim form dimensions and their constituent modes create two paradigmatic classification for rims, one for shouldered vessels and a second classification for unshouldered vessels. A restricted set of dimensions are applied to unshouldered vessels, thus these vessels are not directly comparable to shouldered pots across all dimensions used here. Figures 5.2 and 5.3 display most of the dimensions measured on rim sherds. Tables 5.2 and 5.3 list all of the dimensions and their constituent modes.

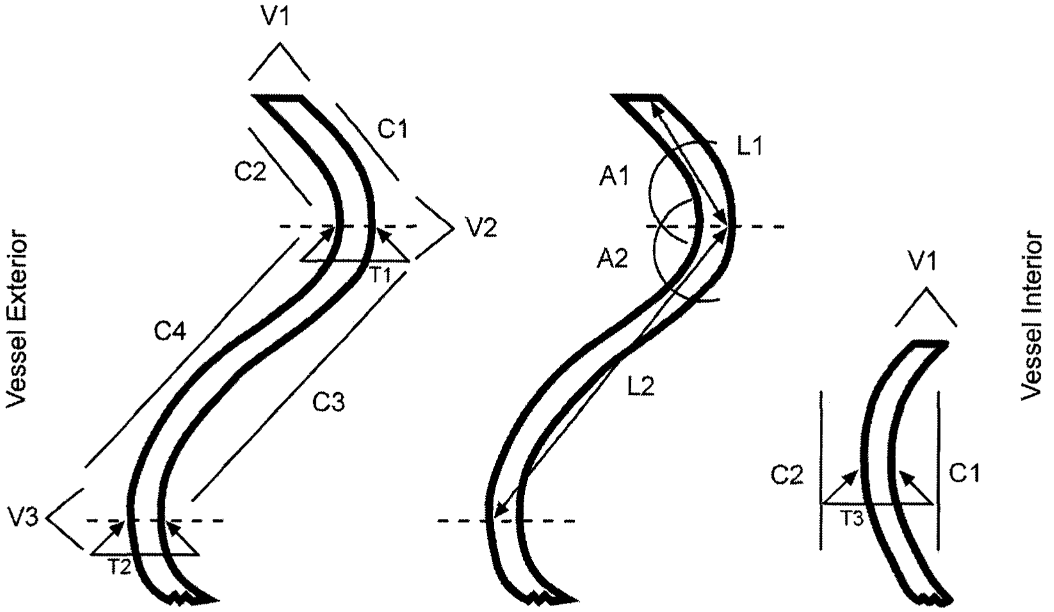


Figure 5.2. Rim classification dimensions adapted from Sterling (2001; see also Ballet 1987). Dimensions described in Table 5.2.

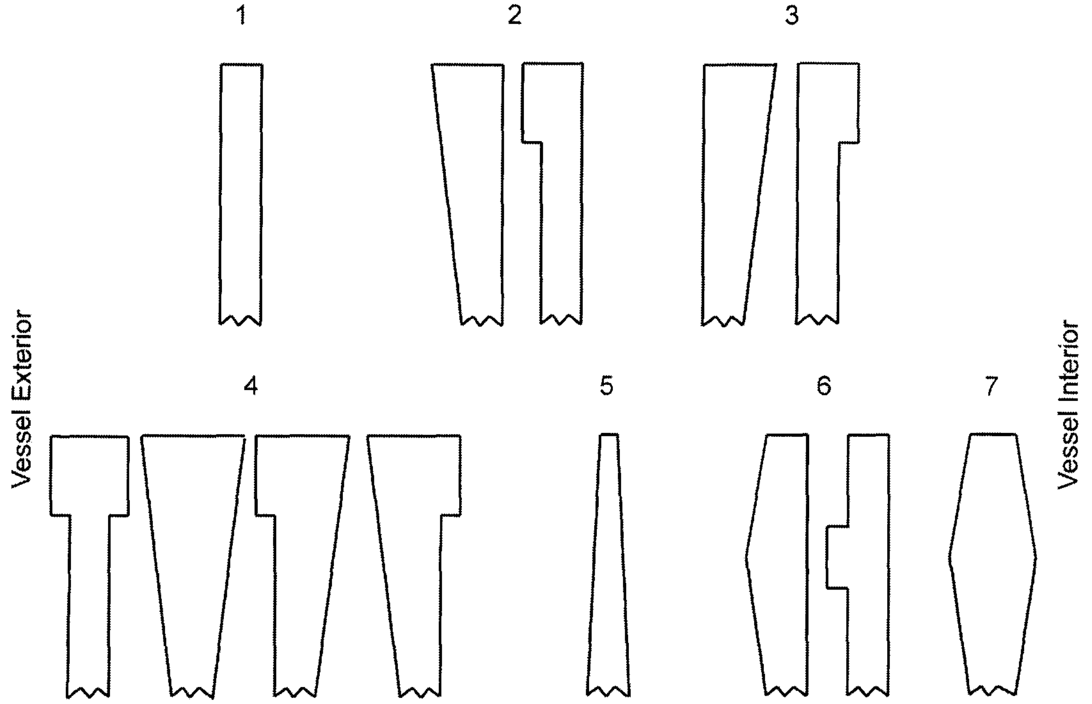


Figure 5.3. Modes for the dimension Rim Symmetry. All modes were identified in the assemblages. Mode six could be reflected on its vertical axis to produce an eighth mode, but this mode was not found in the Yasawas Islands assemblages and is not displayed here.

Table 5.2. Description of modes for dimensions describing shouldered vessel rim sherds.

Dimension	Modes
Vertex 1 (V1)	Measured perpendicular to L1: 1. straight (exhibits distinct corners at interior and exterior lips), 2. pointed (measurable angle at center of V1), 3. rounded (shape of V1 is humped, but without measurable angle)
Vertex 2 (V2)	For everted rim sherds, measured at inflection point where vessel curvature changes from moving toward vessel center-line(measured from top) to moving away from vessel center-line; for inverted rim sherds measured at inflection point where the estimated rate of change in slope of neck is greatest; both measured perpendicular to vertical axis: 1. straight, 2. pointed, 3. rounded
Vertex 3 (V3)	Measured at inflection point where vessel curvature changes from moving away from vessel center-line (measured from top) to moving toward vessel center-line; measured perpendicular to vertical axis: 1. straight, 2. pointed, 3. rounded
Curve 1 (C1)	Measured between inflection point of V2 and upper termination, viewed from vessel exterior: 1. straight, 2. concave, 3. convex, 4. S-shaped (two curves)
Curve 2 (C2)	Measured between inflection point of V2 and upper termination, viewed from vessel exterior: 1. straight, 2. concave, 3. convex, 4. S-shaped (two curves)
Curve 3 (C3)	Measured between inflection points of V2 and V3, viewed from vessel exterior: 1. straight, 2. concave, 3. convex, 4. S-shaped (two curves)
Curve 4 (C4)	Measured between inflection points of V2 and V3, viewed from vessel exterior: 1. straight, 2. concave, 3. convex, 4. S-shaped (two curves)
Length 1 (L1)	Continuous mode: mm in straight line from interior inflection of V2 to interior rim lip
Length 2 (L2)	Continuous mode: mm in straight line from interior inflection of V2 to interior inflection of V3
Angle 1 (A1)	Continuous mode: degrees from line at V2 (0 degrees), perpendicular to central vertical axis (90 degrees), to chord defined by L1.
Angle 2 (A2)	Continuous mode: degrees from line at V2 (0 degrees), perpendicular to central vertical axis (90 degrees), to chord defined by L2.
Thickness 1 (T1)	Continuous mode: mm thickness of sherd wall at V2 perpendicular to exterior and interior sherd walls
Thickness 2 (T2)	Continuous mode: mm thickness of sherd wall at V2 perpendicular to exterior and interior sherd walls
Exterior-Interior Rim symmetry (S)	Measured in cross-section from V2 to top of rim: 1. parallel, 2. exterior expanded, 3. interior expanded, 4. interior and exterior expanded, 5. contracted, 6. exterior expanded and contracted, 7. interior and exterior expanded and contracted,
Orifice diameter (D)	Continuous mode: cm measured on diameter chart
Percentage of rim present (P)	Continuous mode: % measured on diameter chart

Table 5.3. Description of dimensions and modes for unshouldered vessels (bowls).

Dimension	Modes
Vertex 1 (V1)	Measured perpendicular to approximate plane created by sherd: 1. straight (exhibits distinct corners at interior and exterior lips), 2. pointed (measurable angle at center of V1), 3. rounded (shape of V1 is humped, but without measurable angle)
Curve 1 (C1)	Measured between lip and lower termination of sherd: 1. straight, 2. concave, 3. convex, 4. S-shaped (two curves)
Curve 2 (C2)	Measured between lip and lower termination of sherd: 1. straight, 2. concave, 3. convex, 4. S-shaped (two curves)
Thickness 3 (T3)	Continuous mode measured at point of greatest thickness below lip: mm thickness of sherd wall perpendicular to exterior and interior sherd walls
Exterior-Interior Rim symmetry (S)	Measured in cross-section from V2 to top of rim: 1. parallel, 2. exterior expanded, 3. interior expanded, 4. interior and exterior expanded, 5. contracted, 6. exterior expanded and contracted, 7. interior and exterior expanded and contracted
Rim orientation (O)	1. inverted (vessel curvature points toward vessel center-line) , 2. everted (vessel curvature points away from vessel center-line)
Orifice diameter (D)	Continuous mode: cm measured on diameter chart
Percentage of rim present (P)	Continuous mode: % measured on diameter chart

Rim forms for shouldered vessels can be described from the observed modes of the first 15 dimensions in Table 5.2 to create thousands of paradigmatic classes. In practice, however, a limited subset of dimensions were used to create rim form classes in preliminary classifications including: Vertex 1, Vertex 2, Curve 1, Curve 2, Length 1, Angle 1, Thickness 1, and Exterior-Interior Rim Symmetry. Vertex 3, Curves 3 and 4, and Thickness 2 were not observable on any sherd in the collections, but have been included here to illustrate how more observations could be included to construct classes. Orifice diameter and percentage of rim present were not used to construct rim form classes. These dimensions were used to compare the reliability of Angle 1 measurements for sherds of different sizes (see below).

The dimension rim symmetry comprises seven modes (Figure 5.3) describing the relative expansion and contraction of rim margins. For example, Mode 2 describes those sherds whose exterior margin is expanded relative to the interior margin. During preliminary distributional analyses 13 rim-symmetry modes were more precisely defined by including the relative abruptness of expansion or contraction as definitive mode criteria. Thus Mode 2 in Figure 5.3 was previously split into two modes, one described as gradual interior expansion and one as abrupt interior expansion. Relative abruptness and gradualness were later dropped as definitive criteria for all rim-symmetry modes as these criteria produced classes that were too exclusive and contained too few members for valid comparisons.

Several of the rim form dimensions, including Angles 1 and 2 and Thicknesses 1 and 2, arrange variation that is measured continuously. These continuous measurements were translated into discrete units given both expectations from previous research, by examining various histograms using different bin sizes, and by examining batch characteristics (e.g., midspread). For example, the dimension Angle 1 measures the angle of evertedness or invertedness of a rim. After examining different distributions of the raw angle measurements, the dimension was divided into three discrete modes: greater than 90 degrees, 70 degrees to 90 degrees, and less than 70 degrees. The construction of these discrete modes also benefits from previous research that has identified temporal trends in rim angle variation (e.g., Best 1984).

Estimates of measurement error were also calculated for continuous dimensions. For the dimensions of continuous variation, a small subset of the rim sherds were re-measured on different days and the results of the different measurements compared to estimate the amount of measurement error. The four dimensions Orifice Diameter (D), Angle 1 (A1), Thickness 1 (T1), and Length 1 (L1) were measured five times on ten sherds. This is a small number of re-measurements and thus assessment of measurement error here should only be treated as preliminary. The seven sherds were chosen to represent a wide range of observable variation across all the assemblages. These sherds were also variably fragmented, displaying different percentages of the rim present.

To estimate measurement error for these dimensions the pooled standard error was determined. Pooled standard error was used instead of simple standard error as all rims are not equally amenable to repeatedly precise measurement. For example, it may be easier to produce precise measurements of the dimension A1 on rim sherds with greatly curved necks compared to those with more subtlety curved necks. To account for these differences sherds with such different characteristics were placed in different sampling strata for the computation of pooled standard error.

Several simplifications were necessary to derive pooled standard error: each of the seven sherds was taken to represent different sampling strata; the five repeated measurements taken for a particular dimension on one of the seven sherds were considered the sample of that particular sampling stratum; the total number of rim sherds (302) for which measurements in these four dimensions were taken was considered the total population; the number of sherds in each sampling stratum was estimated by dividing the total population of rim sherds (302) by the number of sampling strata (seven sampling strata from the seven sherds), so that six sampling strata consisted of 43 sherds and one stratum consisted of 44 sherds. These simplifications were necessary to determine pooled standard error using Equation 5.1:

Equation 5.1 $$SE_p = \frac{\sqrt{\sum \left(N_h^2\right)\left(SE_h^2\right)}}{N}$$

where SE_p equals the pooled standard error, N_h equals the total number of sherds in a sampling stratum (43 or 44), SE_h is the standard error for the three measurements taken of sampling stratum h, N is the total number of sherds in the entire population (302). Table 5.4 displays the pooled standard error and other statistics for four dimensions of continuous variation.

Table 5.4. Standard errors for dimensions A1, T1, L1, and D.

Dimension	**Highest Standard Error**	**Lowest Standard Error**	**Pooled Standard Error**	**95% C.I. at *N*-1 (301) Degrees of Freedom**
A1	4.25	0.54	0.88	+/- 1.73 degrees
T1	0.53	0	0.13	+/- 0.26 mm
L1	3.41	1.09	0.75	+/- 1.47 mm
D*	2.72	0	0.71	+/- 1.39 cm

* Only six sampling strata used to compute pooled standard error.

The 95% confidence intervals for the four dimensions listed in Table 5.4 give an indication of measurement precision in these dimensions. Since the number of measurements taken per sherd was small, the derived measurement precision should only be considered heuristically valuable at this stage, but even without more robustly derived pooled standard errors, the values in Table 5.4 suggest that measurement in dimensions A1, T1, L1, and D was fairly precise.

5.1.4 Temper

Temper (aplastic) variation is described by the rank-order abundance of each of several grain-types.. Each abundance rank (e.g., most abundant grain-type, second-most abundant grain type, etc.) represents a dimension with modes being the possible observable sand-size grain types. Modes and their descriptions are given in Table 5.5. A particular temper class consists of a number of abundance ranks equal to the different observed modes listed in Table 5.5. For example the class designated 2315 contains in order of abundance ferromagnesian grains, lithic grains, quartzo-feldspathic grains, and voids (following Hunt 1989:125-128). Sherds were assigned a temper class by observing a freshly broken sherd cross-section under low-power microscopy.

Table 5.5. Description of sand-sized temper modes for abundance ranks.

Mode	**Description**
1. Quartzo-feldspathic (QF)	Pale or translucent grains
2. Ferromagnesian (FM)	Black or dark green grains
3. Lithic fragments (LF)	Various gray shaded grains
4. Calcium carbonate (C)	White grains that react with HCL
5. Void*	Temper shaped voids, sometimes containing a possible precipitate, or an accretionary growth forming small stalactites and stalagmites within the void

* Although voids are not aplastics, they appear to have once contained temper, likely calcareous. There are presently no data on the presence of organic tempers that may burn-out during firing to leave voids.

Other researchers in Fiji have measured temper variation differently. Aronson's (1999) petrographic analysis focused on temper mineralology and produced much more precise descriptions of temper composition than is attempted here. Best (1984) also examined temper petrographically and conducted volumetric temper analyses for different temper types. Dickinson (1997a; 1997b; 1998b; 1998c; 1999a; 1999b), in a series of reports referenced in Clark (1999) variously describes the mineralology, roundness, sorting, and size of sand tempers grouped, for example, into quartose-feldspathic, pyribole rich, and mixed placer categories. Clark (1999:196-203) primarily relies on the temper mineralology data to examine temper diversity as there appears to be less variation in dimensions such as roundness and sorting. Roundness and sorting can also, however, be indicative of temper sources and manufacturing techniques. This previous research suggests that mineralology encompasses the greatest differences among Fijian ceramic tempers. Mineralology is thus followed here as a preliminary avenue to explore transmission-related variation.

Dickinson (1998a:270) argues that differentiation of "pale grains (QF), grayish grains (LF), and dark grains (FM) in Oceanian tempers has limited scope for provenance determination" as broad temper classes such as oceanic basalt tempers, andesitic arc tempers, and tectonic highland tempers may contain similar abundances of QF, LF, and FM grains. The temper analyses presented here, however, are not conducted with provenance determination in mind. Rather, these analyses attempt to track changes in temper practices within the great number of sherds produced locally (see section 5.2.4) from the andesitic-arc temper resources of the Yasawas. Of primary interest is the variation in abundance of calcareous sand grains and other grain types in ceramics over time (see Best 1984:357).

5.1.5 Surface Modification

Surface modification includes visible changes to a vessel's surface that are a product of vessel forming or post-forming additions such as slipping or manipulation of the vessel's surface by tools. The tables in Chapter Four list Yasawa Islands ceramic assemblages and the abundance of various kinds of surface modification as they are commonly discussed in the Fijian archaeological literature.

In the classification used here different forms of surface modification are each treated as a dimension with various possible modes (each dimension includes the mode "not present"). An additional dimension notes the location of the surface modification (i.e., body, neck, rim, and lip). More precise locational modes (e.g., lip interior) create classes with too few members for valid comparisons.

The most abundant forms of surface modification found in Fiji define the different dimensions employed (Table 5.6). Each dimension of surface modification contains modes to generate more precise descriptions (Table 5.7 and Figure 5.4). Figure 5.4 indicates one way the modes of some dimensions may be collapsed to examine the distribution of hierarchically related surface modification classes. The modes listed in Table 5.7 may also be combined in a single dimension to create a new mode. For example, a sherd may exhibit incision of both curvilinear parallel line (mode 2) and rectilinear parallel line (mode 6) modes. A new mode, combined curvilinear and rectilinear parallel line incision, can be constructed to classify this surface treatment.

Table 5.6. Description of surface modification dimensions.

Dimension	Description
Wiping	Passing a rough textured tool (e.g., coconut husk) over the wet or leather-hard vessel surface creating multiple non-parallel striations
Slipping	Applying a clay slurry to the vessel surface
Burnishing	Passing a dense flat or rounded tool across the leather hard surface of a vessel so that the outer-most layer of the vessel displays linear facets
Paddle Impressing	Beating the leather-hard surface of the vessel with a flat tool while placing a small anvil (e.g., a rounded stone) on the opposite side
Punctation	Pushing a tool into the wet or leather-hard vessel to leave a depression in the vessel surface
Incising	Dragging a pointed tool across the wet or leather-hard vessel to leave an incised line
Appliqué	Affixing separate pieces of clay to the wet or leather-hard vessel
Molding	Manipulating the wet surface of a vessel with hands to produce topography on the vessel surface

Table 5.7. Descriptions of modes for each surface modification dimension.

Dimension	Modes*
Wiping	1. faint: majority of striations are estimated less than 0.5 mm deep 2. deep: majority of striations are estimated greater than 0.5 mm deep
Slipping	1. red 2. other color
Burnishing	1. present
Paddle Impressing	1. plain paddle: anvil marks present on vessel interior, but no repeated patterns on vessel exterior 2. thin parallel-rib carved paddle: parallel ribs on vessel exterior are 1.2 mm or less apart 3. thick parallel-rib carved paddle: parallel ribs on vessel exterior are greater than 1.2 mm apart 4. oval carved paddle: oval-shaped (length at least 1.5 times width) impression on vessel exterior 5. round carved paddle: round (length and width roughly equal) relief on vessel exterior 6. triangular carved paddle: triangular-shaped impression on vessel exterior 7. diamond carved paddle: diamond-shaped impressions on vessel exterior 8. rectangular carved paddle: rectangular to square impressions on vessel exterior
Punctation	1. dentate, complex: created with a carved stamps 2. dentate, simple: created with carved and plain roulettes 3. circular tool-end: circular to oval punctation 4. cylindrical tool-end: basin-shaped or "V"-shaped punctation created by impressing the longitudinal surface of a cylinder or wedge into the vessel surface 5. finger tip: finger tip is the tool used to create the punctation
Incising	1. curvilinear, single lines: single curved lines incised 2. curvilinear, parallel lines: parallel curved lines created with toothed tool incised on vessel surface 3. curvilinear, intersecting lines: multiple curved lines intersecting to create "hashing" 4. curvilinear, parallel broken: parallel curved lines created with toothed tool that is lifted from vessel surface at intervals of 1-8 mm 5. rectilinear, single lines: single straight lines incised 6. rectilinear, parallel lines: parallel straight lines created with toothed tool incised on vessel surface 7. rectilinear, intersecting lines: multiple straight lines intersecting to create "hashing" 8. rectilinear, parallel broken: parallel straight lines created with toothed tool that is lifted from vessel surface at intervals of 1-8 mm
Appliqué	1. button: one or more circular pieces of clay applied to vessel surface 2. curvilinear fillet: curved linear piece of clay applied to vessel surface 3. rectilinear fillet: straight linear piece of clay applied to vessel surface
Molding	1. linear: vessel surface manipulated by hand to create linear topography 2. ovoid: vessel surface manipulated by hand to create circular or oval relief (e.g., knobs)

* The mode 0 is possible for any dimension and signifies "not present."

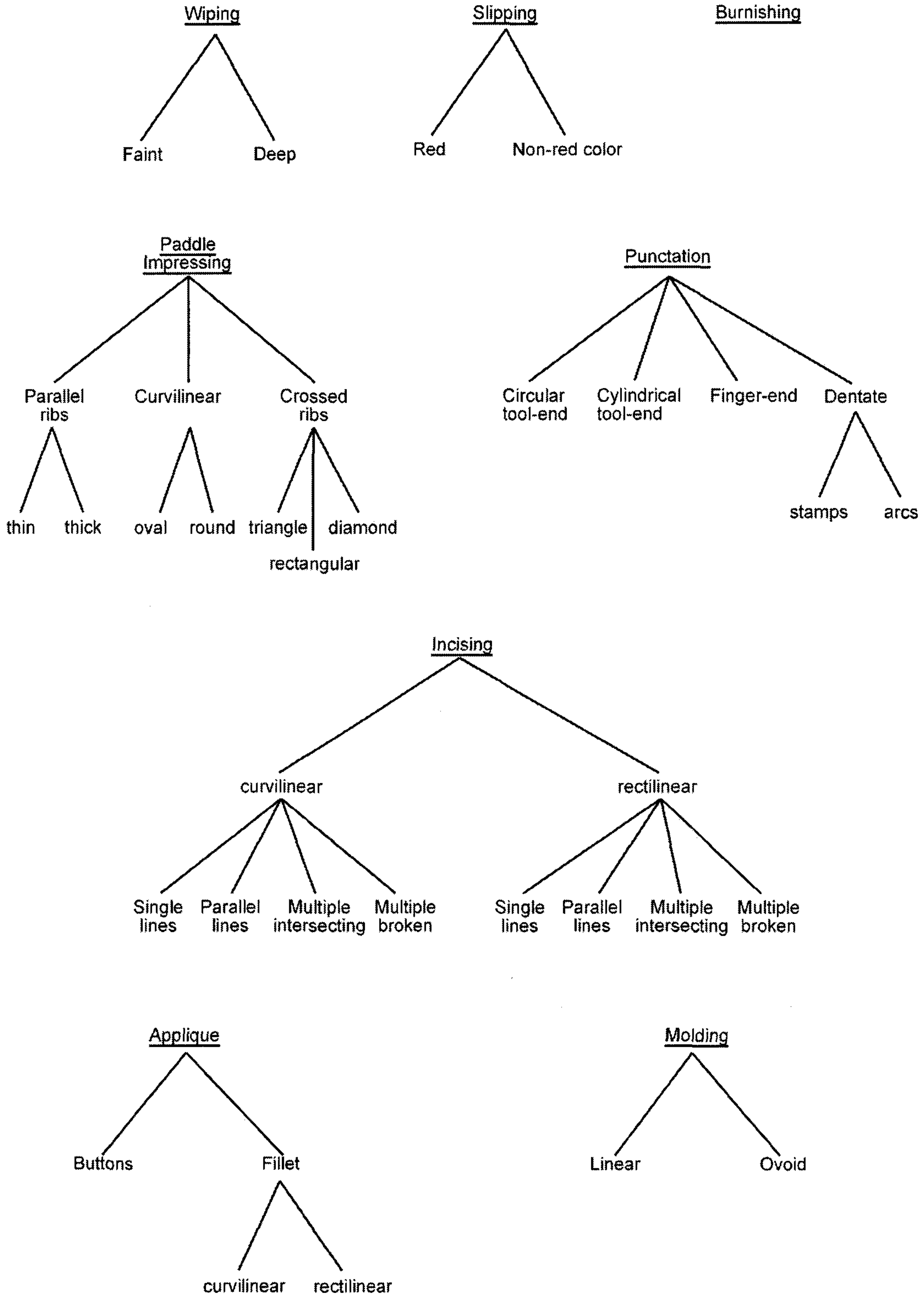


Figure5.4. Surface modification dimensions (underlined) and modes. Some modes within a dimension may be collapsed.

5.1.6 Clay Elemental Composition

Archaeologists primarily resort to grouping methods (e.g., principal components analysis) to analyze differences in the clay elemental composition of sherds. The ceramic compositional groups created are often used to infer whether the depositional location of the sherd is similar to the location of vessel manufacture (Bishop, et al. 1982)—simply put, was the vessel made from local or non-local materials?

Clay composition may also be an important dimension of variation in transmission analyses. Clay composition reflects choices made by potters that may be transmitted and thus can be used to track historical relatedness (Neff 1993). The usefulness of clay compositional variation to track transmission in this fashion depends, in part, on the geological heterogeneity of an area. In geologically homogenous areas there may be little variation in the chemical composition of local ceramics. When there is little variation in a dimension, such as chemical composition, it is difficult to use this dimension to define transmission lineages. Moreover, in a large and geologically homogenous area, human groups that share little transmission-defined similarity may produce ceramics that are compositionally similar. This possibility is an instance of parallelism, the similar character state changes in separate populations that may confound our ability to detect transmission lineages. This potential problem for transmission analyses may be controlled by examining compositional variation as one dimension of a multi-dimensional ceramic cultural trait class.

As compositional variation is linked to particular environments, we can also examine compositional variation within an ecological framework (Neff 1995). When pottery production occurs at an individual scale (currently a reasonable hypothesis for

Fiji, see Chapter Two), changes in the diversity of compositional groups exhibited by assemblages in a region may reflect changes in the spatial component of transmission processes (Neff 1995:73). Changes in the spatial scale of transmission systems may be explained by selection and changes in available clay resources, population distribution, or other ecological parameters.

Compositional analyses were carried out using Laser Ablation Inductively Coupled Plasma Mass Spectroscopy (LA-ICP-MS). LA-ICP-MS was chosen for several reasons: it is minimally destructive when using a laser to induce samples, laser ablation allows only clays to be analyzed without the confounding effects of temper noted by other researchers in Fiji (see below), the technique has c. 70 target analytes and low detection limits (ppm to ppb) necessary for making distinctions within the relatively geologically homogenous Yasawa Islands, low cost per sample, and minimal sample preparation.

5.1.6.1 Inductively Coupled Plasma Mass Spectrometry

Although Inductively Coupled Plasma Mass Spectrometry (ICP-MS) has been consistently used in the geological and life sciences for over a decade, it is a relatively new technique for determining the chemical make up of archaeological materials (Kennett, et al. 2002). ICP-MS instruments work by introducing a sample to an inductively coupled argon plasma torch (c. 8,000 C) which atomizes and ionizes elements in the sample. The torch then sends the sample through a set of orifices called sampler and skimmer cones into the quadrupole detector where an alternating voltage allows ions of different element masses to be detected. The output of this mass spectrometer is made in counts of a particular ion per second. These frequency data are later converted to abundance data (e.g., ppm) for each sample. Additional information on the procedures, technology, and applications of ICP-MS to provenance studies of archaeological ceramics can be found in Mallory-Greenough et al. (1998), Neff (2003), Kennett et al. (2002), and Gratuze et al. (2000).

Previous ICP-MS analyses of Fijian ceramics have used microwave digestion (MD) as a sample-induction technique (e.g., Bentley 2000; Clark 1999; Cruz, et al. 2001; Kennett, et al. 2004). Solid samples such as sherds must be introduced as a liquid or aerosol to the plasma torch in an ICP-MS. The microwave digestion technique transforms a bulk ceramic sample (i.e., clay and temper) into a liquid through a series of acid baths and microwave bombardment. This liquid is then introduced to the torch and the resulting analysis of chemical composition includes both temper and clay constituents. Because of the impossibility of separating the chemical signatures of clay and temper in a whole sherd fragment in MD-ICP-MS results, interpreting the archaeological significance of compositional groups may be difficult (see Ambrose 1993; Arnold, et al. 1991; Burton and Simon 1993; Neff, et al. 1989).

Previous researchers (e.g., Bentley 2000; Clark 1999) in Fiji have noted difficulties in interpreting the contribution of clays and tempers to bulk composition. Bentley (1997; 2000) has examined this problem for a set of sherds from the Yasawas and Viti Levu assayed by MD-ICP-MS. Bentley determined that calcium carbonate temper (most often reef detritus and to a much lesser degree, limestone) complicated group distinctions (Bentley 2000:87). Additionally, in some cases bulk compositional group membership was determined by the shared *absence* of ferromagnesian rich tempers derived from placer sands (Bentley 2000:88). These factors are significant as calcium carbonate temper is present in different abundances in sherds produced at different times and the shared absence of ferromagnesian tempers does not necessarily reflect a similarity that defines a transmission lineage, but instead may represent parallelism or convergence.

To mitigate the interpretive difficulties associated with bulk chemical assays, the analysis presented here uses laser ablation (LA) as a sample induction technique. LA-ICP-MS is a recent addition to the chemical analysis of ceramics (Gratuze, et al. 2000; Neff 2003) whereby specifically targeted phases of a ceramic paste (e.g., the clay matrix between tempers, or individual temper grains) are ablated and the vaporized sample is then introduced to the plasma torch. LA-ICP-MS has the potential to make fine chemical discriminations between various ceramic phases with less ambiguity in the archaeological meaning of the compositional groups created.

5.1.6.2 Relationships Between Clay Elemental Data and Human Populations in Fiji

Recent studies in Fiji have used clay provenance analysis to analyze patterns of human interaction (e.g., Bentley 2000; Clark 1999; Cruz, et al. 2001). These analyses are based on the long-used idea (e.g., Sayre and Dodson 1957) that similarity in ceramic chemical composition across assemblages is a result of similar raw material sources used in the manufacture of ceramics (Bishop, et al. 1982; Rands and Bishop 1980). Most analyses of ceramic chemical composition attempt to differentiate "local" from "non-local" ceramics in investigations of exchange and production. Hector Neff (1993:33) points out that "implicit in the distinction [between local and non-local pottery] is an assumption that local pottery is likely to pertain to a single (local) tradition of pottery manufacture, within which pottery-making information was perpetuated [i.e., transmitted] over some period of time". Additionally, chemical similarity of pottery clays is ultimately dependent on the complex geological and geochemical processes that create clay deposits. Thus we would not expect chemically similar clays, at the ppm level of precision, to occur in different regions.

The identification of cultural transmission from compositional similarity may be confounded by the effects of ancient clay preparation (Carpenter and Feinman 1999; Neff and Bishop 1988), convergence and parallelism among temporally separated populations in a single geological environment (Neff 1993:34), migration (Zedeño 1994), and specialized ceramic production and distribution (Blinman and Wilson 1992). Many of these problems, however, can be controlled in the present analysis. While pottery has certainly been transported throughout Fiji in prehistory (Palmer 1971a:77; Palmer and Shaw 1968:59, 87), there is little archaeological evidence for a specialized ceramic production industry confined to only a few areas. If future research demonstrates that this assumption is inaccurate, this compositional analysis may be redesigned. The present chemical analysis focuses on ceramic clays though laser sampling of the ceramic matrix that avoids temper particles, so the effects of temper on chemical composition are obviated. The compositional effects of other clay preparation techniques such as levigation, sieving, and mixing are not considered. Finally, the effect of diagenic processes on ceramic clay composition are addressed below.

5.1.6.3 Geological Overview of the Yasawas

To guide initial construction of compositional groups from clay chemical data it is important to have a basic understanding of the geology of the Yasawas. The geological history of the Yasawas islands is fairly simple compared to other regions of Fiji. This geological simplicity makes it relatively easy to identify archaeological sherds whose clays are exotic to the Yasawas. Fiji's islands are continental with the oldest rocks approximately 35 million years old and confined to southwest Viti Levu as part of the Fiji Platform (Hathway and Colley 1994). The rotation of this platform, surrounded by the Pacific and Indo-Australian plates, created the multiple island arcs and geological events such as local eruptions, folding, faulting, subduction and rifting that give the many different rock groups in Fiji distinct characteristics (Rodda 1994).

The islands of western Fiji can be divided into four geographic sets (Rodda and Lum 1990:56): the Yasawa group comprising the main islands of Yasawa in the north to Kuata in the south; the Narokorokoyawa group including Kadomo, Vomo, and other small islands; the Mamanuca group is composed of a series of smaller islands including Navadra, Yanuya, Mana, and Tavua[13]; and the Malolo group at the southern end consists of Malolo and the smaller islands clustered around it.

The Yasawa, Narokorokoyama, and Mamanuca islands, formed during the late Miocene (8-6 million years ago), erupted from a fissure system with eruption centers at various points in the islands. These eruptions produced mostly basalts with large quantities of iron and magnesium (derived from mafic minerals). Crustal movement after

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[13] The Narokorokoyama and Mamanuca groups are often referred to only as the Mamanuca group. On some maps, the Narokorokoyama islands are labeled the Mamanuca-i-ra Group (upper Mamanucas), and the islands here called the Mamanucas are labeled the Mamanuca-i-cake Group (lower Mamanucas).

the Miocene created folds and thrusts in these island (Rodda and Lum 1990) which can be seen in some of the dramatic peaks on Waya. The rocks of the Yasawa, Narokorokoyama, and Mamanuca islands are mainly basaltic pillow lavas (i.e., erupted under water), although subaerial eruptions also occurred. Even though there is geological variation within these groups (e.g., Rodda 1990a, b), similar rock formations and unconformities across these islands suggest they are all a product of the same late Miocene event. Rodda (1994:151) suggests that possibly even the small island of Qalito to the northwest of Malolo may also be a product of the late Miocene volcanism along this fissure system. Malolo itself, however, may have developed from events during the early Miocene, 19 million years ago (Rodda and Lum 1990).

The geological history of the western Fijian islands suggests that clays from the Yasawa group in the north to the Mamanuca group in the south will be broadly similar in their major element abundances. Malolo, which formed c. 10 million years before the other western islands, is likely to produce clays with a significantly different chemical signature. Finally, clay sources in western Viti Levu near the Yasawas derive from multiple rock groups ranging in age from 35 to 3 million years old (Rodda and Lum 1990) and are also likely different in their major element abundances. For example, the chemical signatures of the largely mafic basalts of the western islands contrast with the andesitic rocks of Viti Levu (Bentley 1997).

5.1.6.2 LA-ICP-MS Procedures for the Analysis of Yasawan Ceramics

Elemental Abundance data were generated for 277 sherds. This analytical sample was collected across sampling strata as defined at the beginning of section 5.1 so that the sherds analyzed sherds were distributed across islands, sites, depositional units, arbitrary excavation units, and vessel parts. Analyses were conducted with a Perkin Elmer 6100DRC ICP-MS housed at the California State University, Long Beach. A New Wave Research 266UV laser ablation system and associated software was used for sample induction.

Samples were prepared by snapping off a fragment of a sherd (typically about 1 cm^2) and mounting this fragment in modeling clay on a microscope slide so the freshly uncovered inner-surface of the sherd was exposed to the laser in the induction chamber. Using a freshly exposed sherd surface minimizes the introduction of unrelated sediments that may adhere to the outside of the sherd. Sets of eight or ten sherd fragments were mounted in modeling clay on a slide and placed in the chamber. The laser ablation system includes video monitoring of the induction chamber so ablation patterns can be configured for each sherd using the instrument software. Ablation patterns were set so that only the clay matrix was ablated by the 100 micron diameter beam and each pass removed five microns of material. Patterns were of a size such that only two or three ablation passes (after a first pass to remove possible surface contaminants) were needed to generate accurate frequency data in the ICP-MS. More than three ablation passes tends to create a trough-effect where the greater depth of the ablated pattern begins to influence the amount of vaporized material that is retrieved by the induction system. This in turn can adversely affect the accuracy of the chemical abundance data generated (Hector Neff, personal communication, 2003).

As ICP-MS is a precise measuring tool, frequent calibration is required to offset instrument drift over the course of an analysis. After each slide of 8 or 10 samples was analyzed a set of standards and a blank analysis were performed. The blank analysis (no sample is induced) records residual element abundances in the LA-ICP-MS system. The standards included Little Glass Buttes obsidian (Glascock 1999), NIST SRM612 and SRM610, and a sample of Ohio Red Clay used by the Missouri University Research Reactor (MURR). The red clay brick made for the present analysis was labeled New Ohio Red Clay to differentiate it from the reference bricks used at MURR. The element abundances calculated from the analysis of blanks and standards were compared to the known values for these materials (zero abundances for the blank analysis) to correct for instrument drift.

Abundance data for 43 elements were generated for each sherd analyzed. These data are included in the pocket material of this dissertation.

5.2. TECHNOLOGICAL AND SURFACE MODIFICATION VARIATION IN YASAWA ISLANDS CERAMICS

In the remainder of this chapter the various dimensions of ceramic variation—rim form, temper, surface modification, and clay composition—are examined to generate classifications that may track cultural transmission in the Yasawas Islands. Ceramic variation is presented relative to archaeological sites and chronology, so the reader has some indication of possible spatial and temporal trends in the data. The goal of this section is to take the reader through the iterative process of classification. Data on the technological and surface modification observations for each sherd are available in the pocket material of this dissertation.

5.2.1 Rim Form Variation

Different rim classes are variably distributed over time and across occupations in the Yasawa Islands. The current paradigmatic classification of shouldered vessel, or jars for simplicity, rim forms uses six of the dimensions listed in Table 5.2: Curve 1 (C1), Curve 2 (C2), Angle 1 (A1), Rim Symmetry (S), Length 1 (L1), and Thickness 1 (T1). Several dimensions originally thought to be useful for tracking cultural transmission, for example Vertex 1 and Vertex 2, did not appear to define classes that separated variation due to transmission processes. Additionally, preliminary examination of variation in the dimensions of continuous variation lead to the creation of categorical modes (see section 5.1.3). The dimension A1 is divided into three modes: > 90 degrees, ≥ 70 and ≤ 90 degrees, < 70 degrees. The dimension L1 is divided into two modes: < 58 mm, ≥ 58 mm. The dimension T1 is divided into three modes: < 4 mm, ≥ 4 and ≤ 14 mm, > 14 mm.

The dimensions C1 and C2 were combined into a single new dimension, Rim Curvature (C). The combination of C1 and C2 occurred after separate observations had been made in these dimensions. Classifications employing C1 and C2 as separate dimensions had a very large number of classes with few members in each class. By combining C1 and C2 into a single dimension variation in rim curvature is still maintained as a component of the rim form classification. The dimension Rim Curvature has eight dimensions: 1. at least one curve straight, 2. both concave, 3. both convex, 4. exterior concave, interior convex, 5. both S-shaped, 6. exterior S-shaped, interior convex, 7. exterior S-shaped, interior concave, 8. exterior convex, interior concave.

5.2.1.1 Shouldered Vessel (Jar) Rim Form Variation at Olo, Site Y2-25

Rim forms at the earliest identified occupation in the Yasawa Islands derive from the primary cultural deposit, Layer II (anthropogenic sand layer), in test units 3 and 5. These units contain a similar Layer II, while Layer II in test unit 9 appears to be the edge of a sloping dune and is not easily comparable to units 3 and 5 in terms of the vertical position of artifacts within the layer.

Of the 264 rim sherds from shouldered vessels in test units 3 and 5, Layer II, 127 sherds were sufficiently intact so that modes in all five dimensions of the shouldered rim classification could be unambiguously observed. These 127 sherds are distributed across 33 classes (Table 5.8) out of a possible 1152 rim classes (the product of the total number of modes).

Table 5.8. Site Y2-25, TUs 3 and 5, Layer II, Rim Classes (Five Dimension Classification) for Shouldered Vessels (Jars).

						Dimensions					
Class Name	**Mode Code**					**C (interior, exterior)**	**A1 (deg)**	**L1 (mm)**	**T1 (mm)**	**S**	**N of sherds**
Ext. expanded rim	1	2	1	2	2	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. expanded	23
Concave rim	2	2	1	2	1	both concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	18
Straight rim	1	2	1	2	1	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	16
Concave ext. exp. rim	2	2	1	2	2	both concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. expanded	10
Straight collared rim	1	2	1	2	6	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. exp & cont	8
Interior expanded rim	1	2	1	2	3	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	int. expanded	5
Flared concave rim	2	3	1	2	1	both concave	< 70	< 58	≥ 4 & ≤ 14	parallel	5
Inverted straight rim	1	1	1	2	1	1 or 2 straight	> 90	< 58	≥ 4 & ≤ 14	parallel	4
Inverted ext. exp. rim	1	1	1	2	2	1 or 2 straight	> 90	< 58	≥ 4 & ≤ 14	ext. expanded	4
Concave contracted rim	2	2	1	2	5	both concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	contracted	3
Concave expanded rim	2	2	1	2	4	both concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. & int. exp.	3
Straight expanded rim	1	2	1	2	4	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. & int. exp.	3
Straight contracted rim	1	2	1	2	5	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	contracted	3
Convex contracted rim	3	2	1	2	5	both convex	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	contracted	2
Expanded rim	4	2	1	2	4	concave-convex	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. & int. exp.	2
Flared rim	1	3	1	2	1	1 or 2 straight	< 70	< 58	≥ 4 & ≤ 14	parallel	2
Invert. concave ext exp.	2	1	1	2	2	both concave	> 90	< 58	≥ 4 & ≤ 14	ext. expanded	1
Inverted collared rim	1	1	1	2	6	1 or 2 straight	> 90	< 58	≥ 4 & ≤ 14	ext. exp & cont	1
Thin straight expanded	1	2	1	1	4	1 or 2 straight	≥ 70 & ≤ 90	< 58	< 4	ext. & int. exp.	1
Thin ext. expanded rim	1	2	1	1	2	1 or 2 straight	≥ 70 & ≤ 90	< 58	< 4	ext. expanded	1
Thin contracted rim	1	2	1	1	5	1 or 2 straight	≥ 70 & ≤ 90	< 58	< 4	contracted	1
Straight long rim	1	2	2	2	1	1 or 2 straight	≥ 70 & ≤ 90	> 58	≥ 4 & ≤ 14	parallel	1
Flared contracted rim	1	3	1	2	5	1 or 2 straight	< 70	< 58	≥ 4 & ≤ 14	contracted	1
Invert. concave rim	2	1	1	2	1	both concave	> 90	< 58	≥ 4 & ≤ 14	parallel	1
Invert. concave expand	2	1	1	2	4	both concave	> 90	< 58	≥ 4 & ≤ 14	ext. & int. exp.	1
Invert. concave collared	2	1	1	2	6	both concave	> 90	< 58	≥ 4 & ≤ 14	ext. exp & cont	1
Thin concave ext exp	2	2	1	1	2	both concave	≥ 70 & ≤ 90	< 58	< 4	ext. expanded	1
Flared concave int. exp.	2	3	1	2	3	both concave	< 70	< 58	≥ 4 & ≤ 14	int. expanded	1
Convex rim	3	2	1	2	1	both convex	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	1
Thin expanded rim	4	2	1	1	4	concave-convex	≥ 70 & ≤ 90	< 58	< 4	ext. & int. exp.	1
Ext. expanded rim 2	4	2	1	2	2	concave-convex	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. expanded	1
Invert thin concave expanded rim	2	1	1	1	4	both concave	> 90	< 58	< 4	ext. & int. exp.	1

The shouldered rim classes present at Olo (site Y2-25) exemplify late Lapita forms found at other sites in Fiji (Birks 1973; Burley and Dickinson 2004; Clark 1999). The presence of other distinctive sherds in the deposits is also similar to late Lapita sites: there are three slightly carinated body sherds with carination angles between 120 and 150 degrees, a single strap handle, and four pot stand fragments of various types.

Table 5.8 lists the mode codes, and mode descriptions for the five dimension classification used. The number of sherds in each class is also presented. The class names mirror, where possible, the general terms used to describe similar rim classes by other researchers. For example, "collared" rims have appear to have an exterior collar around the rim, "flared" rims are those that are strongly everted so that they are less then 70 degrees above a perpendicular plane through the vessel, and "expanded" rims are thicker at their termination than the neck. Similarity between the class names in Table 5.8 and names used by other researchers does not, however, indicate identical class definitions. Here classes are defined strictly by their constituent modes.

5.2.1.1.1 Example Assessment of Rim Classification and Sample Representativeness

A study of Table 5.8 reveals that half the rim classes have two or more members and the other half of the classes each contain only one member. In some instances, those classes with only one member seem to be a slight variation on a class with multiple members. For example, in the middle of Table 5.8, the "inverted collared rim" class (modes: 11126) with one member is only slightly different from the "straight collared rim" class (modes: 12126) with eight members near the top of Table 5.8. Combining these classes by removing dimension A1 from the class definitions would be easy enough, but at this stage we do not know what effect removing dimension A1 would have on our attempts to define transmission lineages and population relatedness using the ceramic assemblages from other occupations in combination with the Olo ceramics. The removal of some dimensions from class definitions for examining cultural transmission will be considered in the next chapter.

Table 5.8 also indicates that sample representativeness may be a problem when using the five-dimension shouldered jar classification as half of the classes have only one member. Since sample representativeness is in part a function of the precision of classes, changing class precision may alleviate this problem. Using only three dimensions, C, A1, and S, creates a classification with 168 possible classes, where 132 sherds can be unambiguously described by the three dimensions. Of the 168 classes, 25 have members (Table 5.9).

Table 5.9. Site Y2-25, TUs 3 and 5, Layer II, Rim Classes (Three Dimension Classification) for Shouldered Vessels (Jars).

		Dimensions			
Class Name	**Mode Code**	**C (interior, exterior)**	**A1 (deg)**	**S**	**N of sherds**
Ext. expanded rim	1 2 2	1 or 2 straight	≥ 70 & ≤ 90	ext. expanded	26
Straight rim	1 2 1	1 or 2 straight	≥ 70 & ≤ 90	parallel	19
Concave rim	2 2 1	both concave	≥ 70 & ≤ 90	parallel	18
Concave ext. exp. rim	2 2 2	both concave	≥ 70 & ≤ 90	ext. expanded	11
Straight collared rim	1 2 6	1 or 2 straight	≥ 70 & ≤ 90	ext. exp. & cont.	8
Flared concave rim	2 3 1	both concave	< 70	parallel	5
Straight expanded rim	1 2 4	1 or 2 straight	≥ 70 & ≤ 90	ext. & int. exp.	5
Interior expanded rim	1 2 3	1 or 2 straight	≥ 70 & ≤ 90	int. expanded	5
Straight contracted rim	1 2 5	1 or 2 straight	≥ 70 & ≤ 90	contracted	4
Inverted ext. exp. rim	1 1 2	1 or 2 straight	> 90	ext. expanded	4
Inverted straight rim	1 1 1	1 or 2 straight	> 90	parallel	4
Expanded rim	4 2 4	concave-convex	≥ 70 & ≤ 90	ext. & int. exp.	3
Ext. expanded rim 2	4 2 2	concave-convex	≥ 70 & ≤ 90	ext. expanded	3
Concave contracted rim	2 2 5	both concave	≥ 70 & ≤ 90	contracted	3
Concave expanded rim	2 2 4	both concave	≥ 70 & ≤ 90	ext. & int. exp.	3
Convex contracted rim	3 2 5	both convex	≥ 70 & ≤ 90	contracted	2
Invert concave exp. rim	2 1 4	both concave	> 90	ext. & int. exp.	2
Flared rim	1 3 1	1 or 2 straight	< 70	parallel	2
Convex rim	3 2 1	both convex	≥ 70 & ≤ 90	parallel	1
Flared concave int. exp.	2 3 3	both concave	< 70	int. expanded	1
Invert. concave collared	2 1 6	both concave	> 90	ext. exp. & cont.	1
Invert. concave ext exp.	2 1 2	both concave	> 90	ext. expanded	1
Invert. concave rim	2 1 1	both concave	> 90	parallel	1
Flared contracted rim	1 3 5	1 or 2 straight	< 70	contracted	1
Inverted collared rim	1 1 6	1 or 2 straight	> 90	ext. exp. & cont.	1

The three dimension classification in Table 5.9 seems at first glance to produce classes that parcel variation in a manner that is more representative of the ceramic population as a whole. The ratio of classes with one member to total classes with two or more members is lower, thus evenness may be better estimated.

To objectively compare the two classifications in terms of sample representativeness, however, a more rigorous assessment of richness and evenness is necessary. Instead of simple richness versus sample-size plots, a bootstrapped distribution was used to evaluate the richness and evenness of assemblages classified using either the five or three dimension classification. The procedure is straightforward (Efron and Tibshirani 1993): an assemblage is treated as a population and then re-sampled with replacement many times (e.g., 1000) at increasing resample sizes with mean richness calculated for each re-sample size. Figure 5.5 displays mean richness plotted against re-sample sizes for several different assemblages at Olo[14]. For samples that adequately represent the richness and evenness of an underlying population, the richness curve should level-out, reaching an asymptote, prior to or at the actual sample size (G. Cochrane 2003; Lipo 2001b; Lipo, et al. 1997). Richness distributions are plotted for the five dimension classification (hashed line) and the three dimension classification (solid line), and for each 10 cm excavation level of the cultural layer at Olo, as well as the entire cultural layer (levels 15-17).

Except for the level 15 assemblage where the five and three dimension classifications produce almost identical richness distributions, the three dimension classification produces re-sampled richness distributions that more closely resemble representative samples as they level-out to a greater degree prior to reaching final sample size more so than the five dimension classification. However, the three dimension richness distributions are obviously not perfectly asymptotic, suggesting that increased

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[14] Richness calculations made using a PERL program written by Lipo (2001). The original program was modified to use updated PERL libraries.

sampling of the ceramic population through re-collection might further increase sample representativeness.

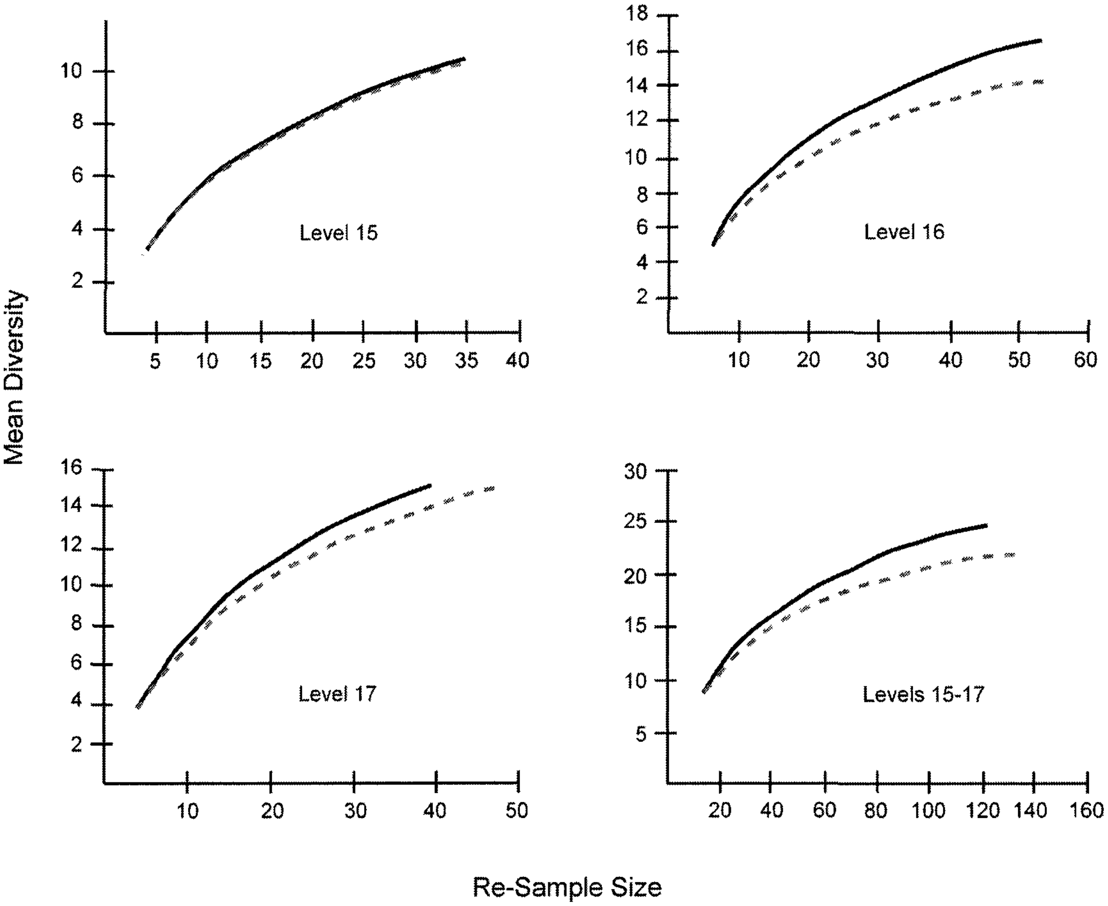

Figure 5.5. Richness-sample size plots for shouldered rim classification of Olo (Y2-25) sherds. Solid line represents five dimension classification. Hashed line represents three dimension classification. Assemblages divided into ten re-sample units of increasing size. Mean richness derived by 1000 random draws with replacement.

Still, the question of are these samples "adequate enough" has not been answered. G. Cochrane (2003) has recently examined the problem of objectively evaluating sample representativeness through bootstrapped richness distributions. First, he notes that adequacy is relative, so that when comparing samples we can say that one is more adequate than the other (Figure 5.5). To determine the overall adequacy of a particular sample, however, G. Cochrane develops an index of flatness for bootstrapped mean richness curves. A dramatic change in flatness indices between different curves is treated as an indication that the boundary of adequacy has been crossed. Ultimately, Cochrane's flatness index is also somewhat subjective. Cochrane's technique of comparing multiple mean richness curves to determine the relatively most adequate sample is used here. The three dimension classification produces a more representative samples for the Olo deposits, but with the addition of assemblages from other occupations to the classification, the five dimensional classification may produce an equally or more representative (and more precise) classification.

5.2.1.2 Unshouldered Vessel (Bowl) Rim Form Variation at Olo, Site Y2-25

Along with shouldered rim sherds there are 80 unshouldered rim sherds derived from bowls in the Layer II Olo deposits. Of these, 42 sherds, can be unambiguously classified by the four dimensions used to construct the bowl classification (see Table 5.3): Vertex 1 (V1), C (combination of C1 and C2 similar to shouldered classification), S (Rim Symmetry), and O (Rim Orientation). The four dimension bowl classification contains 336 classes of which 19 have members in the Olo deposits (Table 5.10).

The bowl rim classes present at Olo (site Y2-25) are similar to those found at other contemporaneous sites in Fiji (Birks 1973; Burley and Dickinson 2004; Clark 1999). Table 5.8 lists the bowl rim class and their constituent modes, along with the number of sherds in each class. Like the five dimension shouldered rim classification, about half of the bowl rim classes have only one member. The sample representativeness implications of this classification are discussed in Chapter Six along with transmission analyses.

Table 5.10. Site Y2-25, TU3, Layer II, Rim Classes for Unshouldered Vessels (Bowls).

					Dimensions and Modes					
General Name	**Mode Code**				**V1**	**C (interior, exterior)**	**S**	**O**	**N of sherds**
Convex inverted contracted bowl	3	3	5	2	Round	both convex	contracted	inverted	10
Convex inverted bowl	3	3	1	2	Round	both convex	parallel	inverted	4
Straight inverted bowl	1	1	1	2	Straight	1 or 2 straight	parallel	inverted	4
Straight everted bowl	3	1	1	1	Round	1 or 2 straight	parallel	everted	3
Convex everted bowl	1	3	1	1	Straight	both convex	parallel	everted	3
Convex inverted bowl 2	1	3	1	2	Straight	both convex	parallel	inverted	2
Convex inverted contracted bowl 2	1	3	5	2	Straight	both convex	contracted	inverted	2
Straight everted contracted bowl	3	1	5	1	Round	1 or 2 straight	contracted	everted	2
Convex everted bowl 2	3	3	1	1	Round	both convex	parallel	everted	2
Straight inverted bowl 2	3	1	1	2	Round	1 or 2 straight	parallel	inverted	1
Two-curved inverted bowl	3	4	5	2	Round	concave-convex	contracted	inverted	1
Convex inverted expanded bowl	1	3	2	2	Straight	both convex	exterior expanded	inverted	1
Convex everted expanded bowl	3	3	2	1	Round	both convex	exterior expanded	everted	1
Convex everted contracted bowl	3	3	5	1	Round	both convex	contracted	everted	1
Concave everted bowl	1	2	1	1	Straight	both concave	parallel	everted	1
Straight everted contracted bowl 2	1	1	5	1	Straight	1 or 2 straight	contracted	everted	1
Straight inverted expanded bowl	1	1	2	2	Straight	1 or 2 straight	exterior expanded	inverted	1
Straight everted expanded bowl	1	1	2	1	Straight	1 or 2 straight	exterior expanded	everted	1
Convex everted contracted bowl 2	1	3	5	1	Straight	both convex	contracted	everted	1

The general names of classes listed in Table 5.10 are given as an intuitive way to refer to the bowl rim classes. Like the shouldered vessels, archaeologists in Fiji often reference Birks' (1973:25-27) type descriptions for late-Lapita bowls. Birks describes five general bowl types, three of which vary primarily by their degree of rim inversion or eversion. A fourth Birks type (Type 2D) is "deep bowl with an incurved rim" (Birks, 1973:26,111) and is similar to the first two classes in table 5.8. Again, these comparisons with the Birks-types are meant to convey some of the general characteristics of members of each bowl rim class for readers familiar with Fijian archaeology. These comparisons do not indicate that the classes in Table 5.8 are analytically identical to the types constructed by Birks and used by other researchers.

5.2.1.3 Jar and Bowl Rim Form Variation at Qaranicagi, Site Y2-39

Different shouldered vessel rim classes are present throughout the Qaranicagi deposits. Some classes have long temporal distributions while others are restricted to particular parts of the Qaranicagi sequence (Tables 5.11 and 5.12). Many of the jar rim classes present at Qaranicagi are also present in the Olo deposits.

Like the jar rim classification applied to the Olo ceramics, the richness and evenness of classes at Qaranicagi displayed in Tables 5.11 and 5.12 suggests that sample representativeness should be closely evaluated. Comparison of Tables 5.11 and 5.12 also demonstrates that again the five and three dimension shouldered rim classifications produce samples of different richness and evenness. Sample representativeness evaluations are made in Chapter 6 with transmission analyses.

Some classes at Qaranicagi have temporal distributions that span separate portions of the entire sequence. The classes concave-expanded-rim and straight-expanded rim are found in the earliest and latest deposits at Qaranicagi. Such "re-invention" of particular mode combinations may make attempts to define transmission lineages more difficult as it suggests our phylogenies may include instances of homoplasy explained by convergence, parallelism, or chance similarities related to class definitions. Other shouldered rim classes are found in what are more likely continuous blocks of time and are represented, for example, in the bottom half of the Qaranicagi excavation levels, or the middle levels.

The Level 1, 2, and 3 ceramics from the Sigatoka Dunes site described by Birks (1973) include rim forms similar to those found throughout the Qaranicagi deposits. Variation among vessel rims is depicted in multiple illustrations (Birks 1973:74-148).

Table 5.11. Site Y2-39, TUs 1, 2, and 3, Rim Classes (Five Dimension Classification) for Shouldered Vessels (Jars).

		Dimensions						
Class Name	**Mode Code**	**C (interior, exterior)**	**A1 (deg)**	**L1 (mm)**	**T1 (mm)**	**S**	**N**	**Excavation Levels**
Straight rim	1 2 1 2 1	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	10	20, 17-15, 11
Concave rim	2 2 1 2 1	both concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	5	20, 19, 16, 15, 13
Straight contracted rim	1 2 1 2 5	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	contracted	4	16, 12
Flared concave rim	2 3 1 2 1	both concave	< 70	< 58	≥ 4 & ≤ 14	parallel	3	21, 17
Straight expanded rim	1 2 1 2 4	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. & int. exp.	3	20, 17, 1
Thin concave rim	2 2 1 1 1	both concave	≥ 70 & ≤ 90	< 58	< 4	parallel	2	16, 15
Thin straight rim	1 2 1 1 1	1 or 2 straight	≥ 70 & ≤ 90	< 58	< 4	parallel	2	16, 15
Concave collared rim	2 2 1 2 6	both concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. expand & contract	2	22, 21
Flared contracted rim 2	2 3 1 2 5	both concave	< 70	< 58	≥ 4 & ≤ 14	contracted	2	15
Convex rim	3 2 1 2 1	both convex	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	2	20, 8
Flared contracted rim 3	3 3 1 2 5	both convex	< 70	< 58	≥ 4 & ≤ 14	contracted	2	12, 7
Concave expanded rim	2 2 1 2 4	both concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. & int. exp.	2	21, 1

Table 5.11 (continued). Site Y2-39, TUs 1, 2, and 3, Rim Classes (Five Dimension Classification).

		Dimensions						
Class Name	**Mode Code**	**C (interior, exterior)**	**A1 (deg)**	**L1 (mm)**	**T1 (mm)**	**S**	**N**	**Excavation Levels**
Flared expanded rim	2 3 1 2 4	both concave	< 70	< 58	≥ 4 & ≤ 14	ext. & int. exp.	1	20
Flared concave int. exp.	2 3 1 2 3	both concave	< 70	< 58	≥ 4 & ≤ 14	int. expanded	1	no data
Expanded rim 2	8 2 1 2 4	convex-concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. & int. exp.	1	2
Convex contracted rim	3 2 1 2 5	both convex	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	contracted	1	13
Invert. concave rim	2 1 1 2 1	both concave	> 90	< 58	≥ 4 & ≤ 14	parallel	1	1
Flared contracted rim	1 3 1 2 5	1 or 2 straight	< 70	< 58	≥ 4 & ≤ 14	contracted	1	14
Flared rim	1 3 1 2 1	1 or 2 straight	< 70	< 58	≥ 4 & ≤ 14	parallel	1	12
Ext. expanded rim 2	4 2 1 2 2	concave-convex	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	exterior expanded	1	20
S-shaped rim 2	5 2 1 2 1	both S-shaped	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	1	18
Ext. expanded rim	1 2 1 2 2	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	exterior expaneded	1	22
S-shaped rim	6 2 1 2 6	S shape-convex	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	ext. expand & contract	1	2

Table 5.12. Site Y2-39, TUs 1, 2, and 3, Rim Classes (Three Dimension Classification) for Shouldered Vessels (Jars).

		Dimensions				
Class Name	**Mode Code**	**C (interior, exterior)**	**A1 (deg)**	**S**	**N of sherds**	**Excavation Levels**
Straight rim	1 2 1	1 or 2 straight	≥ 70 & ≤ 90	parallel	13	20,17-15, 11
Concave rim	2 2 1	both concave	≥ 70 & ≤ 90	parallel	7	20, 19, 16, 15, 13
Straight contracted rim	1 2 5	1 or 2 straight	≥ 70 & ≤ 90	contracted	5	16, 12
Flared concave rim	2 3 1	both concave	< 70	parallel	3	21, 17
Straight expanded rim	1 2 4	1 or 2 straight	≥ 70 & ≤ 90	ext. & int. exp.	3	20, 17, 1
Ext. expanded rim	1 2 2	1 or 2 straight	≥ 70 & ≤ 90	ext. expanded	2	22, 20
Concave expanded rim	2 2 4	both concave	≥ 70 & ≤ 90	ext. & int. exp.	2	21, 1
Concave collared rim	2 2 6	both concave	≥ 70 & ≤ 90	ext. exp. & cont.	2	22, 21
Flared contracted rim 2	2 3 5	both concave	< 70	contracted	2	15
Convex rim	3 2 1	both convex	≥ 70 & ≤ 90	parallel	2	20, 8
Flared contracted rim 3	3 3 5	both convex	< 70	contracted	2	12, 7
Flared expanded rim	2 3 4	both concave	< 70	ext. & int. exp.	1	20
Expanded rim 2	8 2 4	convex-concave	≥ 70 & ≤ 90	ext. & int. exp.	1	21
Convex contracted rim	3 2 5	both convex	≥ 70 & ≤ 90	contracted	1	13
Invert. concave rim	2 1 1	both concave	> 90	parallel	1	1
Flared contracted rim	1 3 5	1 or 2 straight	< 70	contracted	1	14
Flared rim	1 3 1	1 or 2 straight	< 70	parallel	1	12
Ext. expanded rim 2	4 2 2	concave-convex	≥ 70 & ≤ 90	ext. expanded	1	20
S-shaped rim 2	5 2 1	both S-shaped	≥ 70 & ≤ 90	parallel	1	18
S-shaped rim	6 2 6	S shape-convex	≥ 70 & ≤ 90	ext. exp. & cont.	1	2
Flared concave int. exp.	2 3 3	both concave	< 70	int. expanded	1	no data

Bowl rim classes are also present in the Qaranicagi deposits represented by 56 sherds. Twenty-seven of these sherds can be unambiguously classified by the four dimensions used in the bowl rim classification (see section 5.2.1.2). The Qaranicagi bowl classes are displayed in Table 5.13.

Like the shouldered vessels, many of the bowl rim classes at Qaranicagi are also present in the Olo deposits. Additionally, the bowl rim classes at Qaranicagi display different temporal distributions with some classes restricted to only a few excavation levels while other classes have more extended distributions across time.

Table 5.13. Site Y2-39, TUs 1, 2, and 3, Rim Classes for Unshouldered Vessels (Bowls).

		Dimensions and Modes					
General Name	**Mode Code**	**V1**	**C (interior, exterior)**	**S**	**O**	**N of sherds**	**Excavation levels**
Straight everted bowl	1 1 1 1	Straight	1 or 2 straight	parallel	everted	6	20, 16, 15, 12, 1
Convex inverted bowl 2	1 3 1 2	Straight	both convex	parallel	inverted	4	20, 17, 11
Convex everted bowl	1 3 1 1	Straight	both convex	parallel	everted	3	22, 16, 1
Convex everted bowl 2	3 3 1 1	Round	both convex	parallel	everted	2	13, 8
Convex inverted contracted bowl 2	1 3 5 2	Straight	both convex	contracted	inverted	2	16, 12
Convex everted contracted bowl 2	1 3 5 1	Straight	both convex	contracted	everted	2	16, 12
Straight everted contracted bowl 2	1 1 5 1	Straight	1 or 2 straight	contracted	everted	2	15, 11
S-shaped inverted bowl	3 5 1 2	Round	both S-shaped	parallel	inverted	1	8
Convex inverted bowl	3 3 1 2	Round	both convex	parallel	inverted	1	21
Straight everted bowl	3 1 1 1	Round	1 or 2 straight	parallel	everted	1	8
S-shaped inverted bowl 2	1 5 1 2	Straight	both S-shaped	parallel	inverted	1	16
Concave everted bowl	1 2 1 1	Straight	both concave	parallel	everted	1	16
Straight inverted bowl	1 1 1 2	Straight	1 or 2 straight	parallel	inverted	1	18

5.2.1.4 Jar and Bowl Rim Form Variation at Natia (Site Y1-15)

Rim form variation at Natia is described by eleven classes in the five-dimension classification. Only 25 rim sherds were recovered from Test Units 4 and 5 at Natia, with 19 sherds complete for assignment to a class. There are also eleven classes in the three-dimension classification, with 22 sherds distributed across them (Tables 5.14 and 5.15).

Many of the shouldered rim classes at Natia are also present in the Olo and Qaranicagi deposits, but there are classes unique to Natia as well. Some of the rim classes at Natia are broadly distributed across excavation levels, while others appear in a single level, or across widely discontinuous levels.

The Level 1, 2, and 3 ceramics from the Sigatoka Dunes site described by Birks' (1973) include rim forms similar to those found throughout the Natia deposits (see illustrations in Birks [1973:74-148]). There is much less variation, however, among Natia rim forms.

Table 5.14. Site Y1-15, TUs 4 and 5, Rim Classes (Five Dimension Classification) for Shouldered Vessels (Jars).

		Dimensions						
Class Name	**Mode Code**	**C (interior, exterior)**	**A1 (deg)**	**L1 (mm)**	**T1 (mm)**	**S**	**N of sherds**	**Excavation Levels**
Straight rim	1 2 1 2 1	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	5	14, 12, 10, 8, 6
Concave rim	2 2 1 2 1	both concave	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	parallel	3	11, 1
Straight contracted rim	1 2 1 2 5	1 or 2 straight	≥ 70 & ≤ 90	< 58	≥ 4 & ≤ 14	contracted	2	7, 2
Inverted straight rim	1 1 1 2 1	1 or 2 straight	> 90	< 58	≥ 4 & ≤ 14	parallel	2	11, 8
S-shaped rim 3	5 3 1 2 5	both S-shaped	< 70	< 58	≥ 4 & ≤ 14	contracted	1	6
Inverted expanded-contracted rim	4 1 1 2 7	concave-convex	> 90	< 58	≥ 4 & ≤ 14	int. & ext. expanded & contracted	1	7
Flared contracted rim 2	2 3 1 2 5	both concave	< 70	< 58	≥ 4 & ≤ 14	contracted	1	8
Flared expanded rim 2	2 3 1 2 2	both concave	< 70	< 58	≥ 4 & ≤ 14	interior expanded	1	13
Flared expanded rim 3	1 3 1 2 3	1 or 2 straight	< 70	< 58	≥ 4 & ≤ 14	exterior expanded	1	6
Flared thin rim	1 3 1 1 1	1 or 2 straight	< 70	< 58	< 4	parallel	1	3
Thin straight rim	1 2 1 1 1	1 or 2 straight	≥ 70 & ≤ 90	< 58	< 4	parallel	1	10

Table 5.15. Site Y1-15, TUs 4 and 5, Rim Classes (Three Dimension Classification) for Shouldered Vessels (Jars).

		Dimensions				
Class Name	**Mode Code**	**C (interior, exterior)**	**A1 (deg)**	**S**	**N of sherds**	**Excavation Levels**
Straight rim	1 2 1	1 or 2 straight	≥ 70 & ≤ 90	parallel	7	15, 14, 12, 10, 8, 6
Concave rim	2 2 1	both concave	≥ 70 & ≤ 90	parallel	3	11, 1
S-shaped rim2	5 2 1	both S-shaped	≥ 70 & ≤ 90	parallel	2	11, 4
Straight contracted rim	1 2 5	1 or 2 straight	≥ 70 & ≤ 90	contracted	2	7, 2
Inverted straight rim	1 1 1	1 or 2 straight	> 90	parallel	2	11, 8
S-shaped rim 3	5 3 5	both S-shaped	< 70	contracted	1	6
Inverted expanded-contracted rim	4 1 7	concave-convex	> 90	int. & ext. expanded & contracted	1	7
Flared contracted rim 2	2 3 5	both concave	< 70	contracted	1	8
Flared expanded rim 2	2 3 2	both concave	< 70	interior expanded	1	13
Flared expanded rim 3	1 3 3	1 or 2 straight	< 70	exterior expanded	1	6
Flared rim	1 3 1	1 or 2 straight	< 70	parallel	1	3

Bowls or unshouldered vessels are also present in the Natia deposits. Forty-two bowl rim sherds were recovered from Test Units 4 and 5, with 24 sherds classifiable by the four bowl dimensions. These sherds are distributed across 14 classes (Table 5.16) with most of the bowl classes also present in the Olo and Qaranicagi deposits. Like shouldered vessel rim classes, some bowl rim classes at Natia are present in multiple excavation levels and others appear in a single level.

Table 5.16. Site Y1-15, TUs 4 and 5, Rim Classes for Unshouldered Vessels (Bowls).

General Name	Mode Code	Dimensions and Modes				N of sherds	Excavation levels
		V1	C (interior, exterior)	S	O		
Straight everted bowl	1 1 1 1	Straight	1 or 2 straight	parallel	everted	4	11, 10, 7, 6
Convex inverted bowl 2	1 3 1 2	Straight	both convex	parallel	inverted	3	14, 4
Straight inverted expanded bowl2	1 1 3 2	Straight	1 or 2 straight	ext. expanded	inverted	3	7, 5, 2
Straight everted contracted bowl	3 1 5 1	Round	1 or 2 straight	contracted	everted	2	6, 2
Straight everted bowl	3 1 1 1	Round	1 or 2 straight	parallel	everted	2	8
Straight everted expanded bowl 2	1 1 3 1	Straight	1 or 2 straight	ext. expanded	everted	2	6, 5
Convex everted contracted bowl 2	1 3 5 1	Straight	both convex	contracted	everted	1	5
Convex inverted expanded bowl 2	1 3 3 2	Straight	both convex	ext. expanded	inverted	1	9
Convex everted expanded bowl 2	1 3 3 1	Straight	both convex	ext. expanded	everted	1	4
Convex everted bowl	1 3 1 1	Straight	both convex	parallel	everted	1	10
Concave everted bowl	1 2 1 1	Straight	both concave	parallel	everted	1	10
Straight everted contracted bowl 2	1 1 5 1	Straight	1 or 2 straight	contracted	everted	1	4
Straight everted expanded bowl 2	1 1 4 1	Straight	1 or 2 straight	expanded	everted	1	7
Straight inverted bowl	1 1 1 2	Straight	1 or 2 straight	parallel	inverted	1	4

5.2.1.5 Jar and Bowl Rim Form Variation at Yasawas Surface Sites

The thirteen surface deposits examined here contain a great variety of rim classes (Tables 5.17 and 5.18). There are 46 shouldered rim classes in the five-dimension classification distributed across 97 classifiable sherds out of 146 total shouldered rim sherds. For the three-dimension classification there are 30 classes describing 114 classifiable sherds. The surface sites as a group comprise a slightly richer assemblage of rim classes than the Olo site, the next most diverse assemblage with 25 three-dimension classes describing 132 sherds.

Table 5.17. Surface Site Rim Classes (Five Dimension Classification) for Shouldered Vessels (Jars).

General Rim Class Name	Mode Code (C, A1, L1, T1, S)					Yasawa Islands Surface Sites													Total N
						Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	
Flared contracted rim	1	3	1	2	5					2	5	4				1			12
Flared rim	1	3	1	2	1					2	2	3		1					8
Flared thick rim	1	3	1	3	1	1				2		1			1	1			6
Flared thick contracting rim	1	3	1	3	5					1					1	4			6
Flared long contracting rim	1	3	2	2	5		1			3	1				1				6
Concave rim	2	2	1	2	1						2	1					1		4
Flared long rim	1	3	2	2	1				1		1	2							4
Flared long thick contracting rim	1	3	2	3	5						1				2				3
Straight rim	1	2	1	2	1						2								2
Straight contracted rim	1	2	1	2	5			1			1								2
Straight thick rim	1	2	1	3	1					1		1							2
Straight thick contracting rim	1	2	1	3	5			1		1									2
Flared contracted rim 2	2	2	1	2	5		2												2
Flared convex rim	3	3	1	2	1						1	1							2
Flared convex thick contracting rim	3	3	2	3	5							1				1			2
Contracted rim	6	2	1	2	5					1	1								2
Flared contracted rim 4	6	3	1	2	5						1					1			2
Flared contracted rim 5	4	3	1	2	5					1	1								2
S-shaped rim 2	5	2	1	2	1							1							1
S-shaped flared rim	5	3	1	2	1					1		1							1
Flared expanded rim 2	1	3	1	2	4						1								1
Flared expanded rim 3	1	3	1	2	3							1							1
Concave contracted rim 2	2	2	2	2	5					1									1
Thick contracted rim	6	2	1	3	5					1									1
Straight collared rim	1	2	1	2	6						1								1
Flared expanded and contracted rim	6	3	1	2	6							1							1
Interior Expanded rim	1	2	1	2	3											1			1

Table 5.17 (continued). Surface Site Rim Classes (Five Dimension Classification) for Shouldered Vessels (Jars).

General Rim Class Name	Mode Code (C, A1, L1, T1, S)					Yasawa Islands Surface Sites													Total N
						Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	
Exterior Expanded rim	1	2	1	2	2					1									1
Flared expanded and contracted rim 2	6	3	1	2	7						1								1
Thick straight rim	1	2	2	3	1					1									1
S-shaped thick contracted rim	5	2	1	3	5		1												1
Convex rim 2	3	2	2	2	1		1												1
Convex inverted rim	3	1	1	2	1							1							1
Flared concave contracted rim	2	3	2	3	5		1												1
Flared concave thick rim	2	3	2	3	1			1											1
Flared thick short rim	2	3	1	3	1						1								1
Flared exterior expanded & contracted	4	3	1	2	6					1									1
Flared concave rim	2	3	1	2	1							1							1
Flared exterior expanded	1	3	2	2	2							1							1
Inverted Exterior Expanded rim	1	1	1	2	2				1										1
Expanded rim	4	2	1	2	4			1											1
Flared thick rim	1	3	2	3	1										1				1
Flared expanded rim 4	4	3	1	2	2						1								1
Flared expanded rim 5	1	3	2	2	4											1			1
Flared Contracted rim 3	3	3	1	2	5					1									1
Flared Contracted rim 2	2	3	1	2	5							1							1

Table 5.18. Surface Site Rim Classes (Three Dimension Classification) for Shouldered Vessels (Jars).

General Rim Class Name	**Mode Code (C, A1, S)**			**Yasawa Islands Surface Sites**													**Total N**
				Y2-9	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**	
Flared contracted rim	1	3	5		1			6	10	4		1	4	6			32
Flared rim	1	3	1	1			2	4	4	6		1	2				20
Straight rim	1	2	1				1	2	2	1							6
Concave rim	2	2	1						2	1					1		4
Flared convex rim	3	3	1		1				1	1				1			4
Straight Contracted rim	1	2	5			2		1	1								4
Flared Contracted rim	3	3	5					1		2				1			4
Flared Concave rim	2	3	1			1			1	1							3
Contracted rim	6	2	5					2	1								3
Concave Contracted rim	2	2	5		2			1									3
Flared expanded rim 2	1	3	4						1					1			2
Flared contracted rim 5	4	3	5					1	1								2
Flared Contracted rim 2	2	3	5		1					1							2
Exterior Expanded rim	1	2	2					1					1				2
S-shaped rim	5	2	6						2								2
Flared contracted rim 4	6	3	5						1					1			2
Flared exterior expanded rim	1	3	2							1							1
Flared expanded rim 3	1	3	3							1							1
Interior Expanded rim	1	2	3											1			1
Inverted Interior Expanded rim	1	1	2				1										1
Straight collared rim	1	2	6						1								1
Inverted Straight rim	1	1	1													1	1
Convex rim	3	2	1		1												1
S-shaped contracted rim	5	2	5		1												1
Convex flared int. expanded rim	3	3	3											1			1
Expanded rim	4	2	4			1											1
Flared expanded rim 4	4	3	2						1								1
Flared exterior expand. & contracted	4	3	6					1									1

Table 5.18 (continued). Surface Site Rim Classes (Three Dimension Classification) for Shouldered Vessels (Jars).

General Rim Class Name	**Mode Code (C, A1, S)**			**Yasawa Islands Surface Sites**													**Total N**
				Y2-9	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**	
S-shaped rim 2	5	2	1							1							1
S-shaped flared rim	5	3	1					1									1
S-shaped flared expanded rim	5	3	4											1			1
Flared expanded & contracted rim	6	3	6							1							1
Flared expanded & contracted rim 2	6	3	7						1								1
Convex inverted rim	3	1	1							1							1

The surface sites Y2-58, Y2-61, and Y2-62 have the largest number of classifiable rim sherds and the richest assemblages. The most abundant rim classes in both the five- and three-dimension classification can be described as “flared” rims similar to Best’s description of the Fijian *kuro* (Best 1984:294, Table 3.2). In contrast, at the earliest end of the Yasawan ceramic sequence (i.e., at Olo and the deepest levels at Qaranicagi) straight and expanded rims seem to predominate.

Bowls as a class of vessel outnumber jars or shouldered vessels in the surface deposits. This contrasts with the earliest deposits where more jar forms are found. Of the 177 unshouldered rim sherds at surface sites, 150 are classifiable. These sherds are distributed across 26 classes (Table 5.19).

Table 5.19. Surface Site Rim Classes for Unshouldered Vessels (Bowls).

General Rim Class Name	Mode Code (V,C, S, O)				Yasawa Islands Surface Sites													Total N
					Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	
Straight everted bowl	1	1	1	1		11	5		5	6	5			1	4			37
Convex everted bowl	1	3	1	1		6	6		1	4	3	2	1		1		2	26
Straight everted Contracted bowl 2	1	1	5	1		2			2	3	5	1		1	2			16
Straight evert. int. expanded bowl	1	1	3	1		3	1		3	3		1		1	1			13
Straight evert. ext. expanded bowl	1	1	2	1		3			1					3				8
Convex inverted bowl	1	3	1	2		2			2		1	1						6
Convex everted expand bowl	1	3	4	1		2			2	1		1						6
Convex everted int. expand bowl	1	3	3	1		1	1			1	1							4
Straight everted ext. expand bowl	1	1	4	1		2		1			1							4
Straight inverted int. expand bowl	1	1	3	2		1			1	1								3
Convex inverted bowl 2	1	3	3	2					1			1				1		3
Convex everted contracted bowl 2	1	3	5	1		1						1			1			3
Convex everted contracted bowl	3	3	5	1		1			1						1			3
Convex everted ext. expanded bowl	1	3	2	1					1	1								2
Straight everted bowl	3	1	1	1			1				1							2
Concave everted bowl	1	2	1	1				1		1								2
Straight evert. ext. expanded bowl 2	3	1	2	1			2											2
Convex everted bowl 2	3	3	1	1	1	1												2
S-shaped everted bowl	3	5	5	1		1												1
Everted expanded bowl	1	4	4	1		1												1
Inverted expanded bowl	1	4	5	2		1												1
S-shaped everted bowl 2	1	5	1	1												1		1
Convex everted expanded bowl 2	3	3	4	1												1		1
Convex inverted contracted bowl	3	3	5	2							1							1
Straight inverted bowl	1	1	1	2					1									1
Convx evert.ext.expanded bowl 2	1	3	2	2					1									1

5.2.1.6 Rim Form Variation Summary

The entire shouldered rim assemblage from the Yasawas consists of 440 sherds. Using the five- and three-dimension classifications, 294 and 322 sherds are classifiable, respectively. The five-dimension classification contains 76 classes and the three-dimension classification contains 51 classes (Tables 5.20 and 5.21).

Jar or shouldered rim classes are variably distributed across different sites and over time in the Yasawa Islands. The most abundant classes such as "Straight rims," "Concave rims," various "Flared rims," and "Exterior Expanded rims" are found in the northern and southern Yasawas, but with differing frequencies over time. Those classes with only one or two members seem to occur more often in surface deposits than in the older deposits of Olo, Qaranicagi, and Natia.

There are 359 bowl or unshouldered rims in the Yasawa Islands deposits examined here. Using the unshouldered rim classification 247 sherds can be classified by 36 classes (Table 5.22). The most abundant unshouldered rim classes such as "Straight Everted Bowl," "Convex Everted Bowl," and "Straight Everted Contracted Bowl 2" are found across sites in the Yasawas and throughout the ceramic sequence (except for the absence of "Straight Everted Bowls" from the Olo deposits). Rare classes are fairly evenly distributed across all sites.

Table 5.20. Distribution of Shouldered Vessel Classes (Five-Dimension Classification) Across Yasawas Sites.

Mode Code (C, A1, L1, T1, S)					Y2-25	Y2-39			Y1-15			Surface Sites													
					lyr. II	lvls 22-16	lvls 15-9	lvls 8-1	lvls 15-11	lvls 10-6	lvls 5-1	Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	Total N
1	2	1	2	1	16	7	3		2	4	1						2								33
2	2	1	2	1	18	3	2		2		1						2	1					1		30
1	2	1	2	2	23	1										1									25
1	3	1	2	5	1		1									2	5	4				1			14
1	2	1	2	5	3	2	2							1			1								11
1	3	1	2	1	2		1									2	2	3		1					11
2	2	1	2	2	10																				10
1	2	1	2	6	8												1								9
2	3	1	2	1	5	3												1							9
1	1	1	2	1	4				1	1															6
1	3	1	3	1								1				2		1			1	1			6
1	3	1	3	5												1					1	4			6
1	3	2	2	5									1			3	1				1				6
1	2	1	2	4	3	2		1																	6
1	2	1	2	3	5																	1			6
1	1	1	2	2	4																				5
2	2	1	2	5	3								2												5
2	2	1	2	4	3	1		1																	5
1	3	2	2	1																					4
2	3	1	2	5			2			1								1							4
3	2	1	2	1	1	1		1																	3
3	2	1	2	5	2		1																		3
3	3	1	2	5			1	1								1									3
4	2	1	2	4	2									1											3
1	3	2	3	5													1				2				3
1	2	1	1	1		1	1			1															3
6	2	1	2	5												1	1								2

Table 5.20 (continued). Distribution of Shouldered Vessel Classes (Five-Dimension Classification) Across Yasawas Sites.

Mode Code (C, A1, L1, T1, S)					**Y2-25**	**Y2-39**			**Y1-15**			**Surface Sites**													
					lyr. II	**lvls 22-16**	**lvls 15-9**	**lvls 8-1**	**lvls 15-11**	**lvls 10-6**	**lvls 5-1**	**Y2-9**	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**	**Total N**
6	3	1	2	5													1								2
2	1	1	2	1	1																				2
1	3	1	2	3						1								1							2
2	2	1	2	6		2																			2
1	2	1	3	5										1		1									2
6	2	1	2	6	1			1																	2
2	2	1	1	1		1	1																		2
5	2	1	2	1		1												1							2
4	3	1	2	5												1	1								2
3	3	1	2	1													1	1							2
3	3	2	3	5														1				1			2
2	3	1	2	3	1																				2
1	2	1	3	1												1		1							2
4	2	1	2	2	1	1																			2
1	3	1	1	1							1														1
1	1	1	2	6	1																				1
6	2	1	3	5												1									1
1	3	1	2	4													1								1
1	2	1	1	2	1																				1
1	2	1	1	5	1																				1
1	2	2	3	1																					1
7	2	1	3	5									1												1
1	2	2	2	1	1																				1
6	3	1	2	7													1								1
6	3	1	2	6														1							1
1	2	1	1	4	1																				1

Table 5.20 (continued). Distribution of Shouldered Vessel Classes (Five-Dimension Classification) Across Yasawas Sites.

Mode Code (C, A1, L1, T1, S)					Y2-25	Y2-39			Y1-15			Surface Sites													Total N
					lyr. II	lvls 22-16	lvls 15-9	lvls 8-1	lvls 15-11	lvls 10-6	lvls 5-1	Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	
2	3	1	2	4		1																			1
5	3	1	2	5						1															1
5	3	1	2	1												1		1							1
4	3	1	2	6												1									1
4	3	1	2	2													1								1
4	2	1	1	4	1																				1
4	1	1	2	7						1															1
3	2	2	2	1									1												1
3	1	1	2	1														1							1
2	3	2	3	5									1												1
2	1	1	2	4																					1
2	3	1	3	1													1								1
2	1	1	2	1				1																	1
1	3	2	2	2														1							1
2	3	1	2	2					1																1
2	2	2	2	5												1									1
8	2	1	2	4		1																			1
2	1	1	2	6	1																				1
2	2	1	1	2	1																				1
2	1	1	2	2	1																				1
2	1	1	1	4	1																				1
1	3	2	3	1																	1				1
1	3	2	2	4																		1			1
2	3	2	3	1										1											1

Table 5.21. Distribution of Shouldered Vessel Classes (Three-Dimension Classification) Across Yasawas Sites.

Mode Code (C, A1, S)			Y2-25	Y2-39			Y1-15			Surface Sites													Total N
			lyr. II	lvls 22-16	lvls 15-9	lvls 8-1	lvls 15-11	lvls 10-6	lvls 5-1	Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	
1	2	1	19	9	4		3	4					1	2	2	1							45
1	3	5	1		1						1			6	10	4		1	4	6			34
2	2	1	18	4	4		2		1						2	1					1		32
1	2	2	26	2										1					1				30
1	3	1	2		1				1	1			2	4	4	6		1	2				25
1	2	5	4	2	3			1	1			2		1	1								15
2	2	2	11																				11
2	3	1	5	3								1			1	1							11
1	2	6	8												1								9
1	2	4	5	2		1																	8
1	1	1	4				1	1														1	7
2	2	5	3								2			1									6
3	3	5			1	1						2		1	1								6
1	2	3	5																	1			6
1	1	2	4										1										5
2	2	4	3	1		1																	5
2	3	5			2			1			1					1							5
6	2	6				1									2								4
4	2	4	3									1											4
3	3	1									1				1	1				1			4
3	2	1	1	1		1					1												4
5	2	1		1			1		1							1							4
6	2	5												2	1								3
3	2	5	2		1																		3
4	3	5												1	1								2
2	3	3	1																				2
1	3	3						1								1							2

Table 5.21 (continued). Distribution of Shouldered Vessel Classes (Three-Dimension Classification) Across Yasawas Sites.

Mode Code (C, A1, S)			**Y2-25**	**Y2-39**			**Y1-15**			**Surface Sites**													
			lyr. II	**lvls 22-16**	**lvls 15-9**	**lvls 8-1**	**lvls 15-11**	**lvls 10-6**	**lvls 5-1**	**Y2-9**	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**	**Total N**
1	3	4													1					1			2
2	2	6		2																			2
6	3	5													1					1			2
4	2	2	3	1																			2
2	1	4	2																				2
2	1	1	1			1																	2
1	1	6	1																				1
1	3	2														1							1
4	3	2													1								1
7	2	5									1												1
6	3	7													1								1
6	3	6														1							1
5	3	5						1															1
5	3	4																		1			1
2	3	2					1																1
4	3	6												1									1
2	1	2	1																				1
4	1	7						1															1
3	3	3																		1			1
3	1	1														1							1
8	2	4		1																			1
2	3	4		1																			1
2	1	6	1																				1
5	3	1												1									1

Table 5.22. Distribution of Unshouldered Vessel Classes (Bowls) Across Yasawas Sites.

Mode Code (V,C, S, O)				Y2-25	Y2-39			Y1-15			Surface Sites													
				lyr. II	lvls 22-16	lvls 15-9	lvls 8-1	lvls 15-11	lvls 10-6	lvls 5-1	Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	Total N
1	1	1	1		3	2	1	1	3			11	5		5	6	5			1	4			47
1	3	1	1	3	2		1		1			6	6		1	4	3	2	1		1		2	33
1	1	5	1	1		2				2		2			2	3	5	1		1	2			20
1	1	3	1						1	1		3	1		3	3		1		1	1			15
1	3	1	2	2	3	1		1		2		2			2		1	1						15
3	3	5	2	10													1							11
1	1	2	1									3			1					3				9
3	1	1	1	3			1		2				1				1							8
1	3	5	1	1	1	1				1		1						1			1			7
1	1	1	2	4	1					1					1									7
1	1	3	2						2	1		1			1	1								6
1	3	3	1							1		1	1			1	1							6
1	3	4	1									2			2	1		1						6
3	3	1	1	2		1	1				1	1												6
3	1	5	1	2					1															6
1	1	4	1						1			2		1			1							5
1	2	1	1	1	1				1					1		1								5
3	3	1	2	4	1																			5
1	3	3	2						1						1			1				1		4
1	3	5	2	2	1	1																		4
3	3	5	1	1								1			1						1			4
3	1	2	1										2											2
1	3	2	2	1											1									2
1	3	2	1												1	1								2
1	4	5	2									1												1
3	5	1	2				1																	1
3	4	5	2	1																				1

Table 5.22 (continued). Distribution of Unshouldered Vessel Classes (Bowls) Across Yasawas Sites.

Mode Code (V,C, S, O)				**Y2-25**	**Y2-39**			**Y1-15**			**Surface Sites**													
				lyr. II	**lvls 22-16**	**lvls 15-9**	**lvls 8-1**	**lvls 15-11**	**lvls 10-6**	**lvls 5-1**	**Y2-9**	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**	**Total N**
1	1	2	2	1																				1
3	3	4	1																			1		1
1	5	1	2		1																			1
1	1	5	2																	1				1
3	1	1	2	1																				1
1	4	4	1									1												1
1	7	1	1																			1		1
3	6	5	1									1												1
3	3	2	1	1																				1

5.2.2 Temper Variation

Ceramic tempers in the Yasawa Islands assemblages are dominated by calcareous and ferromagnesian sand grains in the first abundance rank. The temper classes presented here are constructed by combining the various modes (i.e., kinds of grain present, see Table 5.5) of the first three temper abundance ranks. This results in 216 possible classes. The 1,915 sherds analyzed are placed into forty-eight of these classes (Table 5.23). Temper shaped voids were considered to be calcium carbonate grains in the construction of these classes. Temper-shaped voids were observed predominantly in sherds from Olo (site Y2-25) and the middle and lower levels of Qaranicagi (site Y2-39), suggesting that post-depositional processes (e.g., leaching) at these sites may have removed calcium carbonate grains. Future analyses will evaluate this hypothesis.

Table 5.23. Temper classes in the Yasawa Islands assemblages

Temper Abundance Rank 1	Temper Abundance Rank 2	Temper Abundance Rank 3	Number in Class
C	FM		312
C	FM	QF	310
FM	QF		162
C	QF	FM	141
QF	FM		100
FM	C	QF	90
FM	LF		77
C	FM	LF	74
C	QF		70
C			65
FM	C		60
C	LF	FM	59
QF	LF	FM	34
LF	FM	QF	34
LF	QF	FM	30
FM			30
FM	LF	QF	29
LF	FM		28
FM	C	LF	22
C	LF		20
C	LF	QF	20
QF	C	FM	19
LF	C	FM	16
FM	QF	C	15
QF	LF		14
FM	LF	C	12
QF	FM	LF	11
C	QF	LF	9
QF			6
FM	QF	LF	5
LF	QF		5
QF	FM	C	5
QF	C		4
LF	FM	C	4
C	FM	FM	4
LF	QF	C	3
LF	C	QF	3
QF	LF	C	2
FM	QF	QF	2
LF	C		1
LF			1
C	LF	C	1
FM	C	FM	1
QF	C	LF	1
FM	CC		1
QF	QF		1
FM	FM	LF	1
C	LF	LF	1

For the purposes of tracking cultural transmission temper variation in the Yasawa Islands assemblages appears to be most usefully described by differences in the first temper abundance rank. Other temper abundance ranks appear to differ in a largely random fashion uncorrelated with differences in the spatial location of assemblages or their chronological relationships. The distribution of first abundance rank modes in the Yasawa Islands assemblages is given in Table 5.24.

Table 5.24. Frequency (%) of sherds with different first abundance rank temper modes for Yasawa Islands assemblages.

First Rank	**Y2-25**	**Y2-39**			**Y1-15**			**Surface Sites**												
	lyr. II	**lvls 24-16**	**lvls 15-9**	**lvls 8-1**	**lvls 15-11**	**lvls 10-6**	**lvls 5-1**	**Y2-9**	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**
C	40	62	57	60	84	71	40	86	69	21	75	50	79	62	48	43	25	38	28	5
FM	29	29	25	10	12	19	35	0	14	12	6	33	12	22	13	48	34	48	54	82
QF	19	6	5	24	2	5	11	14	14	61	0	10	6	9	26	5	3	9	9	3
LF	12	3	13	6	2	5	14	0	3	6	19	7	3	7	13	4	38	5	9	10

Temporal and spatial trends are visible in the frequencies of different first abundance rank temper modes. At site Y2-39 the frequency of sherds predominantly tempered with calcium carbonate (reef-derived) sands is relatively similar throughout the occupation of this site. There use of ferromagnesian sands as a predominant temper type decreases over time, while quartzo-feldspathic tempers show the opposite trend (see also Aronson 1999). At site Y1-15 calcium carbonate sands decrease over time as a predominant temper type, while all other temper types increase.

The surface sites of Waya and Naviti Islands (Y2-9, -22, -45, -46, -58, -61, -62) in the southern half of the Yasawa chain contain a high proportion of sherds predominantly tempered with calcareous sand. Site Y2-45 on Waya Island is an exception with over 60% of the sherds here predominantly tempered with quartzo-feldspathic sands. Site Y2-45 may be unique in certain aspects of the human occupation here.

Ceramic assemblages from surface sites in the northern half of the Yasawa chain (Y1-1, -4, -12, -15, -29, -30) contain fewer sherds predominantly tempered with calcium carbonate sands and a higher proportion of sherds tempered with ferromagnesian sands. Independent sample *t*-tests confirm that there is a significant difference between the southern and northern assemblages when compared by the proportion of predominantly calcium carbonate tempered sherds ($t = -2.98$, $df = 11$, $p = 0.01$) and the proportion of predominantly ferromagnesian tempered sherds ($t = 3.36$, $df = 11$, $p = 0.01$). If variation in the frequency of predominant temper type tracks cultural transmission, then transmission is at least partially structured by space late in Yasawa Islands prehistory.

5.2.3 Surface Modification Variation

Surface modifications on ceramics in the Yasawa Islands assemblages vary throughout time and across the islands. Some of these modifications are commonly considered decorative such as various incised designs. Other modifications may influence the performance of ceramic vessels in various contexts, so that their distribution may not reflect only transmission processes.

There are 78 surface modification classes in the Yasawa Islands filled by 717 sherds. The surface modification classes were constructed from a set of modes and dimensions slightly modified from those presented in Table 5.7. While all the modes listed in Table 5.7 were used to make initial observations, some of the classes produced by combinations of these modes appeared to be poor measures of transmission related similarities. For example, classes distinguished by either parallel or single curvilinear incised lines had too few members to reliably track transmission. Attempts to create more inclusive classes by removing the dimension characterizing the location of the surface modification (e.g., neck, rim) resulted in class distributions with such broad temporal and spatial distributions as to be unusable for determining the spatial and temporal characteristics of transmission lineages. However, by combining some of the modes of particular dimensions in Table 5.7 new classes with limited temporal and spatial distributions were created. The new collapsed modes for each surface modification dimension are listed in Table 5.25. Thus far, these collapsed-mode classes appear to best exhibit the qualities of fidelity, fecundity, and longevity that facilitate transmission analyses. The number of members in each class across the Yasawa Islands assemblages is listed in Table 5.26.

Table 5.25. Descriptions of collapsed-modes for each surface modification dimension.

Dimension	Modes*
Wiping	1. faint: majority of striations are estimated less than 0.5 mm deep 2. deep: majority of striations are estimated greater than 0.5 mm deep
Slipping	1. red 2. other color
Burnishing	1. present
Paddle Impressing	1. parallel-rib carved paddle: parallel ribs on vessel exterior are greater than 1.2 mm apart 2. oval carved paddle: oval-shaped (length at least 1.5 times width) impression on vessel exterior 3. triangular carved paddle: triangular-shaped impression on vessel exterior 4. diamond carved paddle: diamond-shaped impressions on vessel exterior 5. rectangular carved paddle: rectangular to square impressions on vessel exterior
Punctation	1. dentate, complex: created with a carved stamps 2. dentate, simple: arcs 3. circular tool-end: circular to oval punctation 4. cylindrical tool-end: basin-shaped or "V"-shaped punctation created by impressing the longitudinal surface of a cylinder or wedge into the vessel surface 5. finger tip: finger tip is the tool used to create the punctation
Incising	1. curvilinear 2. rectilinear
Appliqué	1. button: one or more circular pieces of clay applied to vessel surface 2. fillet: linear piece of clay applied to vessel surface
Molding	1. linear: vessel surface manipulated by hand to create linear topography 2. ovoid: vessel surface manipulated by hand to create circular or oval relief (e.g., knobs)

* The mode 0 is possible for any dimension and signifies "not present."

Traditionally, archaeologists have described ceramic surface modification in Fiji using categories different from those listed in Table 5.25. Clark (1999), for instance does not distinguish the location of surface modifications in his analyses, and both Clark (1999) and Best (1984) use different labels for some of the classes in Table 5.25. For example, what Best (1984:296)and others call "Rim Notching," a form of decoration found in late Lapita deposits, I have termed "Punctation, Cylindrical, Rim." While my class labeling system may be initially cumbersome, each term in the class indicates the surface modification dimension, mode, and location, thus dimensional similarities between classes are inherent in class labels.

Table 5.26. Distribution of Surface Modification Classes (Counts) Across Yasawas Sites.

Surface Modification Class	Y2-25	Y2-39			Y1-15			Surface Sites													
	lyr. II	lvls 22-16	lvls 15-9	lvls 8-1	lvls 15-11	lvls 10-6	lvls 5-1	Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	Total N
Paddle Imp., Ribs, Body	5	11	39		2	30	15		12	6		10	4	3	2			3			142
Incising, Rectilinear, Body		6		11	1	4	7					12	3	4	1	3	8	22	2	9	85
Paddle Imp., Rectangle, Body	7		24			5	4					3	3		1						47
Punctation, Cylindrical, Lip	5	6	6			1		1	12	1	1	3	4	2				2	1		45
Incising, Rectilinear, Neck		6		7									2	1	2		2	10	1	5	36
Incising, Rectilinear, Lip	1			3				3	6	2			4	2	1		3			1	26
Burnishing, Lip to Body	23	1																			24
Wiping, Deep, Neck	20	1				1															22
Incising, Curvilinear, Body										1	1	2	1	2	1	2	7	3		1	21
Incising, Rectilinear, Rim			12			1			3					1			1	2		1	21
Burnishing, Lip	15	1	2		1	1									1						21
Paddle Imp., Diamond, Body	1		3			7						5	1	1	1						19
Incising, Curvilinear, Body, & Rectilinear, Body									1					2			7	4		4	18
Paddle Imp., Rib, Rim										10					3						13
Wiping, Deep, Body	8	4																			12
Punctation, Circular, Lip	1	2											2	3		1	1				10
Paddle Imp., Rib, Neck	2		4			3															9
Wiping, Deep, Neck & Rim	8																				8
Punctation, Cylindrical, Body & Appliqué, Fillet, Body				7								1									8
Molding, Linear, Body	1					6															7
Punctation, Cylindrical, Rim	5	1											1								7
Paddle Imp., Oval, Body					1	5	1														7

Table 5.26 (continued). Distribution of Surface Modification Classes (Counts) Across Yasawas Sites.

Surface Modification Class	**Y2-25**	**Y2-39**			**Y1-15**			**Surface Sites**													
	lyr. II	**lvls 22-16**	**lvls 15-9**	**lvls 8-1**	**lvls 15-11**	**lvls 10-6**	**lvls 5-1**	**Y2-9**	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**	**Total N**
Paddle Imp., Rectangle, Neck						7															7
Paddle Imp., Triangle, Body			5												1						6
Molding, Ovoid, Lip				1							2		1	1					1		6
Wiping, Deep, Rim	4	1																			5
Punctation, Circular, Body			3	1			1														5
Slip, Red, Rim, Neck, Body	4	1																			5
Slip, Red, Rim, Neck, Body & Burnishing, Lip to Body	5																				5
Punctation, Finger tip, Lip	1					1					1		1								4
Incising, Curvilinear & Rectilinear, Neck																1		1		1	3
Appliqué, Fillet, Body			1	1								1									3
Molding, Linear, Lip									2												2
Punctation, Cylindrical, Body			1															1			2
Punctation, Cylindrical, Neck & Molding, Linear, Neck	2																				2
Punctation, Finger tip, Neck							1								1						2
Wiping, Deep, Rim and Lip	2																				2
Incising, Curvilinear, Neck	1																1				2
Burnishing, Lip & Punctation, Circular, Lip	1						1														2
Appliqué, Button, Rim & Molding, Ovoid, Lip							2														2

Table 5.26 (continued). Distribution of Surface Modification Classes (Counts) Across Yasawas Sites.

Surface Modification Class	**Y2-25**	**Y2-39**			**Y1-15**			**Surface Sites**													
	lyr. II	**lvls 22-16**	**lvls 15-9**	**lvls 8-1**	**lvls 15-11**	**lvls 10-6**	**lvls 5-1**	**Y2-9**	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**	**Total N**
Punctation, Finger tip, Rim & Incising, Rectilinear, Rim			2																		2
Punctation, Circular, Body & Appliqué, Fillet, Body				2																	2
Punctation Circular & Cylindrical, Lip									1				1								2
Appliqué, Fillet, Neck & Molding, Ovoid, Rim																		1	1		2
Paddle Imp., Rib, Lip	1									1											2
Dentate, Shell Arc, Lip	1	1																			2
Appliqué, Button, Body																1	1				2
Incising, Curvilinear, Rim														1							1
Wiping, Deep, Rim & Burnishing, Lip	1																				1
Punctation Circular & Cylindrical, Rim													1								1
Punctation, Circular & Cylindrical, Rim & Incising, Rectilinear, Rim & Molding, Ovoid, Rim													1								1
Punctation, Cylindrical, Lip & Rim																		1			1
Punctation, Cylindrical, Lip & Incising, Rectilinear, Lip									1												1
Punctation, Cylindrical, Lip & Serrated Tool, Rim												1									1

Table 5.26 (continued). Distribution of Surface Modification Classes (Counts) Across Yasawas Sites.

Surface Modification Class	**Y2-25**	**Y2-39**			**Y1-15**			**Surface Sites**													
	lyr. II	**lvls 22-16**	**lvls 15-9**	**lvls 8-1**	**lvls 15-11**	**lvls 10-6**	**lvls 5-1**	**Y2-9**	**Y2-22**	**Y2-45**	**Y2-46**	**Y2-58**	**Y2-61**	**Y2-62**	**Y1-1**	**Y1-4**	**Y1-12**	**Y1-15**	**Y1-29**	**Y1-30**	**Total N**
Punctation, Cylindrical, Neck & Appliqué, Fillet, Neck	1																				1
Punctation, Cylindrical, Rim, Molding, Linear, Rim	1																				1
Wiping, Deep, Neck & Burnishing, Lip	1																				1
Burnishing, Rim, Body & Punctation, Circular, Lip	1																				1
Appliqué, Button, Lip									1												1
Appliqué, Fillet, Lip									1												1
Molding, Linear, Neck			1																		1
Molding, Linear, Rim																		1			1
Incising, Rectilinear, Neck, Lip & Appliqué, Button, Neck & Molding, Linear, Rim																	1				1
Punctation, Serrated Tool, Body & Molding, Linear, Body												1									1
Paddle Imp., Rib, Body & Incising, Rectilinear, Body			1																		1
Paddle Imp., Rib, Rim & Punctation, Circular, Lip										1											1
Paddle Imp., Triangle & Oval, Body			1																		1

Table 5.26 (continued). Distribution of Surface Modification Classes (Counts) Across Yasawas Sites.

Surface Modification Class	Y2-25	Y2-39			Y1-15			Surface Sites													
	lyr. II	lvls 22-16	lvls 15-9	lvls 8-1	lvls 15-11	lvls 10-6	lvls 5-1	Y2-9	Y2-22	Y2-45	Y2-46	Y2-58	Y2-61	Y2-62	Y1-1	Y1-4	Y1-12	Y1-15	Y1-29	Y1-30	Total N
Paddle Imp., Rectangle & Diamond, Neck			1																		1
Wiping, Lip, Rim, Neck							1														1
Punctation, Circular, Neck						1															1
Punctation, Circular, Lip & Rim			1																		1
Punctation, Circular, Rim	1																				1
Punctation, Circular & Cylindrical, Lip													1								1
Punctation, Finger tip, Body & Incising, Rectilinear, Body			1																		1
Incising, Curvilinear, Lip									1												1
Appliqué, Button, Rim, Body																		1			1
Burnishing, Body & Incision, Rectilinear, Lip	1																				1
Punctation, Serrated Tool, Lip & Incising, Curvilinear, Rectilinear, Rim																		1			1

5.2.3.1 Assessment of Surface Modification Classification and Sample Representativeness

Like rim form variation, previous research on surface modification suggest that surface modification variation is structured by transmission processes and population characteristics. Thus our classification of this variation should adequately represent underlying diversity and evenness if we are to explain variation as a result of cultural transmission. After comparing two classifications of surface modification, the original dimension and modes in Tables 5.6 and 5.7, and the collapsed-mode classification in Tables 5.25 and 5.26, the collapsed-mode classes better represent surface modification diversity in the Yasawa Islands. Figure 5.6 presents bootstrapped mean richness distributions for both classifications (procedure follows section 5.2.1.1.1). The mean-richness distribution of the collapsed-mode classification (hashed line) depicts a sample that is a relatively better representation of diversity as it levels-out and more closely approximates an asymptote, prior to the actual sample size.

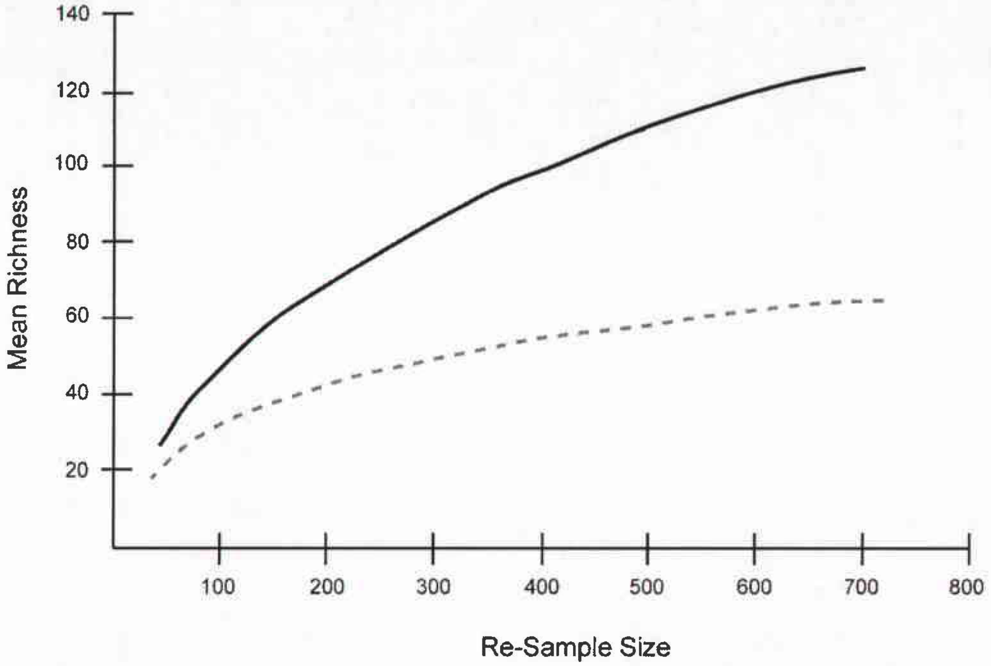

Figure 5.6. Richness-sample size plot for surface modification classifications of all sherds. Hashed line represents collapsed mode classification. Solid line represents original classification based on all observed modes in Table 5.7. Sherds divided into 20 re-sample units of increasing size. Mean richness derived by 1000 random draws with replacement.

A second assessment of variation in surface modification should be carried out prior to transmission analyses. The ability to observe particular classes of surface modification on sherds may be related to sherd size (see Lipo 2001b:217-223). With larger sherds we are more likely to identify surface modification only identifiable across relatively large fields, thus if we use similarities in surface modification to track transmission, we must control the effects of differently sized sherds on our measures of similarity.

Two kinds of surface modification classes are potentially adversely affected by sherd size. Those surface modification classes in Table 5.26 defined by multiple dimensions (e.g., Incising, Punctation, and Appliqué) are one set of classes more likely to be non-randomly distributed across sherds of different sizes. This is so because in the Yasawa Islands different surface modification dimensions are spatially separated, such that with more dimensions, more space is generally required. Another set of classes, single dimension classes (e.g., Punctation on the lip), may be more often found on smaller sherds than on larger sherds, because with larger sherds there is more room for additional dimensions of surface modification to be described (e.g., Punctation on lip combined with Incising on neck).

We can assess the effects of sherd size on the identification of particular classes through chi square tests where the distribution of a particular surface modification class across sherd sizes is compared to a null expectation based on the distribution of all sherds across size classes (Figure 5.7).

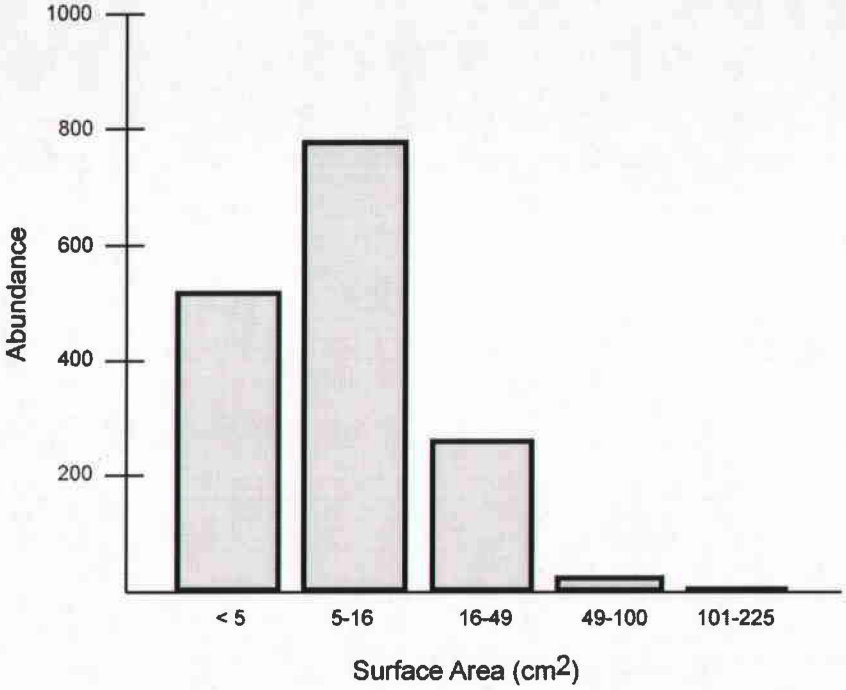

Figure 5.7. Histogram of sherd sizes for Yasawa Islands ceramics. Number of sherds measured is 1,566.

Table 5.27 presents chi-square data for a series of tests on the 13 most abundant surface modification classes in the Yasawa Islands. These classes (save for one) have enough members so that no expected value is less than 1 and no more than 20% of expected values are less than five (see Drennan 1996:197). In Table 5.26, chi-square tests conducted with 2 degrees of freedom use only the three most abundant size classes to generate expected values. With these tests, the number of measured sherds was too low to generate an expected value from the 49-100 cm^2 size class (which has only 20 members total, about 1% of the population).

Table 5.27. Chi-square tests of association between surface modification classes and sherd size classes.

Surface Modification Class	x^2	**df**	**p**	**Difference from Expected Distribution (95% confidence intervals)**	**Total N measured**
Paddle Imp., Ribs, Body	16.01	3	0.001	moderately fewer 16-49 cm^2 sherds	119
Incising, Rectilinear, Body	14.53	3	0.002	moderately more < 5 cm^2 sherds	85
Paddle Imp., Rectangle, Body	10.38	2	0.006	moderately more < 5 cm^2 sherds and moderately fewer 16-49 cm^2 sherds	45
Punctation, Cylindrical, Lip	1.60	2	0.449	not different from expected	34
Incising, Rectilinear, Neck	8.99	2	0.011	moderately less < 5 cm^2 sherds and moderately more 16-49 cm^2 sherds	29
Incising, Rectilinear, Lip	8.90	2	0.011	moderately less < 5 cm^2 sherds and moderately more 16-49 cm^2 sherds	20
Burnishing, Lip to Body	4.73	2	0.094	not different from expected	24
Wiping, Deep, Neck	5.34	2	0.069	not different from expected	22
Incising, Curvilinear, Body	2.57	2	0.277	not different from expected	20
Incising, Rectilinear, Rim*	-	-	-	-	-
Burnishing, Lip	6.55	2	0.038	moderately more 5-16 cm^2 sherds	20
Paddle Imp., Diamond, Body	0.08	2	0.961	not different from expected	19
Incising, Curvilinear, Body, & Rectilinear, Body	5.46	2	0.065	not different from expected	18

*Too few sherds with size measurements for valid comparison.

The chi-square test results suggest that the identification of some surface modification classes is influenced by sherd size. For example, the class "Paddle Imp., Ribs, Body," the first row in Table 5.26, is found on fewer 16-49 cm^2 sherds than we would expect given the overall proportion of 16-49 cm^2 sherds analyzed. Thus the distribution of this surface modification class across sites and over time may partially reflect differential breakage patterns across sites and time. Refining the surface modification classification, the sherd size classification (e.g., more precise size classes), and increased ceramic collection may mitigate this problem.

Is this potential bias in the identification of surface modification classes equally shared across all Yasawas Island assemblages? If assemblages contain quite different proportions of sherd size classes, we might expect sherd size to have an additional adverse effect on our measurement of cultural transmission with surface modification classes. A comparison of the relative proportions of sherd size classes in excavated deposits, however, shows that there are no significant differences ($x^2 = 22.417$, df = 18, p = 0.214).[15] In contrast, among surface assemblages grouped by island there is a significant difference in the proportion of sherd size classes ($x^2 = 23.802$, df = 12, p = 0.021). This is caused by the assemblages on Naviti Island (Y2-61, 62, and 58) that have a greater than expected number of the larger sherd size classes. Without the Naviti assemblages there is no significant difference among surface assemblages ($x^2 = 12.453$, df = 9, p = 0.189). There is also a significant difference in sherd size classes when comparing excavated and surface assemblages without Naviti Island ($x^2 = 161.035$, df = 27, p = 0). Three conclusions stem from these analyses: sherd size biases on surface modification classes in excavated assemblages are systematic, these biases are also systematic when only surface assemblages are compared without Naviti Island, and finally, these biases are unsystematic (therefore more difficult to control) when comparing excavated and surface assemblages. To mitigate these problems we could restrict our analyses of surface modification to a single sherd size class, but this would then create smaller samples and adversely affect sample representativeness. At this point we can continue with our analysis using all sherd sizes, but the effects of sherd size on our analyses should be re-evaluated after additional ceramic collection efforts in the Yasawa Islands.

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[15] For this chi-square analysis excavated deposits were divided into the groups used in Table 5.25: Y2-25, Layer II; Y2-39, levels 22-16, 15-9, 8-1; Y1-15 levels 15-11, 10-6, 5-1.

5.2.3.2 Surface Modification Variation in the Yasawa Islands Assemblages

Examination of Table 5.26 suggests some general temporal and spatial patterns in surface modification among Yasawa Islands ceramics. First, there are only a few surface modification classes that occur only in the oldest deposits: burnishing across a vessels entire surface (Burnishing, Lip to Body), various forms of wiping, slipping, some forms of punctation on the lip and rim, and other classes. The early occurrence of such classes is similar to the surface modifications identified by others in late Lapita and immediately post-Lapita deposits in Fiji (e.g., Best 1984; Burley and Dickinson 2004; Clark, et al. 2001; Clark 1999; Gifford 1951; Hunt 1980; Parke 2003).

In these earliest deposits there are also surface modification classes more regularly associated with later time periods variously referred to as the Mid-Sequence, Period III, or the Navatu Phase (see Figure 2.1). For example, paddle-impressed classes appear in small numbers in the early Yasawas deposits such as Y2-25, Layer II, but are found in greater numbers in more recent deposits at Y2-39 and Y1-15.

Other surface modification classes are confined to more recent time periods. Various classes of curvilinear incising appear only across surface deposits in the Yasawa Islands. A class of ovoid molding appearing as scallop shapes along vessel lips occurs only in the most recent deposits and may be unique the Yasawa Islands.

Fewer classes of surface modification appear to have relatively restricted spatial distributions. Paddle-impressed ceramics with oval-shaped relief are found only at site Y1-15 in the northern Yasawas. The early classes of burnished ceramics and slipped ceramics are found only on Waya Island at the southern end of the chain. The lack of early slipped ceramics at the northern site of Y1-15 could also be a product of differential preservation of such surface modifications at this site relative to sites Y2-25 and Y2-39.

The preceding is a qualitative examination of variation in surface modification and suggests that this variation is not randomly distributed through time and space. The temporal and spatial patterning of surface modification classes suggest that such variation can be examined through transmission analyses.

5.2.4 Clay Paste Chemical Variation

Considering previous archaeological research on Fijian and Yasawas geology we can formulate several expectations for the distribution of clay chemical compositions. The geological homogeneity of the Yasawas Islands suggests that analytically defined compositional groups may not be spatially distinct in the multi-dimensional space of element abundances. Significant discontinuities between compositional groups, however, may identify exotic sherds from elsewhere in Fiji, including some of the geologically distinct islands directly south of the Yasawa chain (e.g., Malolo).

Research on prehistoric interaction, broadly conceived, may also be used to generate expectations regarding compositional group variation that is patterned by cultural transmission processes. Several archaeologists have identified changes in ceramic decoration and vessel forms c. 2300 BP (Best 1984; Burley and Dickinson 2004; Clark 1999). If these changes represent changes in transmission patterns, particularly the spatial component of transmission, we may see changes in ceramic compositional group diversity related to ceramics being manufactured from raw materials distributed across a larger or smaller geographic area. Changes in the frequency and spatial extent of interaction in Fiji have also been documented through lithic artifacts and their chemical provenance (Best 1992; Clark 2002). These data suggests renewed contact between Fijian and West Polynesian populations beginning between 900 and 500 BP. Again, changes in the spatial scale of interaction at this time may be reflected in ceramic compositional changes. Finally, several researchers have noted linkages between environmental change approximately 700 BP and changes in prehistoric interaction (Field 2004; Nunn 1997). If environmental changes affects populations to the degree that spatial transmission patterns are altered we may again see coordinated compositional changes.

5.2.4.3 Compositional Groups in the Yasawa Islands Ceramics

Compositional groups are created for the purpose of identifying the clay compositional diversity of Yasawa ceramics over time and across space in the islands. Compositional groups are generated by placing sherds into groups which maximize both similarity of within group elemental abundances and dissimilarity between groups. Multivariate analyses are required to identify grouping patterns in large data matrices such as those examined here (Baxter 1994; Bishop and Neff 1989), but for the generated compositional groups to have archaeological significance, preliminary partitioning of the data matrix into archaeological meaningful units (e.g., wares, site types, time periods) should be performed. Partitioning may represent hypotheses regarding the nature of compositional group variation (Neff 2002:16). Here, partitioning reflects possible temporal changes in cultural transmission patterns. Table 5.28 groups 259 sherds with known elemental abundances into units that are used to initially structure the multivariate analysis[16]. The abundance data (ppm) were transformed to natural logarithms prior to multivariate and other analyses so that order of magnitude differences in the abundances of different elements would not overwhelm results(Neff 2002:16-17). Also some elements were removed from specific analyses due to variation in elements abundances that could not be linked to variation in clay sources. These analytical decisions are discussed in specific sections below.

Table 5.28. Archaeological assemblage groups used to structure initial multivariate analyses

Sherd Catalog Numbers	**Number of sherds**	**Depositional Context**	**Approximate Age†**
1991-1020-103 to 1991-1022-73	28	Qaranicagi Site (Y2-39), Test Unit 1, levels 20 and 22	2760 - 2360 BP
1994-18-1 to 1994-18-326	93	Olo Site (Y2-25), Test Unit 3, level 17	2760 - 2470 BP
2002-20-1 to 2002-21-7, 2002-29-1 and 2	21	Natia Site (Y1-15), Test Unit 1, levels 13-14	2380 - 2000 BP
1991-1012-110 to 1991-1017-67	63	Qaranicagi Site (Y2-39), Test Unit 1, levels 17-12	2000 - 900 BP
1991-1001-11 to 1991-1011-83	20	Qaranicagi Site (Y2-39), Test Unit 1, levels 11-2	900 - 100 BP
1991-2000-3 to 1991-9000-563, 1997-3000-1 through 4.	34	Surface sites Y1-1, 4, 12, 29, and 30; Y2-9, 22, 45, and 61	400 - 100 BP

† Approximate ages derived from Table 4.14

5.3.4.1 Compositional Group Variation During Early Yasawas Prehistory

The 142 sherds from early deposits at Qaranicagi, Olo, and Natia were examined together to determine ceramic compositional group diversity associated with the earliest human groups in the Yasawas. Structure in this dataset was initially explored through hierarchical cluster analysis (for general treatment see Aldenderfer and Blashfield 1984) of the 114 Olo and Natia sherds. The depositional environments of the early Olo and

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[16] Eighteen sherds originally analyzed derive from Sigatoka Valley collections and are not included here.

Natia assemblages are very similar, thus post-depositional processes affecting element abundances in sherds should not confound results. The hierarchical cluster analysis used 38 elements[17] with As, Sn, Sb, and Cs removed as the measured ppm abundance of these elements was zero for some sherds. Therefore, these data could not be log-transformed and those elements were removed from consideration. Agglomerative clusters were formed using both between-cluster average linkage and within-cluster average linkage measured by squared Euclidean distance. These two methods produced comparable dendrograms displayed in Figures 5.8 and 5.9.

The hierarchical cluster analyses displayed in Figures 5.8 and 5.9 are generated to develop an initial idea about patterning in the multivariate data set. Choosing the breakpoints for clusters in a single dendrogram is, however, a subjective enterprise. One possible way to decrease the subjectivity in cluster assignment is to generate multiple dendrograms using different clustering algorithms and determine which clusters cohere across analyses (Aldenderfer and Blashfield 1984:65; Sokal and Sneath 1963:166). The solid brackets in Figures 5.8 and 5.9 identify the clusters of the dendrograms that cohere in both sets of analyses (following Hunt 1989).

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[17] Na23, Mg24, Al27, Si29, K39, Ca44, Sc45, Ti47, V51, Cr52, Mn55, Fe57, Co59, Ni60, Cu65, Zn66, Rb85, Sr88, Zr90, Ba138, La139, Ce140, Pr141, Nd142, Sm152, Eu153, Gd158, Tb159, Dy164, Ho165, Er166, Tm169, Yb174, Lu175, Hf180, Ta181, Pb208, Th232, U38.

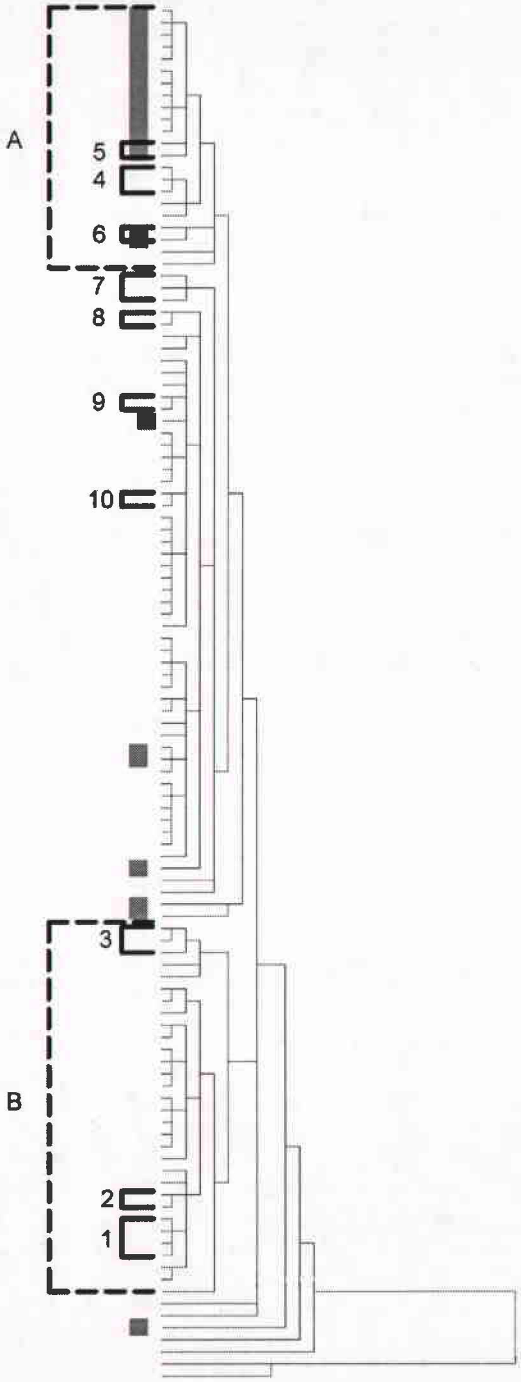

Figure 5.8. Dendrogram produced through hierarchical cluster analysis using squared Euclidean distance between-cluster linkage to group 114 early Yasawas Islands sherds. Individual sherds are represented at dendrogram terminations to left. Solid brackets indicate the groups also found in a within-cluster linkage analysis of same data (Figure 5.9). Hashed brackets identify clusters used during initial PCA. All sherds from the northern site of Natia indicated by grey blocks.

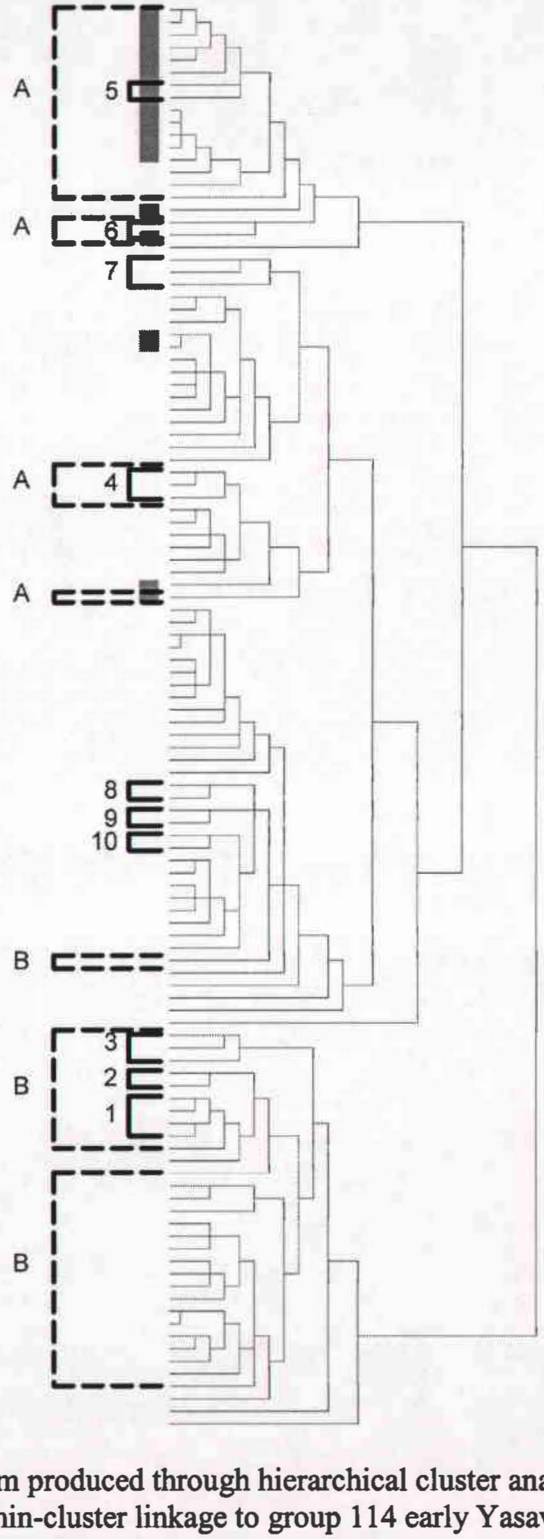

Figure 5.9. Dendrogram produced through hierarchical cluster analysis using squared Euclidean distance within-cluster linkage to group 114 early Yasawas Islands sherds. Individual sherds are represented at dendrogram terminations to left. Solid brackets indicate the groups that are also found in a between-cluster linkage analysis of same data (Figure 5.8). Hashed brackets identify sherds used in initial PCA.

There are only a few clusters that cohere across the dendrograms and these are at the lowest levels of similarity. However, in both dendrograms sherds from the northern site of Natia occur predominantly in clusters at the top of the diagram and sherds from the southern site of Olo dominate the rest of the dendrograms. To see if the dendrograms were potentially arranging sherds predominantly along a single axis of variation large clusters denoted by hashed brackets at either end of the dendrogram in Figure 5.8, labeled A and B, were used to further investigate chemical patterning using principal components analysis (PCA). The sherds in these groups are also indicated in Figure 5.9. These groups are not used as clay compositional groups to measure compositional diversity in further analyses. They are simply starting points for PCA.

The 22 sherds in group "A" in Figure 5.8 derive predominantly (64%) from the Natia site in the northern Yasawas and the Natia sherds are all tightly clustered within that group (13 of 14 Natia sherds occupying the top 13 spots on the dendrogram). The remaining sherds placed in the "A" group were excavated from the early deposits at the Olo site in the southern Yasawas. The sherds in the "B" group identified by a hashed bracket in Figure 5.8 all derive from the Olo site. A few of the sherds that are placed in the dendrogram between these two groups derive from Natia, but most are from Olo. Seven sherds at the bottom of the dendrogram in Figure 5.8 are provisionally identified as outliers for PCA.

While hierarchical clustering does reveal possibly significant structure in the chemical dataset, there are several shortcomings in the technique, especially when used alone (Neff 2002). Principal components analysis builds upon the first look at the data by hierarchical clustering and will likely help identify those elements that provide the best group discrimination. In PCA a large data matrix with many variables is reduced to one of fewer variables (i.e., principal components) and variable scores (also called component loadings) for each case. This component matrix still retains much of the descriptive information in the original matrix. The component matrix comprised of fewer principal components than original variables can be more easily explored to identify grouping patterns among cases. Recent discussions of PCA for archaeological applications are included in Shennan (1997) Baxter (1994) and Bishop(1989). Principal component analyses presented here were performed on unrotated correlation matrices and the associations between multiple principal components, beyond the first two, were examined in each PCA.

The first PCA was run on the 114 early sherds from Olo and Natia[18]. Figure 5.10 plots each sherd based on its first two principal component (PC) scores. While PCs 1 and 2 explain only a little more than 50% of the original variance, they do help refine the grouping tendencies identified through hierarchical clustering.

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[18] This PCA was run on the same variables used in the hierarchical cluster analysis. PC 1 explains 39% of the variance in the component matrix. PC 2 explains an additional 11.2% of the variance.

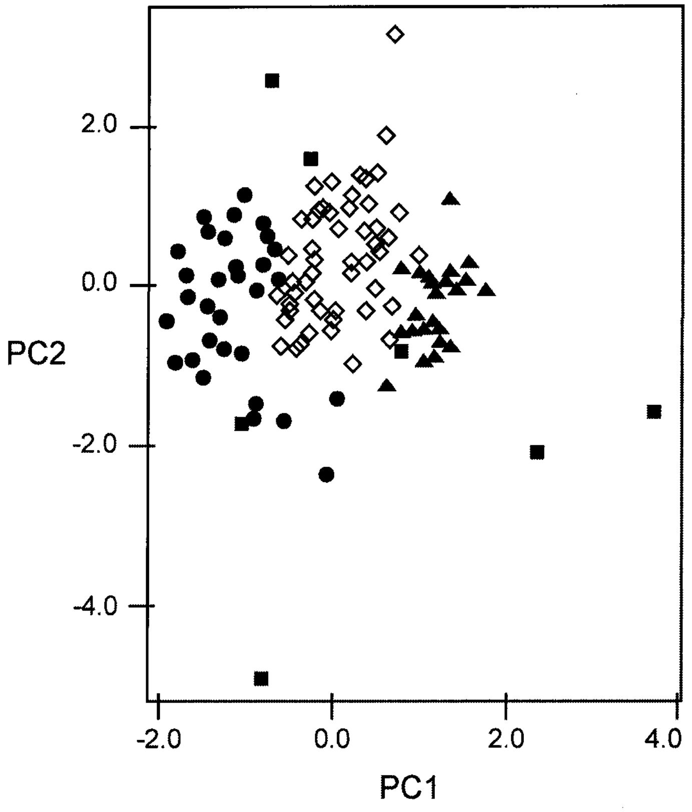

Figure 5.10. Plot of PCs 1 and 2 for the PCA of 114 early sherds from Olo and Natia. Solid circles and triangles are the sherds identified by groups "A" and "B" in Figure 5.8, respectively. Solid squares are the seven sherds at the bottom of Figure 5.8. Open diamonds are the remaining sherds in the PCA.

The data points in the Figure 5.10 plot are coded to match the groups identified in the dendrograms (Figures 5.8 and 5.9). The seven sherds at the bottom of Figure 5.8 do not fit well into other groups in Figure 5.8. These sherds appear to be chemically unlike almost all of the sherds analyzed. This interpretation is also substantiated by the PC plot in Figure 5.10 where the solid square data points are mostly plotted far from the main data cloud. The component matrix for this PCA indicates that PC1 is heavily loaded by rare earth elements[19] (REE), thus the circle and triangle data points, groups "A" and "B" from the dendrograms, in Figure 5.10 at either end of the PC1 axis seem to separate based on REE abundances.

A second PCA of the early Olo and Natia sherds conducted on a 20 variable data matrix using several REEs and a few other elements[20] produces results similar to the first PCA and the dendrogram. The first two PCs of this second PCA are plotted in Figure 5.11. This second PCA was conducted without the putative outliers identified in the dendrogram (bottom seven sherds in Figure 5.8) and first PCA (solid squares in Figure 5.10). The two sherds placed at the bottom right in the second PCA plot (Figure 5.11) have low abundances of Co, Cr, Fe, and Sc. Additional PCAs and examination of PC and bivariate element plots suggest that these two sherds are also outliers or chemically dissimilar from the vast majority of sherds. Bivariate element plots of the Olo and Natia sherds (Figure 5.12) mimic the patterns identified in the PC plots.

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[19] The rare earth elements (REE) La, Ce, Pr, Nd, Sm, Gd, Eu, Tb, Dy, Ho, Er, Tm, Yb, and Lu have component loadings ranging from 0.92 to 0.98. Component loadings may be treated as correlation coefficients, thus PC1 is highly representative of these REE abundances in the analyzed sherds.

[20] The data matrix for the second PCA includes the REEs listed in the footnote immediately preceeding and Hf, Th, Co, Cr, Fe, and Sc. PC 1 explains 67.4% of the variance in the component matrix. PC 2 explains an additional 11.5% of the variance.

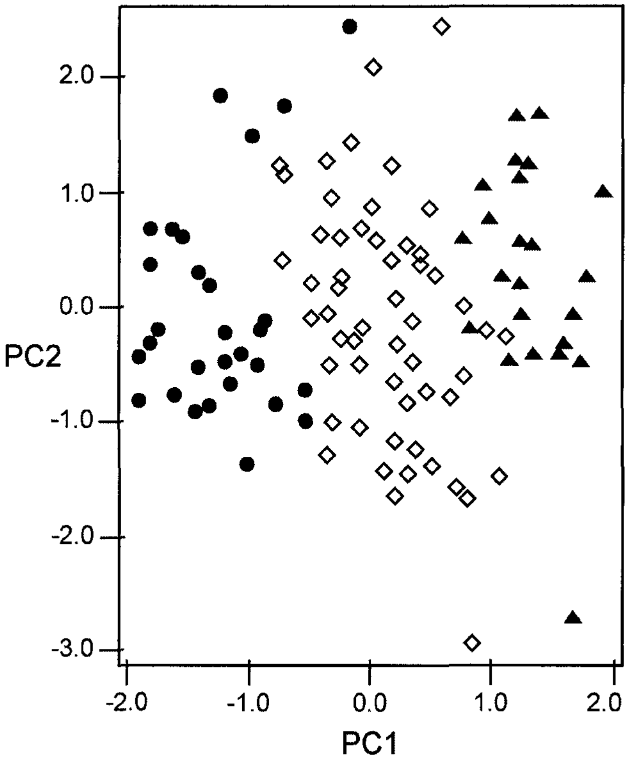

Figure 5.11. Plot of PCs 1 and 2 for the PCA of early sherds from Olo and Natia without the outliers identified in the dendrogram (Figure 5.8). Symbols represent same groups noted in Figure 5.10.

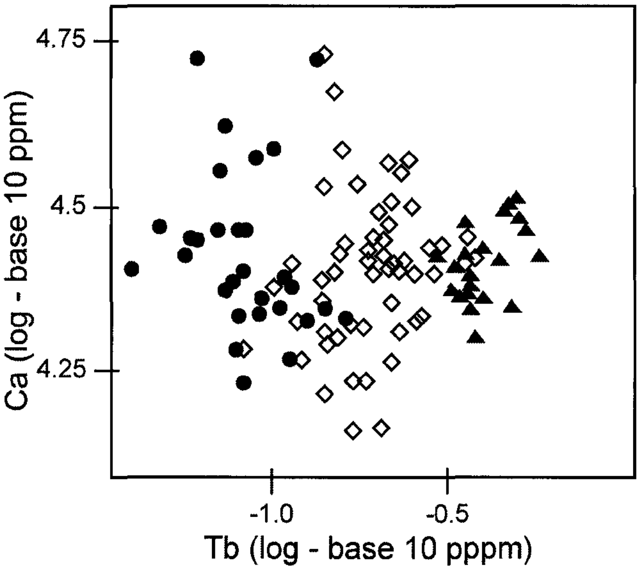

Figure 5.12. Example of a bivariate element plot displaying early sherds from Olo and Natia. Plotted elemental data show similar grouping tendencies as the PC plots (Figures 5.10, 5.11). Symbols represent same groups noted in Figure 5.10

The two PCAs (Figures 5.10 and 5.11), bivariate element plots (Figure 5.12), and the dendrograms (Figures 5.8 and 5.9) suggest that almost all of the 114 early sherds from Olo and Natia can be arrayed along a continuum of REEs. Nine of these sherds, however, appear compositionally distinct; some are separated from other groups until the last agglomerative steps in the hierarchical cluster analysis and most are on the periphery or widely separated from the main data clouds in the PC plots.

In the PC plots of Olo and Natia sherds, PC 1 arrays data points predominantly along a continuum of REE abundances. After identifying the site provenience of the data points in these plots, it is apparent that the abundance of REEs in a sherd is also related to each sherds' site provenience (Figure 5.13). Figure 5.13 is the same plot as Figure 5.11, but the open diamonds (sherds not identified to a group in the dendrogram) have been removed for clarity. Sherds from the Olo site in the southern Yasawas are predominantly low in REEs while sherds from the Natia site in the northern Yasawas are high in REEs.

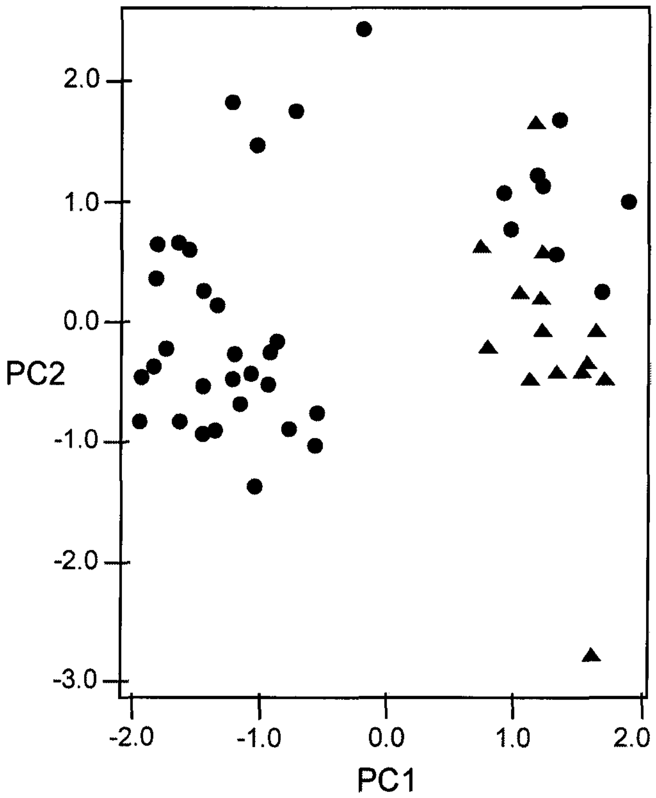

Figure 5.13. Duplicate plot of PCs 1 and 2 for the PCA of early sherds from Olo (closed circles) and Natia (closed triangles) with sherds not assigned to a dendrogram group removed (open diamonds in Figure 5.11). One of the outliers identified in Figure 5.11 (solid triangle at lower right) has been plotted.

Using the criterion of abundance (Bishop, et al. 1982) as a guide, the low REE sherds appear to derive from near the Olo site in the southern Yasawas while the high REE sherds derive from the vicinity of Natia in the northern Yasawas. Although never measured directly through multiple geological samples, a graded continuum of REE abundances in the basalts of the Yasawa Islands is not unreasonable given that the majority of the islands were formed by a single geological event(see Saunders 1984).

The final group of 28 early sherds from the Qaranicagi site (Table 5.28) also fits within the REE continuum established for the Olo and Natia sherds. Principal component analyses of the Qaranicagi, Olo, and Natia sherds using 36 elements[21] again produces a first principal component heavily loaded on REEs. After examining multiple PC plots from this 36 element PCA one sherd was determined to be an outlier. A new PCA was conducted on a more limited range of elements including 14 REEs, Hf, Th, Co, Cr, Fe, and Sc. Figure 5.14 shows a plot of the first two PCs from this 20 element PCA[22]. The Qaranicagi sherds are distributed across the PC 1 axis which is almost exclusively positively loaded on the REEs. The Qaranicagi sherds are also heavily concentrated at the negative end of the PC 2 axis. The PC 2 axis is negatively loaded on Thorium and it seems as if the Qaranicagi sherds have greater than expected abundances of this element, perhaps a result of post-depositional alteration.

The multivariate analyses of elemental data suggest that most of the sherds from the early deposits of Olo, Natia, and Qaranicagi can be placed along a continuum of REEs. The goal of this compositional analysis, however, is to construct compositional groups that can be used to measure transmission related similarities or the spatial extent of transmission systems. To this end, discrete groups should be generated from the continuous compositional data. One way to conceptualize compositional variation among sherds is to picture each sherd as representing a point in multidimensional space, where each dimension is an elemental variable. To generate compositional groups, the

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[21] The PCA of the early Olo, Natia, and Qaranicagi sherds uses the same elements as the first PCA of Olo and Natia sherds, minus Ba and Ca. Examination of element data suggests that Ba is post-depositionally fixed in the cave-site Qaranicagi for unknown reasons. Neff (personal communication 2003) has noticed a similar phenomenon in other cave sites. Calcium appears to be post-depositionally removed from the Qaranicagi sherds (Glascock 1992).

[22] Principal component 1 explains 67.2% of the variance in the component matrix and PC 2 explains 10.2% of the variance.

analyst must draw boundaries around regions in multidimensional space where the cloud of points is particularly dense.

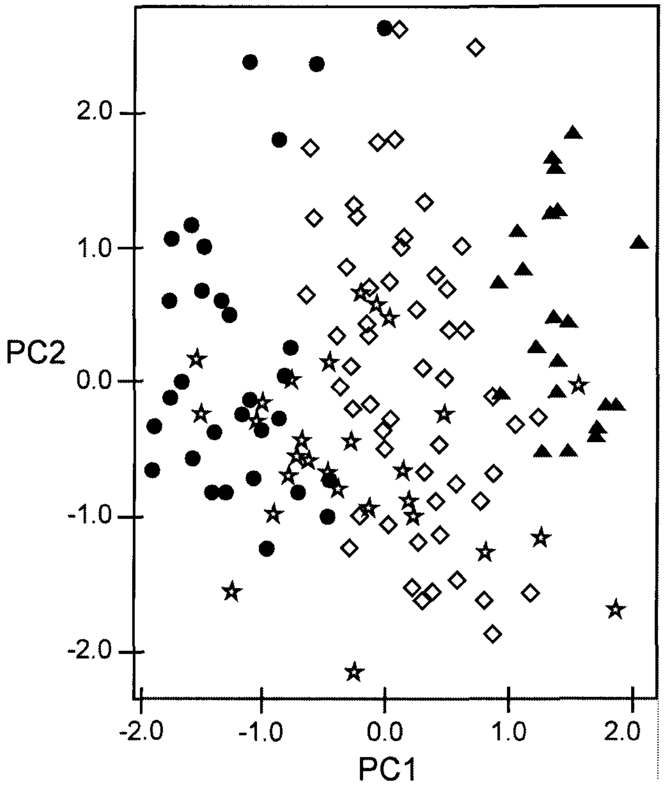

Figure 5.14. Plot of PCs 1 and 2 for the PCA of early sherds from Olo, Natia, and Qaranicagi. Solid triangles and circles are the sherds identified by the "A" and "B" groups in the dendrograms (Figures 5.8 and 5.9). Open diamonds are the remaining sherds from the dendrogram (not including outliers). Open stars are the 28 early Qaranicagi sherds (not including one outlier).

Mahalanobis distance is a measure of the distance between points in multidimensional space and is one technique used to determine the discreteness of groups in multivariate data sets (Bishop and Neff 1989; Neff 2002). In the group evaluations performed here, Mahalanobis distance is a measure between a point (e.g., a sherd) and a group centroid (the center of a point cloud in multidimensional space) that incorporates the variance-covariance structure (i.e., multidimensional shape) of the point cloud.

Mahalanobis distance is the multivariate counterpart to univariate z-scores. Describing variation with groups based on Mahalanobis distance is fundamentally an allocatory procedure such that discrete groups are not forcibly created from the entire cloud of points in multidimensional space. Other group evaluation procedure such as discriminant function analysis are separatory, they will create groups in multidimensional space even if these groups have little coherence within the greater point cloud.

Two possible groups were defined by Mahalanobis distances prior to other evaluations. Mahalanobis distances were calculated[23] for the sherds in the two dendrogram groups "A" and "B" marked by hashed brackets (Figures 5.8 and 5.9) that are also placed at either end of PC 1 in the various PCAs: Group A contains sherds with high REE abundances and is associated with the northern Yasawas (at right in Figure 5.13). Group B contains sherds with low REE abundances and is associated with the southern Yasawas (at left in Figure 5.13); . Centroids were calculated within a 14-variable space defined by REEs for each of these groups. The distance between each sherd and the centroids of both groups was then calculated. Table 5.29 displays the jackknifed probabilities for each sherd belonging to either a Southern Group ("B") or a Northern Group ("A") based on that sherd's distance to each centroid relative to all other sherd-centroid distances. Jackknifed probabilities are calculated after removing the sherd from the group in question (thus changing its centroid slightly). All of the sherds in the putative Southern and Northern groups, except one, were closer to the centroid of their original Southern Group or Northern Group. Sherds were assigned membership in a group if their jackknifed probability indicates that only 1% of sherds putatatively

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[23] All Mahalanobis distances were calculated by Hector Neff using a program written by him in GAUSS.

assigned to the other group are further from the centroid, and the sherd in question does not show a high probability of belonging to the other group. In most case the probabilities of group membership in Table 5.29 are very unbalanced.

Table 5.29. Relative distances to Southern Group ("B") and Northern Group ("A") centroids for Olo and Natia sherds.

Sherd Catalog Number	**% of Sherds Farther from South. Group**	**% of Sherds Farther from North Group**	**Final Group**	**Sherd Catalog Number**	**% of Sherds Farther from South. Group**	**% of Sherds Farther from North. Group**	**Final Group**
1994-18-10	22.398	0.301	south	1994-18-325	94.180	0.032	south
1994-18-125	0.000	3.487	north	1994-18-32	98.866	0.943	south
1994-18-12	16.840	0.035	south	1994-18-36	93.241	1.397	south
1994-18-13	57.714	4.550	south	1994-18-38	35.083	0.005	south
1994-18-148	30.858	0.256	south	1994-18-39	6.438	0.019	south
1994-18-149	22.300	0.095	south	1994-18-44	80.409	1.491	south
1994-18-14	2.588	75.676	north	1994-18-49	65.786	0.164	south
1994-18-154	1.324	58.584	north	1994-18-5	0.025	21.177	north
1994-18-15	56.138	0.835	south	1994-18-83	53.646	0.101	south
1994-18-163	67.379	0.924	south	1994-18-86	23.475	0.011	south
1994-18-179	94.559	0.200	south	1994-18-8	43.895	0.598	south
1994-18-182	0.189	22.140	north	2002-20-10	0.465	77.046	north
1994-18-183[+]	1.268	6.017	south	2002-20-11	7.233	17.051	north
1994-18-191	1.244	48.072	north	2002-20-14	0.093	36.103	north
1994-18-213	93.371	0.083	south	2002-20-1	0.790	98.746	north
1994-18-281	43.789	0.608	south	2002-20-2	0.123	59.584	north
1994-18-295	10.619	0.000	south	2002-20-4	0.380	62.042	north
1994-18-296	52.196	0.074	south	2002-20-5	1.170	38.184	north
1994-18-298	0.089	3.340	north	2002-20-6	1.242	34.961	north
1994-18-299	92.484	0.935	south	2002-20-8	0.270	38.357	north
1994-18-29	1.737	0.001	south	2002-20-9	4.132	79.012	north
1994-18-306	71.050	0.527	south	2002-21-1	6.271	74.613	north
1994-18-309	0.144	52.461	north	2002-21-2	0.539	89.928	north
1994-18-310	17.647	0.014	south	2002-21-6	2.704	75.635	north
1994-18-31	20.573	0.000	south	2002-21-7	0.130	44.634	north
1994-18-321	73.571	0.764	south				

[+] Although by its measured Mahalanobis distance this sherd is closer to the northern centroid than 6% of the Northern Group sherds, it has been placed in the Southern Group. Subsequent multivariate analyses suggested that this sherd inappropriately stretched the boundaries of the Northern Group.

Mahalanobis distances were next calculated for the remaining unassigned early sherds from Olo, Natia, and Qaranicagi. The jackknifed probabilities for each sherd belonging to either the Southern Group or Northern group are displayed in Table 5.30. Five of these sherds are not convincing members of the Southern Group or the Northern Group; they are further away than 99% of the sherds from either group. This suggests that they are on the border between what has been interpreted from the dendrograms and PC plots as southern and northern clay provenance areas. These sherds have been assigned to the nearest group measured by Mahalanobis distance (i.e., not the percentage of sherds farther from the group centroid).

Table 5.30. Relative distances to Southern Group and Northern Group centroids for unassigned Olo, Natia, and Qaranicagi sherds.

Sherd Catalog Number	**% of Sherds Farther from South. Group**	**% of Sherds Farther from North. Group**	**Final Group**	**Sherd Catalog Number**	**% of Sherds Farther from South. Group**	**% of Sherds Farther from North. Group**	**Final Group**
1991-1020-103	95.730	0.019	south	1994-18-176	5.759	1.300	south
1991-1020-104	25.018	0.014	south	1994-18-177	2.188	51.026	north
1991-1020-119	98.955	1.062	south	1994-18-180	68.252	1.147	south
1991-1020-120	83.806	0.009	south	1994-18-181	76.629	6.357	south
1991-1020-132$^+$	0.002	0.001	south	1994-18-188	85.130	8.426	south
1991-1020-134	33.007	0.053	south	1994-18-18	8.754	13.130	north
1991-1020-139	89.491	0.016	south	1994-18-190	37.072	4.310	south
1991-1020-140$^+$	0.167	0.069	south	1994-18-192	11.081	2.521	south
1991-1020-141	41.589	10.872	south	1994-18-195	21.036	0.114	south
1991-1020-149	85.425	0.703	south	1994-18-1	21.149	41.386	north
1991-1020-156	1.054	0.008	south	1994-18-20	17.968	0.112	south
1991-1020-176	0.087	21.890	north	1994-18-233	22.540	24.528	north
1991-1020-181	65.659	0.008	south	1994-18-23	78.593	2.959	south
1991-1020-82$^+$	0.026	0.477	north	1994-18-24	25.089	4.895	south
1991-1022-3	63.109	0.140	south	1994-18-254	54.335	0.388	south
1991-1022-40	79.326	0.092	south	1994-18-264	49.987	10.073	south
1991-1022-41	14.256	0.534	south	1994-18-26	6.724	19.072	north
1991-1022-42	1.699	38.468	north	1994-18-291	41.158	24.922	south

Table 5.30 (continued). Relative distances to Southern Group and Northern Group centroids for unassigned Olo, Natia, and Qaranicagi sherds.

Sherd Catalog Number	**% of Sherds Farther from South. Group**	**% of Sherds Farther from North. Group**	**Final Group**	**Sherd Catalog Number**	**% of Sherds Farther from South. Group**	**% of Sherds Farther from North. Group**	**Final Group**
1991-1022-48	15.883	0.054	south	1994-18-292	38.031	15.710	south
1991-1022-49	11.714	0.258	south	1994-18-293*	4.428	6.281	south
1991-1022-55	1.386	0.230	south	1994-18-2	57.548	9.605	south
1991-1022-64	4.971	0.002	south	1994-18-308	37.800	0.190	south
1991-1022-65	43.030	0.760	south	1994-18-314	39.636	28.417	south
1991-1022-66	98.511	0.692	south	1994-18-315	40.210	0.428	south
1991-1022-70	9.248	0.559	south	1994-18-319	65.219	6.304	south
1991-1022-72	85.360	2.933	south	1994-18-322	16.292	3.324	south
1991-1022-73	15.416	0.198	south	1994-18-326	1.640	28.210	north
1994-18-111	4.958	28.569	north	1994-18-35	29.916	8.794	south
1994-18-113	8.295	33.217	north	1994-18-3	20.935	38.058	north
1994-18-119	5.046	8.652	north	1994-18-43	22.739	3.370	south
1994-18-126	3.767	3.280	south	1994-18-4	20.077	0.694	south
1994-18-130	0.784	17.288	north	1994-18-50	12.436	4.382	south
1994-18-139[+]	0.182	0.000	south	1994-18-63	65.744	4.721	south
1994-18-140	12.145	22.580	north	1994-18-6	0.338	2.514	north
1994-18-145	29.154	7.842	south	1994-18-7	3.207	55.963	north
1994-18-151	59.712	0.351	south	1994-18-9	38.834	7.981	south
1994-18-155	30.238	9.545	south	2002-20-12	16.674	0.070	south
1994-18-156	67.741	3.143	south	2002-21-3	3.057	1.972	south
1994-18-159	62.988	46.213	south	2002-21-4	10.241	12.145	north
1994-18-174[+]	0.266	0.066	north	2002-29-1	47.751	6.731	south

[+] Sherds that are farther away than 99% of sherds from either centroid are assigned to the closest group based on squared Mahalanobis distance.

* Although by its measured Mahalanobis distance this sherd is closer to the Northern Group centroid than 6% of the Northern Group sherds, it has been placed in the Southern Group. Subsequent multivariate analyses suggested that this sherd inappropriately stretched the boundaries of the Northern Group.

Three compositional groups are present in the ceramic assemblages deposited by the first inhabitants of the Yasawa Islands (Table 5.31). The reversed distribution of compositional groups across the southern (Olo, Qaranicagi) and northern (Natia) sites suggests that individuals at these sites predominantly use ceramics made from local materials.

Table 5.31. Distribution of compositional groups across early ceramics assemblages.

Site (n of sherds)	Southern Group (n of sherds)	Northern Group (n of sherds)	Group 3, Exotics (n of sherds)
Olo (93)	69% (n=64)	25% (n=23)	6% (n=6)
Qaranicagi (28)	86% (n=24)	11% (n=3)	3% (n=1)
Natia (21)	14% (n=3)	72% (n=15)	14% (n=3)

The southern and northern compositional groups are linked to Yasawan geography through the criterion of abundance and the numbers of sherds of each compositional group found at the Olo and Natia sites. A single geological sample from Waya Island further strengthens the link between these compositional groups and geological provenances.

The Waya Island geological sample is a fine-grained sediment (silt and clay size particles) collected from a garden plot on the upland slopes of eastern Waya. The sample was collected as it appeared to be part of a natural clay deposit. A portion of the sample was dried, crushed, and molded with deionized water into a ceramic test brick. The brick was fired at 800° C for 20 minutes in a laboratory oven. The test brick was subjected to LA-ICP-MS analyses in the same manner as the archaeological samples.

The Waya Island geological sample is chemically similar to those sherds which fall in the approximate middle of the REE continuum identified previously (Figures 5.15, 5.16). Figure 5.15 is a plot of the first two PCs[24] of a PCA of a 14 variable data matrix describing the geological sample and the defining members of the Southern and Northern compositional groups (listed in Table 5.29). Importantly, the Waya geological sample

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[24] The data matrix consists of the 14 REEs used previously. Principal component 1 explains 95.3% of the variance in the component matrix and PC 2 explains an additional 2.4% of the variance.

occupies the low-end of REE abundances for the Northern group sherds (triangles in Figure 5.15). A similar tendency is exhibited in several element bivariate plots (of which Figure 5.16 is an example).

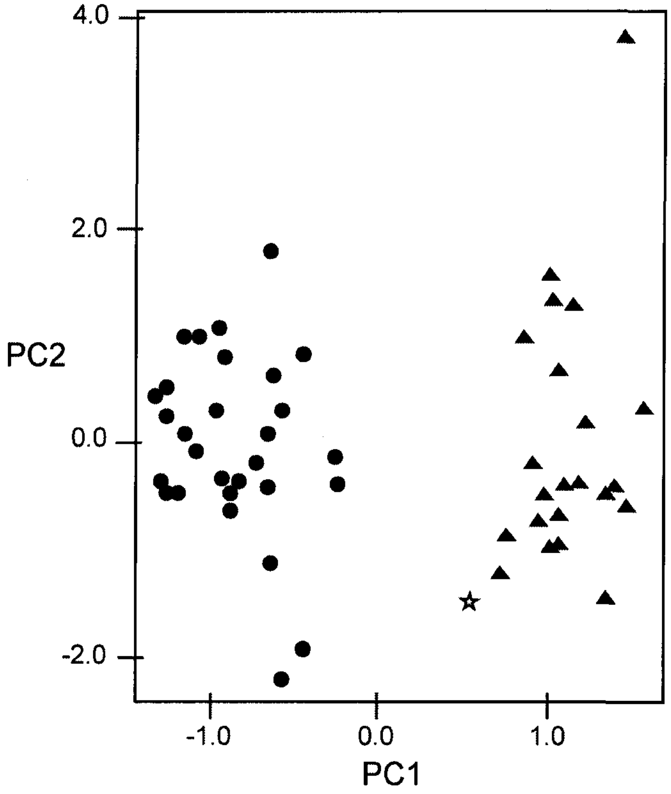

Figure 5.15. Plot of PCs 1 and 2 for the PCA of 51 early sherds defining the Northern and Southern compositional groups, and the Waya Geological sample. Solid triangles and circles are the members of the Northern and Southern compositional groups, respectively. The open star is the Waya geological sample.

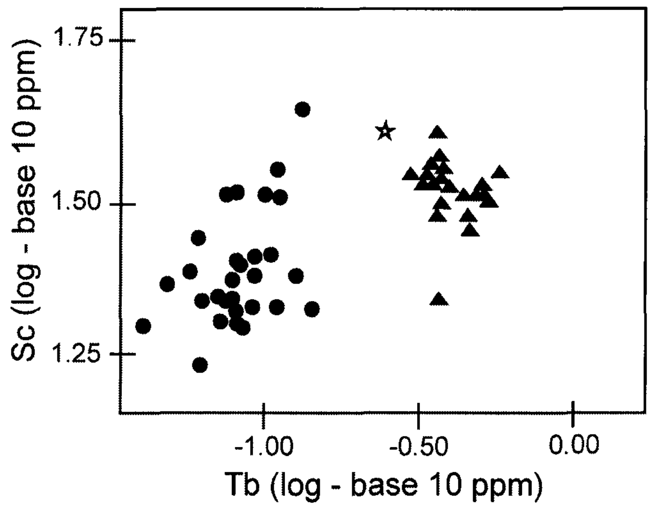

Figure 5.16. Example of bivariate element plot of 51 early sherds defining the Northern and Southern compositional groups, and the Waya Geological sample. Symbols represent same groups as Figure 5.15.

The chemical comparison of the Waya geological sample and the geology of the Yasawa Islands suggests that the geological provenances from which the Northern and Southern group clays derive may be to the north and south of Waya Island, respectively. This implies that the Northern compositional group derives generally from northern Yasawas clays and the Southern compositional group derives generally from clays in the Mamanucas (to the south of Waya). Both the Yasawas and the Mamanucas were formed by the same geological events. Until further geological samples are analyzed the compositional groups will be designated Northern and Southern.

Of the early sherds analyzed from Olo and Qaranicagi, 6% and 3%, respectively, are made of exotic clays, not deriving from the Yasawas or Mamanucas. At Natia, 14% of the recovered early sherds are exotic. These exotic sherds may originate from clay deposits beyond the Yasawa-Mamanuca Island arc including both different regions of Fiji and different archipelagos, or some may conceivable originate from Malolo Island, the geologically distinct island in the Mamanucas. In terms of cultural trait transmission, the early individuals at Olo and Qaranicagi participated in a clay compositionally defined population beyond the Yasawa-Mamanuca islands at a fairly low frequency. Individuals at Natia participated in such a population as much as they participated in a more local Southern population.

5.3.4.2 Compositional Group Variation During Middle-Sequence Yasawas Prehistory

Ceramics deposited during the first millennium AD are represented by 63 Qaranicagi sherds recovered from excavation levels 17-12 in Test Unit 1. The following and subsequent sections suggest significant changes in the distribution of compositional groups at the end of this time period.

The middle-sequence sherds from Qaranicagi are compositionally similar to the early sherds from Qaranicagi, Olo, and Natia. Almost all of these sherds derive from the greater Yasawa-Mamanuca Islands provenance area (Figures 5.17 and 5.18)[25]. Three exotic sherds are in the level 16 Qaranicagi assemblage. These exotic sherds are on the periphery of the data clouds in Figures 5.17 and 5.18 and are easily identified by plotting the first two PCs of a PCA[26] of only the middle-levels sherds from Qaranicagi (Figure 5.19).

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[25] A PCA of the 14 REE data matrix describing these sherds and the defining Northern and Southern Group sherds (Table 5.28) generates PCs 1 and 2, which explain 92.6 % and 3.6% of the variance in the component matrix, respectively. Additional PCAs using larger data matrices produce PCs which similarly place most of these sherds between the original Northern and Southern Group sherds.

[26] This PCA conducted on a 36 variable data matrix (same elements used in the hierarchical cluster analysis minus Ba and Ca) describing only the middle-levels Qaranicagi sherds. Principal component 1 explains 42.3% of the variance in the component matrix, while PC 2 explains an additional 13.7% of the variance.

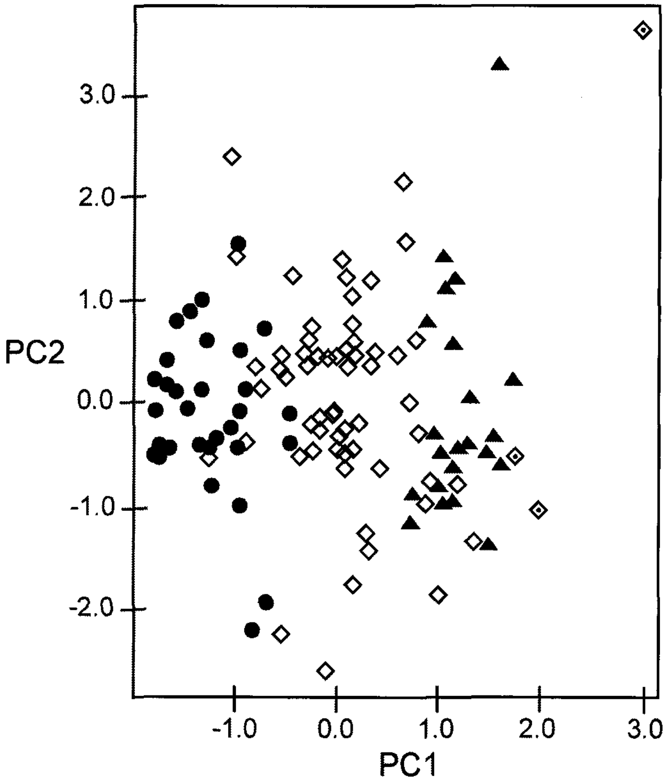

Figure 5.17. Plot of PCs 1 and 2 for 114 sherds from Olo, Natia, and Qaranicagi. Solid triangles and circles are the defining members of the Northern and Southern compositional groups, respectively. Open diamonds are the 63 mid-sequence sherds from Qaranicagi. Open diamonds enclosing a dot represent the three mid-sequence sherds identified as outliers.

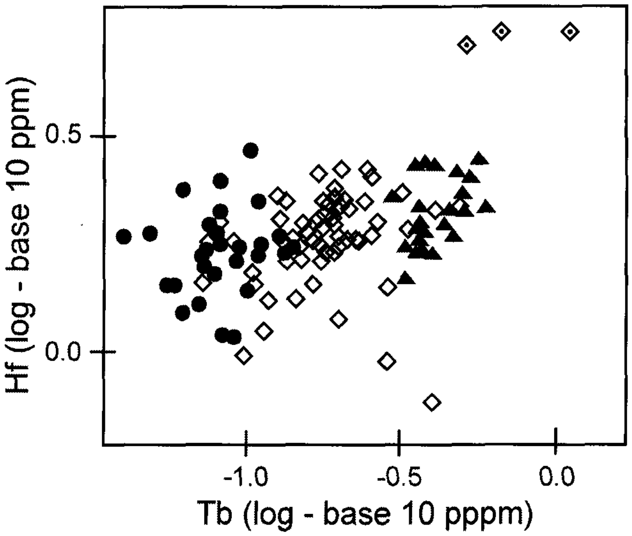

Figure 5.18. Example of a bivariate element plot for the 114sherds from Olo, Natia, and Qaranicagi. Symbols represent same groups as Figure 5.17.

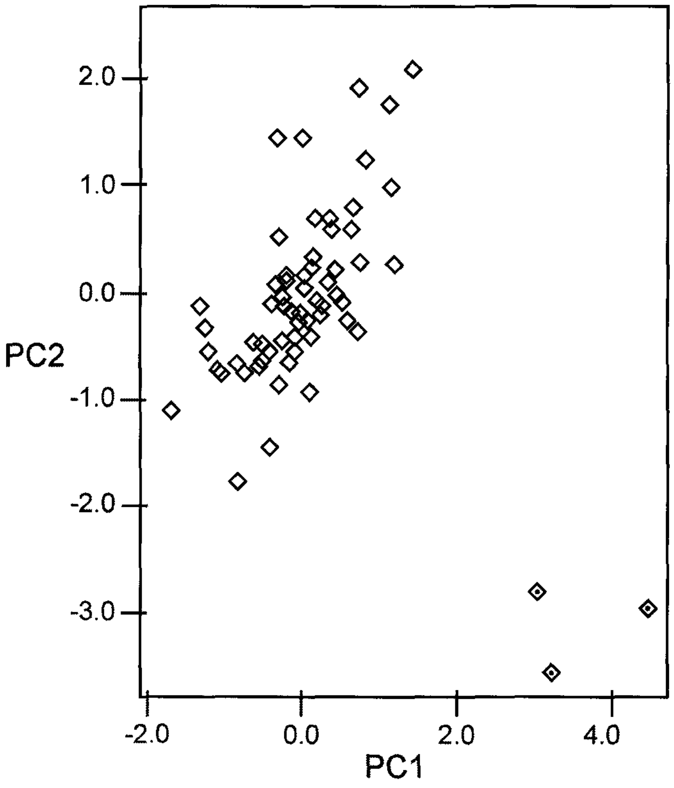

Figure 5.19. Plot of PCs 1 and 2 for the PCA of 63 sherds from levels 17 through 12 at Qaranicagi. Three data points in the lower right corner are sherds of exotic composition.

Two compositional groups likely deriving from a greater Yasawas-Mamanucas provenance area have been established and the mid-sequence sherds from Qaranicagi appear to mostly occupy a position intermediate between the Northern group and Southern Group sherds. To assign these mid-sequence sherds to either group, discriminant function analysis (DFA) was used. Discriminant function analysis generates linear functions that maximally separate hypothesized groups in a multi-dimensional data matrix. Discriminant function analysis also assigns cases to hypothesized groups based on Mahalanobis distances between a case's discriminant function score and the discriminant function score of the hypothesized group centers. Thus while principal component analysis is exploratory, discriminant function analysis presumes that a known set of groups exist in the data (for description of technique see Baxter 1994). In DFA, unknown cases are described with the functions and, depending on their function score assigned to a group. Group assignments can also be assessed with various statistics (e.g., Wilk's Lambda).

The mid-sequence sherds from Qaranicagi were classified by DFA[27] using the defining members of the North and South compositional groups (Table 5.28)as the two hypothesized groups. Each sherd is assigned to one of the two groups in the DFA with a level of probability and most probabilities are quite unbalanced between the two groups (Table 5.32).

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[27] This DFA conducted using 14 REEs used previously. Variables entered together. Wilk's Lamda is small (0.049) suggesting that the two hypothesized groups are quite distinct.

Table 5.32. Probabilities of compositional group membership for middle-level sherds at Qaranicagi.

Sherd Catalog Number	Probability of Southern Group	Probability of Northern Group	Final Group	Sherd Catalog Number	Probability of Southern Group	Probability of Northern Group	Final Group
1991-1017-67	0.999	0.001	south	1991-1015-46	1.000	0.000	south
1991-1017-63	0.361	0.640	north	1991-1015-255	1.000	0.000	south
1991-1017-58	0.001	0.999	north	1991-1015-229	0.994	0.006	south
1991-1017-18	1.000	0.000	south	1991-1015-219	0.003	0.997	north
1991-1016-93	0.984	0.016	south	1991-1015-210	1.000	0.000	south
1991-1016-90	1.000	0.000	south	1991-1015-1	0.021	0.979	north
1991-1016-67	0.987	0.013	south	1991-1015-196	1.000	0.000	south
1991-1016-62	1.000	0.000	south	1991-1015-183	1.000	0.000	south
1991-1016-59	0.000	1.000	north	1991-1015-170	0.000	1.000	north
1991-1016-52	0.000	1.000	north	1991-1015-163	0.076	0.924	north
1991-1016-35	0.000	1.000	north	1991-1015-162	0.111	0.889	north
1991-1016-30	0.000	1.000	north	1991-1015-161	1.000	0.000	south
1991-1016-25	0.000	1.000	north	1991-1015-158	1.000	0.000	south
1991-1016-22	0.005	0.995	north	1991-1015-155	0.989	0.011	south
1991-1016-217	0.000	1.000	north	1991-1015-148	0.000	1.000	north
1991-1016-215	0.035	0.965	north	1991-1015-145	0.966	0.034	south
1991-1016-207	0.976	0.024	south	1991-1015-138	0.009	0.991	north
1991-1016-163	1.000	0.000	south	1991-1015-136	1.000	0.000	south
1991-1016-158	0.000	1.000	north	1991-1015-125	0.000	1.000	north
1991-1016-140	0.158	0.842	north	1991-1015-124	1.000	0.000	south
1991-1016-134	1.000	0.000	south	1991-1015-103	0.001	0.999	north
1991-1016-112	1.000	0.000	south	1991-1014-4	1.000	0.000	south
1991-1016-104	1.000	0.001	south	1991-1014-41	0.000	1.000	north
1991-1016-103	0.850	0.150	south	1991-1014-23	1.000	0.000	south
1991-1016-101	0.993	0.007	south	1991-1012-90	0.878	0.122	south
1991-1015-99	1.000	0.000	south	1991-1012-84	1.000	0.000	south
1991-1015-8	1.000	0.000	south	1991-1012-122	0.000	1.000	north
1991-1015-83	0.000	1.000	north	1991-1012-118	0.000	1.000	north
1991-1015-81	0.478	0.522	north	1991-1012-116	0.016	0.984	north
1991-1015-74	0.676	0.324	south	1991-1012-110	0.000	1.000	north

Three compositional groups are represented by the middle-level deposits at Qaranicagi (Table 5.33). Given that sample size across the middle-sequence excavation levels is so uneven it is difficult to accurately gauge change over this time period. The samples from levels 16 and 15 are certainly the best representatives of underlying trends and they indicate roughly equal frequencies of sherds from both the Northern and Southern compositional groups deposited at this point. Level 17, even though it has few samples, mimics this pattern. With the Exotic group sherds removed from level 16 frequency calculations, Southern group and Northern group frequencies are 52% and 48%, respectively, closer to the direction of comparison in level 15. There is a decrease in the frequency of Exotic sherds across the level 16 and 15 samples. The absence of exotics in levels 14 and 12 may be a result of small sample sizes or a continuation of the pattern identified in level 15.

Table 5.33. Distribution of compositional groups across mid-sequence ceramics.

Qaranicagi level (n of sherds)	**Southern Group (n of sherds)**	**Northern Group (n of sherds)**	**Exotics (n of sherds)**
17 (4)	50% (2)	50% (2)	0%
16 (24)	46% (11)	41.5% (10)	12.5% (3)
15 (26)	58% (15)	42% (11)	0%
14 (3)	67% (2)	33% (1)	0%
12 (6)	33% (2)	67% (4)	0%

5.3.4.3 Compositional Group Variation During the Late Sequence

The late sequence division used here to analyze compositional variation generally coincides with the transition between the Navatu and Vuda phase, but some regional cultural patterns also suggest wide-spread changes at approximately this time (see Chapter 2). The late sequence deposits are represented in a continuous sequence at Qaranicagi in excavation levels 11 through 2.

As a whole the sherds in these deposits at Qaranicagi fit well within the REE continuum established previously. Principal components analyses do not identify any sherds of distinctly unique composition when compared with the defining members of the

Southern and Northern compositional groups[28] (Figure 5.20), or when compared with all previously examined sherds from Olo, Qaranicagi, and Natia[29] (Figure 5.21).

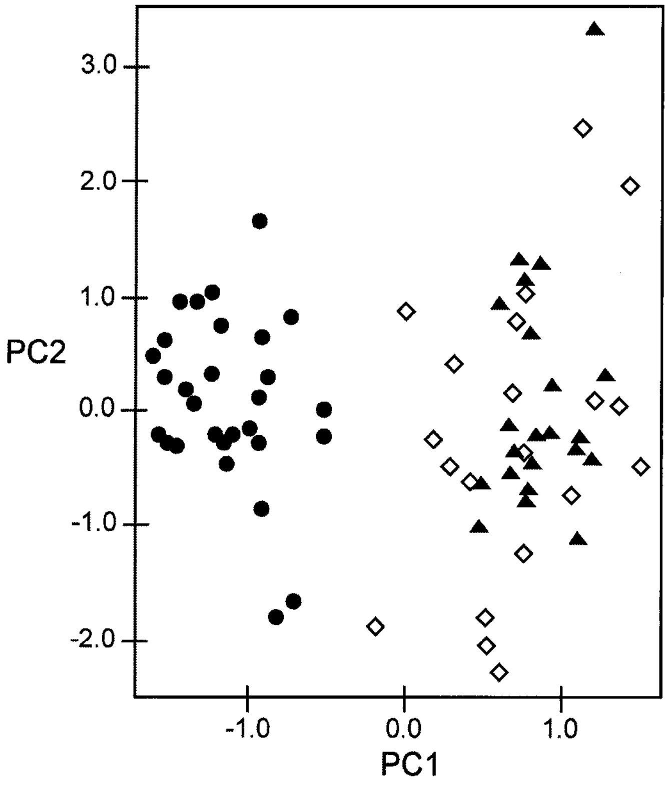

Figure 5.20. Plot of PCs 1 and 2 for the PCA of late sequence Qaranicagi sherds and the defining members of the Southern and Northern groups. Closed circles and triangles represent sherds of the Southern and Northern groups, respectively. Open diamonds are the Qaranicagi sherds.

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[28] This PCA conducted on the 14 REEs used previously. PC 1 explains 94.1% of the variance in the component matrix. PC 2 explains an additional 3%.

[29] This PCA conducted on a 33 variable matrix including all the elements first used to characterize early Olo and Natia sherds (see Footnote 35) except Ba, Ca, Ni, Cr, and Th. Abundances of these elements appear to be post-depositionally altered in the Qaranicagi assemblages. PC 1 explains 42% of the variance in the component matrix and PC 2 explains an additional 11.9%

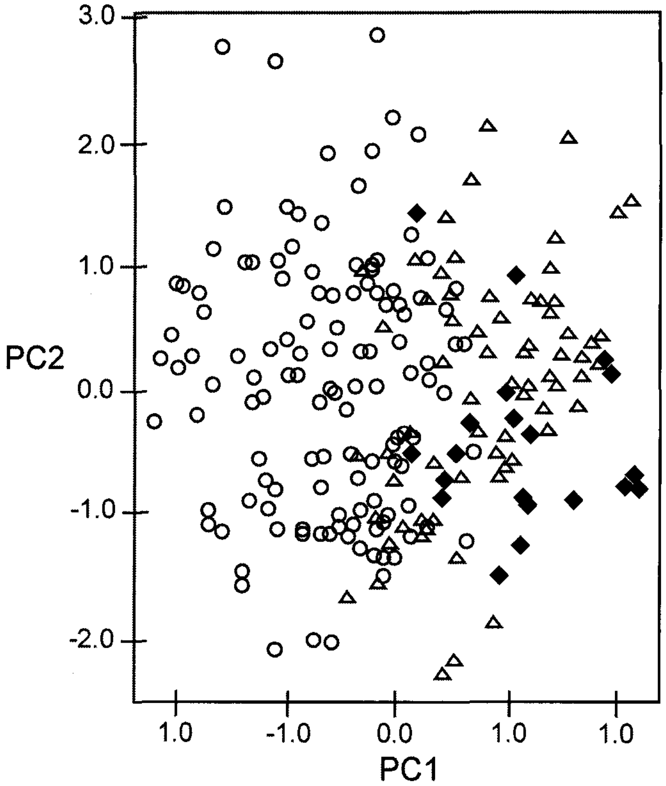

Figure 5.21. Plot of PCs 1 and 2 for the PCA of all early, middle, and late sequence sherds, except those of previously identified exotic composition. Open circles and triangles represent sherds of the Southern and Northern groups, respectively. Closed diamonds are the late sequence sherds from Qaranicagi.

The late sequence sherds from Qaranicagi were also classified by DFA[30] using the defining members of the North and South compositional groups (Table 5.28)as the two hypothesized groups. Each sherd is assigned to one of the two groups in the DFA with a level of probability and all probabilities except two are 100% assignment to the Northern group (Table 5.34).

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[30] This DFA conducted using the 14 REEs used previously. Variables entered together. Wilk's Lamda is small (0.049) suggesting that the two hypothesized groups are quite distinct.

Table 5.34. Probabilities of compositional group membership for late-sequence sherds.

Sherd Catalog Number	Probability of Southern Group	Probability of Northern Group	Final Group	Sherd Catalog Number	Probability of Group 1: North	Probability of Group 2: South	Final Group
1991-1011-830	0.000	1.000	north	1991-1006-162	0.000	1.000	north
1991-1011-82	.000	1.000	north	1991-1006-142	0.000	1.000	north
1991-1011-7	0.092	0.908	north	1991-1004-83	0.000	1.000	north
1991-1011-76	0.000	1.000	north	1991-1004-53	0.000	1.000	north
1991-1011-70	0.000	1.000	north	1991-1004-106	0.000	1.000	north
1991-1011-62	0.000	1.000	north	1991-1002-157	0.000	1.000	north
1991-1007-44	0.000	1.000	north	1991-1002-152	0.571	0.429	south
1991-1007-43	0.000	1.000	north	1991-1001-23	0.000	1.000	north
1991-1007-36	0.000	1.000	north	1991-1001-22	0.000	1.000	north
1991-1007-28	0.000	1.000	north	1991-1001-11	0.000	1.000	north

Among the late-sequence sherds at Qaranicagi, the number of analyzed sherds per level is quite low. Thus each level assemblage is likely not a good representative of compositional diversity at particular points in time. Taken as a whole, however, the compositional diversity of late-sequence sherds at Qaranicagi suggest that throughout this time period individuals overwhelmingly used vessels constructed from Northern Group clays. This contrasts with the early and middle-sequence where individuals equally used vessels constructed from either Northern or Southern Group clays.

5.3.4.4 Compositional Group Variation During the Last Several Hundred Years of Yasawas Prehistory

Sherds recovered from the surfaces of nine sites throughout the Yasawa islands record approximately the last 600-100 years of human occupation. Compositional group diversity was examined in these sherds along with the level 1 sherds at Qaranicagi.

Principal components analyses of the surface sherds and the defining members of the Northern and Southern groups places most of the surface sherds within the continuum of the Northern and Southern Groups. After plotting the first two PCs of several PCAs[31] (examples shown in Figure 5.22 and 5.23), five sherds are positioned beyond the main data cloud. These sherds are compositional outliers identified through further examination with hierarchical cluster analysis, as well as element bivariate plots (Figure 5.24). These outliers are also plotted beyond the main data cloud generated from PC plots and element bivariate plots of only the surface sherds. These outliers are placed in the exotic compositional group.

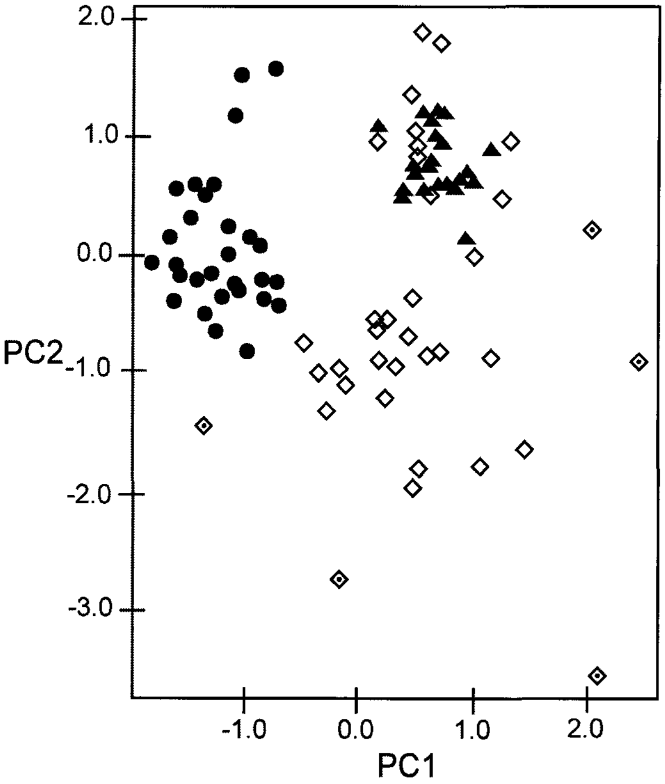

Figure 5.22. Plot of PCs 1 and 2 for a PCA of 38 elements. Surface sherds (open diamonds) and original Northern (closed circles) and Southern (closed triangles) group members are the plotted points. Open diamonds with dots are exotic sherds.

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[31] Figure 5.22 plots the first two PCs of a PCA of 38 elements. Principal component 1 explains 40.1% of the variance in the component matrix, while PC 2 explains an additional 17.2% of the variance. Figure 5.23 plots a PCA conducted on the 14 REEs used previously. Principal component 1 explains 92.1% of the variance in the component matrix. Principal component 2 explains an additional 5%.

The PC plot in Figure 5.22 shows that a group of the surface sherds exhibit lower PC 2 scores than the original Northern and Southern group members. The component matrix for this PCA suggests the low PC2 values of these sherds reflect low Cr and Ni abundances relative to the other sherds. Interpreting these lower element abundances is difficult, but they may represent the exploitation of different clay outcrops in the Yasawas or the removal of more soluble elements (e.g,. Ni) from some of the surface sherds (see McBride 1994). Neither this group of low PC 2 sherds nor any of the other surface sherds show a correlation between PC scores and site provenience.

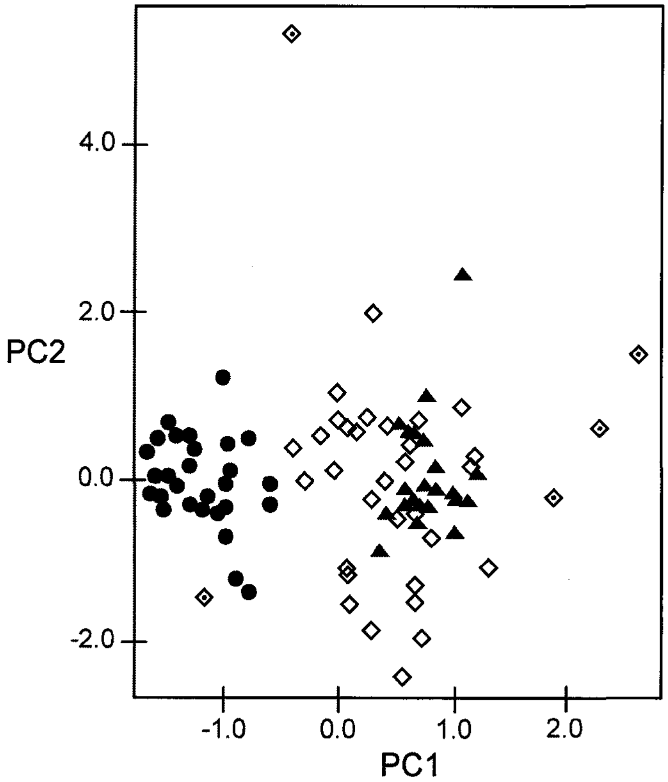

Figure 5.23. Plot of PCs 1 and 2 for the PCA using 14 REEs of surface sherds (open diamonds) and original Northern (closed circles) and Southern (closed triangles) group members. Open diamonds with dots are exotic sherds.

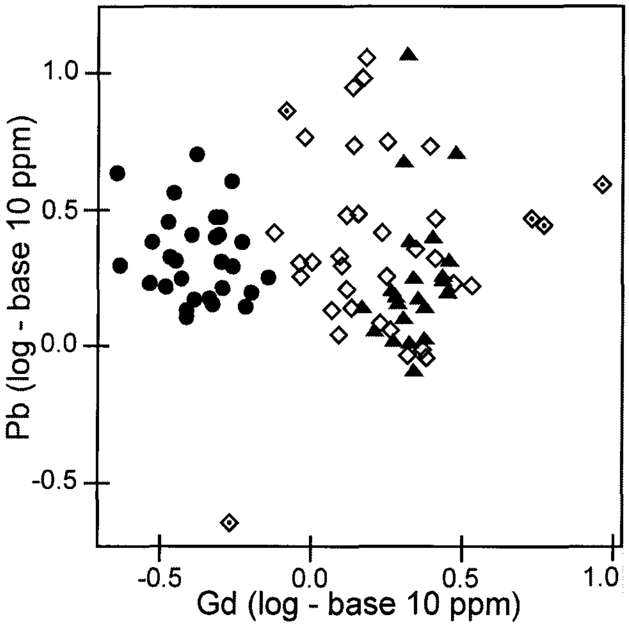

Figure 5.24. Example of a bivariate element plot for the surface sherds (open diamonds) and the original northern (closed triangles) and southern (closed circles) members. Open diamonds with dots are exotic sherds.

Discriminant function analysis was used to assign the non-exotic surface sherds to either the Northern or Southern compositional groups. The non-exotic surface sherds follow the pattern established in the late-sequence with all but four of the surface sherds assigned to the Northern compositional group (Table 5.35). The four sherds assigned to the Southern group come from sites on Waya Island, the most southerly island in the Yasawas (Table 5.36).

Table 5.35. Probabilities of compositional group membership for surface sherds.

Sherd Catalog Number	Probability of Southern Group	Probability of Northern Group	Final Group	Sherd Catalog Number	Probability of Southern Group	Probability of Northern Group	Final Group
1991-1001-11*	0.000	1.000	north	1991-6000-53	0.000	1.000	north
1991-1001-22*	0.000	1.000	north	1991-7000-54	0.000	1.000	north
1991-1001-23*	0.000	1.000	north	1991-7000-8	0.000	1.000	north
1991-2000-3	0.002	0.998	north	1991-8000-16	0.000	1.000	north
1991-2000-54	0.000	1.000	north	1991-8000-28	0.000	1.000	north
1991-2000-5	0.000	1.000	north	1991-8000-31	0.000	1.000	north
1991-3000-12	0.000	1.000	north	1991-9000-115	0.908	0.092	south
1991-3000-1	0.000	1.000	north	1991-9000-226	1.000	0.000	south
1991-3000-32	0.000	1.000	north	1991-9000-265	0.999	0.001	south
1991-4000-32	0.000	1.000	north	1991-9000-280	0.000	1.000	north
1991-4000-44	0.000	1.000	north	1991-9000-366	0.000	1.000	north
1991-4000-84	0.000	1.000	north	1991-9000-527	0.000	1.000	north
1991-5000-161	0.000	1.000	north	1991-9000-563	0.000	1.000	north
1991-5000-177	0.000	1.000	north	1997-3001-2	0.999	0.001	south
1991-2000-3	0.002	0.998	north	1997-3001-3	0.003	0.997	north
1991-6000-50	0.099	0.901	north	1997-3001-4	0.002	0.998	north

* These sherds also appear in the table of Late-sequence sherds (Table 5.34).

Table 5.36. Distribution of compositional groups across surface ceramics.

Site (n of sherds)	Southern Group (n of sherds)	Northern Group (n of sherds)	Exotics (n of sherds)
Y1-30: Yasawa Is. (3)	0%	100% (3)	0%
Y1-29: Yasawa Is. (3)	0%	100% (3)	0%
Y1-12: Drui drui, Nacula Is. (3)	0%	67% (2)	33% (1)
Y1-4: Matacawa Levu Is. (3)	0%	100% (3)	0%
Y1-1: Matacawa Levu Is. (3)	0%	100% (3)	0%
Y2-61: Naviti Is. (3)	0%	67% (2)	33% (1)
Y2-39: Qaranicagi, Waya Is. (3)	0%	100% (3)	0%
Y2-22: Korowaiwai, Waya Is. (8)	37.5% (3)	50% (4)	12.5% (1)
Y2-9: Lakala, Waya Is. (4)	25% (1)	50% (2)	25% (1)

5.3.4.5 Summary: Compositional Groups Variation in the Yasawa Islands Assemblages

Three compositional groups are present in Yasawa ceramic assemblages from initial colonization of the archipelago up to the historic period. Two of these compositional groups comprise sherds whose clays derive from the northern and southern ends of a geological provenance defined by REE abundances. This clay provenance likely stretches over most of the Yasawa-Mamanuca island arc. The third compositional group is made up of sherds whose chemical signature suggests they are exotic to the Yasawas and Mamanucas (or possibly derived from Malolo Island). The clays of these exotic sherds may originate from other regions of Fiji (e.g., western Viti Levu, the Lau Group) or from other archipelagos.

The distribution of compositional groups across Yasawa assemblages has fluctuated over time (Table 5.37). The earliest deposits in the southern Yasawas (Olo and Qaranicagi) contain relatively high proportions of Southern group sherds and low proportions of Northern group sherds. Exotic sherds in these assemblages are present but in low numbers. The earliest deposit in the northern Yasawas (Natia) contains a relatively high proportion of Northern sherds and a low proportion of southern group sherds. Exotic sherds at Natia occur more than twice as frequently than at Olo or Qaranicagi.

Table 5.37. Distribution of compositional groups across archaeological assemblages.

Assemblage (n of sherds)	**Southern Group (n of sherds)**	**Northern Group (n of sherds)**	**Exotics (n of sherds)**
Olo (93)	69% (64)	25% (23)	6% (6)
Natia (21)	14% (3)	72% (15)	14% (3)
Early Qaranicagi (28)	86% (24)	11% (3)	3% (1)
Mid-sequence Qaranicagi (63)	51% (32)	45% (28)	4% (3)
Late-sequence Qaranicagi (20)	5% (1)	95% (19)	0%
Surface assemblages, Yasawas (34)	12% (4)	74% (25)	14% (5)

From approximately 2000-1000 BP sherds from both the Northern and Southern compositional groups make up roughly equal proportions with exotic sherds accounting for only a very small percentage. By approximately 1000 BP, however, a shift in the distribution of compositional groups begins. From this time up to the historic era in the Yasawas, ceramics throughout the islands are made almost exclusively from northern clays. Additionally, no exotic sherds are recovered in the Qaranicagi deposits representing these 1000 years (although this may be explained by small samples).

The last several hundred years in the Yasawas are represented by nine surface sites across the Yasawa Islands. Two sites on Waya contain sherds of exotic composition. Two additional sites in the central and northern Yasawas also have exotic sherds.

5.3 CHAPTER SUMMARY

This chapter first illustrates the classificatory and analytical procedures involved in describing ceramic variation to resolve questions requiring cultural transmission analyses. These procedures focus on four realms of variation: rim form, temper, surface modification, and clay elemental composition. The second half of the chapter presents the data generated and addresses sample representativeness issues. Simple analyses of these data suggest that variation in each realm likely reflects similarities and differences that are related to cultural transmission. Some of these analyses also suggest transmission patterns that may be a function of temporal change and spatial differences.

These data have not, however, been analyzed with techniques built to explain variation as a result of cultural transmission, selection, and other historical processes. We have not yet answered the questions posed at the end of Chapter 1: what domains of ceramic similarity in the Yasawa Islands can be used to define culturally transmitting populations or lineages, what are the spatial and temporal distributions of transmission lineages defined along different avenues of transmission, and what are the possible explanations for the distribution of these lineages? These questions are addressed in the next chapter.

CHAPTER 6. TRANSMISSION AND CULTURAL DIVERSIFICATION IN THE YASAWA ISLANDS

> That compelling [phylogenetic] tree image resides deep in our representation of biology. But the tree is no more than a graphical device; it is not some a priori form that nature imposes upon the evolutionary process. It is not a matter of whether your data are consistent with a tree, but whether tree topology is a useful way to represent your data.
>
> Carl R. Woese (2004:179)
> A New Biology for a New Century,
> *Microbiology and Molecular Biology Reviews* 68

In Chapter 5, non-random distributions of ceramic similarities were identified, but it is unclear whether these similarities can be simply explained as products of inheritance, chance, functional constraints, environmental similarities, or other factors. In this chapter, some of these ceramic distributions are initially analyzed with several techniques to determine the degree to which inheritance explains similarities. After assessing the heritability of ceramic classes, cladistics and other techniques are used to define transmission lineages and groups of transmission lineages.

Cladistically derived trees are one way to represent heritable or homologous relationships between classes, but, as the statement by Woese above indicates, phylogenetic trees do not identify empirical structure. We define empirical structure with our observational classes and cladistically derived trees depict a hypothesis of routes of transmission. Cladistically derived trees will be evaluated as they are presented in this chapter, but these hypotheses require further evaluation over the course of future research. This further evaluation may take the form of new analyses targeting different dimensions of ceramic variation or different realms of material culture. This future work is discussed in Chapter 7.

In the following sections, rim, temper, and surface modification variation is the focus of analysis. Other aspects of ceramic variation may also prove useful for defining transmission lineages and the research here is seen as a first step toward identifying dimensions of material culture variation that can be used to track transmission. This chapter concludes with a preliminary discussion of the scenarios that may account for particular characteristics of transmission within the Yasawa Islands.

6.1 DEFINING MATERIAL CULTURE LINEAGES USING RIM FORM VARIATION

6.1.1 Assessing the Heritability of Rim Form Classes

In section 5.2.1.1.1 a five dimension and a three dimension jar rim classification were compared by their ability to adequately represent diversity and evenness of rim variation. The three dimension classification produces a richness distribution suggesting it more adequately represents underlying diversity in the ceramic population. While the three dimension classification of jar rim forms better represents underlying diversity, other aspects of the classification render it ineffectual for investigating transmission. When the three dimension jar rim classification is applied to all of the Yasawa Islands ceramic assemblages several of the classes describe ceramic similarities that appear in the earliest and latest assemblages (see Table 5.21). Some of these similarities that appear in widely discontinuous time periods may be explained, for example, as chance similarities, or analogous similarities, neither of which moves us unambiguously toward the goal of defining transmission lineages. Both chance and analogous similarities may create homoplasies in cladistically derived trees rendering these trees less useful hypotheses of phylogenetic relatedness.

Given the distributions of jar rim classes in Table5.21 it appears as though the three-dimension classification may not measure variation with enough precision to readily define material culture lineages. The longevity of these classes is too great. We can attempt to reduce the longevity and spatial distributions of classes by adding additional dimensions of variation to their definitions. This creates a more complex class that may measure variability in smaller time-space portions and thus more precisely track variation in cultural transmission patterns. A similar procedure was followed by culture historians (e.g., Phillips 1958; Wheat, et al. 1958) as the manipulated the number of levels (sensu Dunnell 1971) in a classification to produce classes of differing precision by which they tracked variation (Dunnell 1986; Lipo, et al. 1997)

To produce more complex classes, the three dimension classification of jar rims was modified to include an additional rim dimension and a temper dimension. The type of temper that is most abundant in sherds changes over time and across the Yasawa Islands (Table 5.24). Calcium carbonate tempers, for example, are often the most abundant temper type in sherds from later deposits (Best 1984:357; Cochrane 2002a). Temper variation, therefore, may increase the precision and usefulness of our classes. Additionally, modes of the rim form dimension Thickness 1 (identified as T1, see Figure 5.2 and Table 5.2) seem to be differentially distributed across time (see Table 5.20) and this dimension was re-incorporated into the classification to increase class precision. The new five-dimension classification is composed of the following dimensions (see sections 5.1.3 and 5.1.4 for dimension descriptions): Rim Curvature (C), Rim Angle (A1), Rim Thickness[32] (T1), Rim Symmetry (S), and the first temper abundance rank (TM1). This classification produces a total of 2304 classes, of which 142 have members. However, ninety-eight of these classes have only one member. The abundance of single-member classes suggests that with larger collections these single-member classes may differentially add members changing the evenness of the sample, or new classes with members may be added, or both.

The ability of the jar rim-temper classification to produce representative samples is compared to other classifications in Figure 6.1. The generation of this richness distributions follows the same procedures outlined in section 5.2.1.1.1. The topmost hashed line represents the mean richness versus sample size of this new five dimension jar rim-temper classification. This classification produces the least representative samples compared to other classifications. Their ability of the original three and five dimension jar rim classifications to produce more representative samples is due, in part, to their lowered precision: the original three dimension classification contains 168 possible classes and the original five dimension classification contains 1152 possible classes, compared to the 2304 classes of the jar rim-temper classification.

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[32] Rim thickness modes were slightly modified from the definitions presented in section 5.1.3. The modes used here include: < 6 mm, > 6 and < 10 mm, > 10 mm. These mode definitions parcel out variation into classes better suited for the cultural transmission analysis.

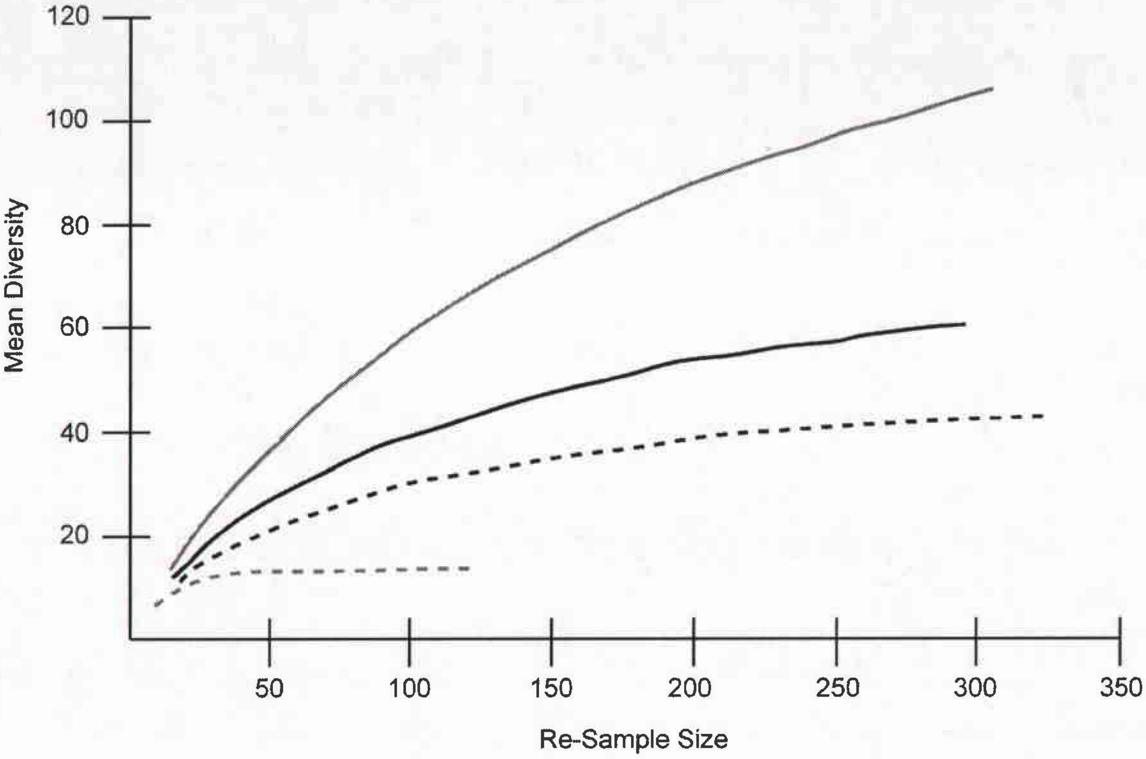

Figure 6.1. Mean richness-sample size curves for four rim classifications. Top gray line represents five dimension rim classification incorporating temper, solid black line is original five dimension classification, black hashed line is three dimension classification, and gray hashed line is five dimension classification with temper showing only the 14 most abundant classes. Curves produced using procedures given in section 5.2.1.1.1.

A compromise solution is presented by the bottom mean richness curve in Figure 6.1. This curve displays the mean richness versus sample size for the five dimension jar rim-temper classification, but represents only the 14 most abundant classes. Each class has at least 4 members, and a total of 120 rim sherds are classified. By using these 14 classes to analyze transmission patterns in the Yasawa Islands, we will be examining only the most frequently transmitted information within the classificatory system created. Lineages and other transmission patterns that we define will describe the modal characteristics of transmission systems in the Yasawa Islands populations (see O'Brien and Lyman 2003:157).

These 14 classes have relatively limited spatial and temporal distributions across the Yasawas Islands deposits suggesting that they may describe homologous similarity produced as a consequence of cultural transmission. Alternatively this similarity may be analogous and explained as a result of parallelism or convergence . At this point in the analysis we can stipulate that this similarity is not explained by convergence or parallelism in separate populations. This is stipulation is based on geographic propinquity of the ceramics (cf. Meltzer 1981) and may be modified after future analyses.

We do not, however, have to rely solely on this stipulation, for we can evaluate the ability of these classes to measure homologous or heritable variation with the model used to construct seriations. Occurrence seriations are constructed so the distributions of classes across assemblages or objects is continuous and overlapping. Barring chance orders, this assures that the classes are arranged to conform with a model of homologous similarity. The typical occurrence seriation is constructed so that groups (objects or assemblages) are described by the presence and absence of a series of classes and the best order is one that arranges groups so the distribution of presences and absences is continuous (Cowgill 1972; Dunnell 1970; O'Brien and Lyman 2000b). If it is not possible to construct an order without discontinuities among presences and absences, then there will often be multiple "best" orders that array classes differently, but with the same number of discontinuities.

When evaluating the jar rim-temper classes with the seriation model we attempt to arrange classes so the distribution of modes across each dimension is continuous (Table 6.1). This is a slightly different procedure than a typical occurrence seriation because instead of groups of phenomena being ordered by classes, classes are ordered by dimensions (cf. O'Brien and Lyman 2003:160-164; O'Brien, et al. 2002). This creates what is called a multi-state transformation series in cladistic analyses and such transformation series are often objects of analysis themselves (Siebert 1992). Additionally, the dimensions used to construct the14 jar rim-temper classes are defined by multiple modes (not just presence and absence) so we can expect many ways to order the classes that produce the same number of discontinuities. Table 6.1 arranges the 14 jar rim classes into an order based on the model of homologous similarity used to construct occurrence seriations. Each row is a particular jar rim class. Each column is a dimension of the classification. Modes are distributed in the columns. Heritable continuity among these classes is apparent where modes overlap across classes.

Table 6.1. Fourteen most abundant classes in the five-dimension jar rim-temper classification arrayed to evaluate heritable continuity.

Dimensions*					
Rim Curvature (C)	Rim Angle (A1)	Rim Thickness (T1)	Rim Symmetry (S)	Temper Mode 1 (TM1)	N of sherds
1	3	3	1	1	6
1	3	3	1	2	4
1	3	3	5	2	4
1	3	3	5	1	15
1	3	2	5	1	9
1	[illegible]	2	1	1	4
1	2	2	1	2	6
1	2	2	1	1	14
1	2	2	2	1	6
1	2	1	2	1	15
1	2	1	1	1	10
2	2	1	1	1	6
2	2	2	1	1	17
2	3	2	1	1	4

*Modes for each dimension: dimension C, (1) straight, (2) concave; dimension A1, (2) ≥ 70 ≤ 90, (3) > 90 degrees; dimension T1, (1) < 6, (2) ≥ 6 ≤ 10, (3) > 10 mm; dimension S, (1) parallel, (2) exterior expanded, (5) thinned; TM1, (1) calcium carbonate dominant, (2) ferromagnesian dominant. See sections 5.1 and 5.2 for additional modes.

In Table 6.1 there are 14 instances where the modes in a dimension change (light and dark shaded cells). This is the most parsimonious order of these classes judged by the number of mode changes as no arrangement with fewer mode changes is possible. Seven of these changes (dark shaded cells) create discontinuous mode distributions violating the model used by occurrence seriations. Thus this specific set of classes may not create empirical groups whose similarity is solely explained as a function of inheritance. This is expected in cladistic analysis of classes defined by multi-mode dimensions (Siebert 1992:86-88) and explanations for the mode discontinuities likely involve homoplasious similarity explained as a result of convergence, parallelism, or chance. These possibilities are discussed below.

We can also assess the potential of our classes to measure heritable similarity by examining the independence of dimensions in our classification. To map transmission patterns, the dimensions used to classify artifacts, should vary independently. If they are not independent, then in our explanations we may be unable to differentiate between class similarity that is a product of transmission, and class similarity that is a product of the mechanical connection of modes across dimensions. For example, a classification of fishhooks may include dimensions such as head shape, lashing device, point angle, and hook raw material, among many others (dimensions from Pfeffer [2001]). Classes constructed from the multiple modes feasible for each of these dimensions could be applied to archaeological specimens in an attempt to define transmission patterns using seriation and cladistic analyses. However, we may find the presence of particular modes in a dimension such as head shape are positively correlated with particular modes in a dimension such as lashing device. In this case, the similarity of different fishhook classes in these two dimensions may be a product of limited number of ways that lashing devices can be combined with particular head shapes. Therefore some portion of class similarity may be explained by functional convergence and not transmission within a population.

One way to examine the possible contribution of interdependent modes on similarity is to generate pair-wise correlation coefficients for all mode combinations across all classes. Table 6.2 presents data to evaluate the hypothesis that dimensions in the jar rim-temper classification are interdependent. More specifically, there are ten separate hypotheses for the ten possible pair-wise dimension combinations. Each cell in the table displays the correlation coefficient of modes in the 14 jar rim classes for the two dimensions given in the row and column. For example in the lower left the cell at the intersection of TM1 (temper type first abundance rank) and C (rim curvature) we see that the hypothesis of dimensional interdependence is falsified as the correlation of particular modes of these dimensions is weak and not significant ($p = 0.35$). Pearson's correlation coefficients for all pair-wise comparisons across the 14 most abundant jar rim classes are generally weak and not significant. The modes of two dimensions, however are moderately-well correlated. We are unable to falsify the hypothesis of interdependence for the dimensions Rim Thickness (T1) and Rim Angle (A1) as the correlation coefficient is 0.71 and this correlation is significant within 99% confidence intervals ($p = 0.004$). This makes intuitive sense as a rim that is dramatically flared out toward the horizontal may require a thicker connection at the shoulder, so the rim doesn't flop down during vessel manufacture. At this point, we can note that further refinement of the rim classification may produce more accurate conclusions regarding transmission.

Table 6.2. Pearson's correlation coefficients (*r*) for pair-wise comparisons of jar rim-temper dimensions. Pearson's *r* is top number in cell, significance is bottom number.

	Dimensions			
Dimensions	**C**	**T1**	**A1**	**S**
C				
T1	-0.17408 p = 0.551719			
A1	-0.30047 p = 0.296568	0.710742 p = 0.004382		
S	-0.32567 p = 0.255848	0.445435 p = 0.110449	0.379908 p = 0.180293	
TM1	-0.27273 p = 0.345494	0.174078 p = 0.551719	0.441873 p = 0.113673	0.108556 p = 0.711825

6.1.2 Jar Rim Transmission Lineages

If we explain similarities in jar rims as a result of cultural transmission then the lineages and groups of lineages, that is clades, we define are hypotheses concerning the temporal and spatial characteristics of populations that are related to each other via inheritance. We can begin evaluating these hypotheses with the initial phylogenetic tree in Figure 6.2. For discussing trees we switch to the terminology of cladistics. Taxa (rim classes) are defined by particular combinations of character states (modes) of a character (dimension).

Figure 6.2 is a 50% majority-rule consensus tree. For these 14 classes, the 13 terminal taxa and the outgroup, there are 1,974 equally parsimonious trees. These trees require the least amount of character state changes, 13, to arrange the classes on the tree. There are of course a vast number of alternate ways to arrange these classes, but those alternate trees all incorporate more steps. Thus using the cladistics software and the principle of parsimony we remove these hypotheses from consideration.

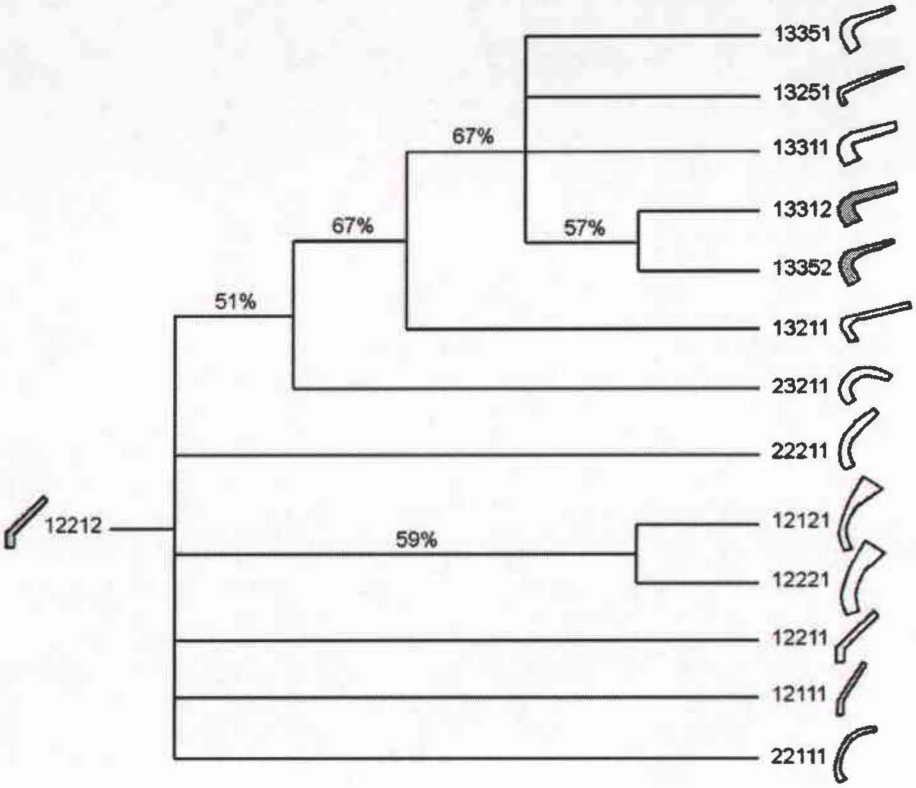

Figure 6.2. Tree representing hypothesized phylogenetic relationships among 14 rim classes. Numbers represent character states (C, A1, T1, S, TM1). Percentages indicate the proportion of trees displaying that bipartition out of 1,974 equally parsimonious trees. Rim pictures (interior of vessel to left) connote characteristics of the class and are illustrative only. Gray rims display the FM temper character state (mode 2, Table 5.5) for the character TM1.

Each of the 1,974 trees are described by a Consistency Index (CI) of 0.54 and a Retention Index (RI) of 0.67. The CI and RI are used to measure the robustness of a particular tree. The CI measures the amount of homoplasy in a tree by dividing the number of characters in a data matrix (Table 6.1 is the data matrix for these taxa with 5 characters) by the number of characters displayed on a tree. The CI can range between zero (complete homoplasy) to one (no homoplasy). The other measure of robustness used here, the RI, is calculated by noting the amount of similarities in different lineages on a tree that do not represent population relatedness (i.e., observed homoplasy), and comparing this with the maximum possible amount of these similarities in the data matrix (i.e., maximum homoplasy). The RI measures the actual amount of homoplasy relative to the maximum amount of homoplasy and ranges from zero to one. Higher RI values occur when character state changes are concentrated primarily at the nodes of a tree and lower RI values occur when character state changes are concentrated at the tips of branches. Thus the higher the RI the more confidence we have that the tree is an accurate representation of phylogenetic (i.e. branching) relationships in the data set (Siebert 1992).

This tree is comprised of one group of seven rim classes (top, Figure 6.2) that derive from a common pool of ancestral character states. This group of seven rim classes, a clade, includes highly everted rims. All of these rims, save for one (23211), are approximately dated to within the last 400 years (see Table 4.14).

The rim class 23211 that splits off first within this clade appears only in the oldest deposits throughout the Yasawas. Therefore this clade joins classes that occur in the earliest (c. 2600 BP) and the latest (c. 400 BP) deposits into a set of related transmission lineages. Measured by these classes, some segment of the colonizing populations of the Yasawas are related to some segment of the most recent prehistoric populations via transmission.

The remaining rim classes in Figure 6.2 are mostly tacked on as polytomies with untraceable phylogenetic relationships among themselves or relative to the single clade. All of these rim classes exist in the oldest deposits and a few are produced for approximately 1,000 years or more. The rim class 12211 is found in the earliest deposits at Olo (Y2-25) and Qaranicagi (Y2-39), along with excavation levels at Natia (Y1-15) dating from c. 2380-2170 BP (level 14) up to 710-590 BP (level 6). Thus, this rim class describes the longest lived consistently reproduced form, appearing in assemblages for perhaps 1,790 years.

This tree is rooted through the outgroup class at the left of the tree. The outgroup determines character state polarity, or the ancestral and derived nature of character states throughout the tree. In choosing an outgroup we should choose a taxon that is closely related (i.e., "ancestral") to the remaining taxa so that character polarity among the remaining taxa is determined in such a way that helps us define ancestor-descendant relationships. The class used here for an outgroup appears primarily in the early deposits, c. 2760 – 2360 BP, of the Yasawa Islands and thus is a possible candidate for an outgroup. This class also describes sherds in deposits dated to c. 1270-920 BP and c. 710-590 BP. Thus the outgroup in Figure 6.2 may be too closely related to the ordered taxa to usefully determine character polarity. If we choose an inappropriate outgroup character polarity may be inaccurately modeled and our resulting tree less useful for resolving phylogenies. The large number of polytomies in Figure 6.2 is evidence that ancestor-descendant relationships have not been well-defined with this outgroup.

One of the advantages of cladistic analysis is that we can generate different hypotheses of transmission generated similarity based on our choice of outgroup (see O'Brien and Lyman 2003:75-81; Ridley 1986:164). The outgroup in Figure 6.2 does not produce a particularly useful phylogeny. Other rim class with temporal distributions limited to the earliest deposits could conceivably be better outgroups. There are a variety of means to evaluate the appropriateness of different outgroups (Kitching 1992a; O'Brien, et al. 2002), but in short a better outgroup more usefully determines character polarity relative to the classes in our analysis, so that either cladistically derived trees contain less instances of homoplasy or homoplasy is differently distributed in the tree so that phylogenetic relationships are defined. Among the 14 classes there are three that occur only in the earliest deposits at Olo, Qaranicagi, and Natia dated to approximately 2600 BP: classes 12121, 12221, and 23211 labeled by the character state designations show in Figure 6.2.

The 50% majority rule consensus trees in Figure 6.3 arrange the same rim classes in Figure 6.2, but using rim class 23211 and class 12221 as outgroups. The Figure 6.3 trees have the same statistical description as the Figure 6.2 tree (length 13, CI = 0.54, RI = 0.67). If class 12121 is used as an outgroup a tree duplicating the Figure 6.3 (b) topology is produced with class 12221 exchanging places with class 12121. The bottom clade in Figure 6.2 (a) comprising classes 13351 to 13321 is also a coherent clade in the trees depicted in Figure 6.2 and 6.3 (b). Besides this clade of late appearing rim classes, the other jar rim classes in these trees either form a clade differentiated from the late jar rim classes, as in Figure 6.3 (a), or are generally connected to the late appearing rim classes as a set of homoplasies without clear phylogenetic relationships.

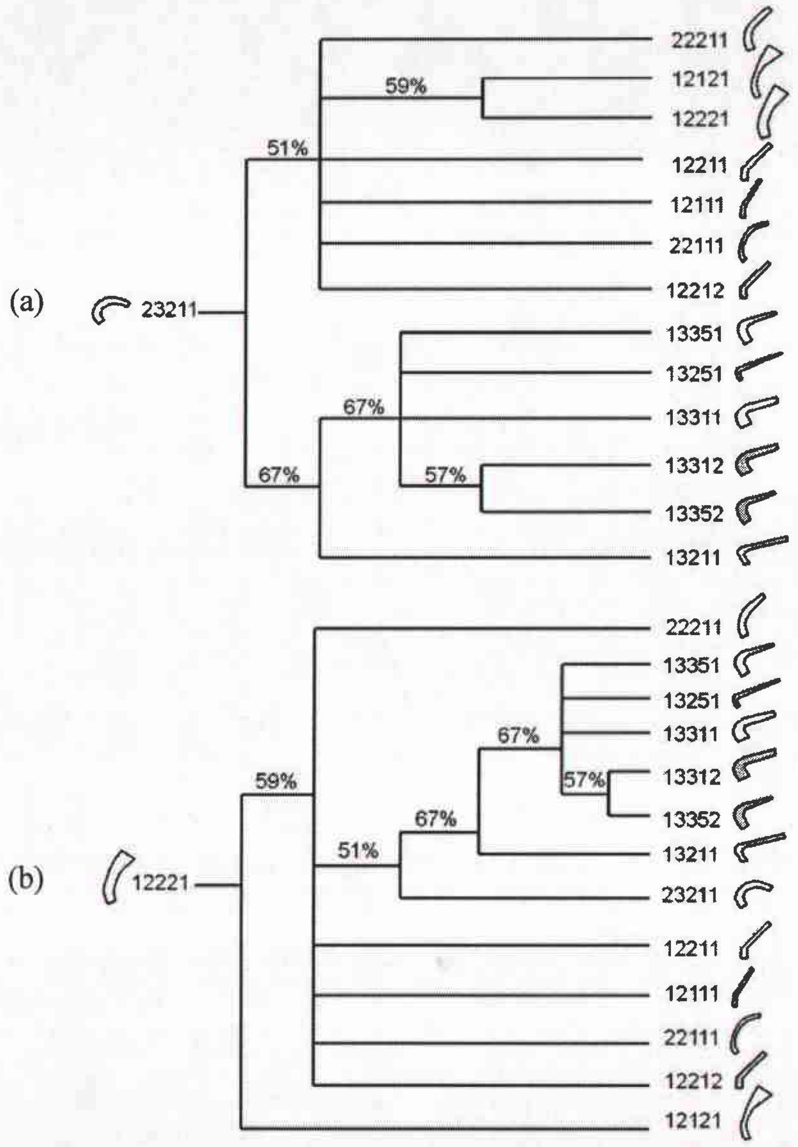

Figure 6.3. Trees representing hypothesized phylogenetic relationships among 14 rim classes using different outgroups. Numbers represent character states or mode codes (C, A1, T1, S, TM1). Percentages indicate the proportion of trees displaying that bipartition out of 1,974 equally parsimonious trees. Rim pictures (interior of vessel to left) convey characteristics of the class and are illustrative only. Gray rims display the FM temper character state (mode 2, Table 5.5) for the character TM1.

All four trees (including the tree produced by swapping outgroup classes in Figure 6.3 (b)) suggest that using ceramics from the Yasawas Islands we can define groups of related transmission lineages, clades, that include the entire temporal occupation of the islands. The Figure 6.2 tree and both trees represented in Figure 6.3 (b) contain a clade comprised of classes 13351 to 23211, whose temporal distributions span the entire chronology of human occupation in the islands. When class 23211 is used as an outgroup in Figure 6.3 (a), two clades are formed of early and late appearing classes and these clades derive from the same pool of ancestral variation signified by the basal node of Figure 6.3 (a).

6.1.3 Bowl Rim Transmission Lineages

Cladistic analysis of bowl rim forms using the four dimension classification presented in Chapter Five (Table 5.10) produces consensus trees composed almost entirely of polytomies. For cladistic analysis, this classification suffers some of the same problems as the original jar rim classifications. The abundance of homoplasies including character state reversals, parallelism, and convergence prevents a representation of hypothetical phylogenetic relationships.

Like the jar rim classification, the addition of a temper character to the bowl rim classification produces classes with more limited distributions in time and space generating more informative phylogenetic trees. The character "first temper abundance rank" (TM1) was added to the four dimension bowl rim classification to create a new five dimension classification. The five dimension classification of bowl rims groups 248 sherds into 79 classes out of a possible 1,008 classes. Forty-five of these classes (57%) have two or more members. Comparison of the four and five dimension bowl rim classifications, however, demonstrates that the four dimension classes better represent the underlying richness and diversity of the bowl rim population (Figure 6.4), a scenario similar to the jar rim classification. While the four dimension classification is more representative of diversity and evenness among the groups created, using different sets of classes, those with 2, 3, and 4 or members, from the five dimension classification produces phylogenetic trees with less instances of homoplasy. Mean diversity at different re-sample sizes using the fourteen classes with the most members in the five dimension bowl rim classification is also shown in Figure 6.4.

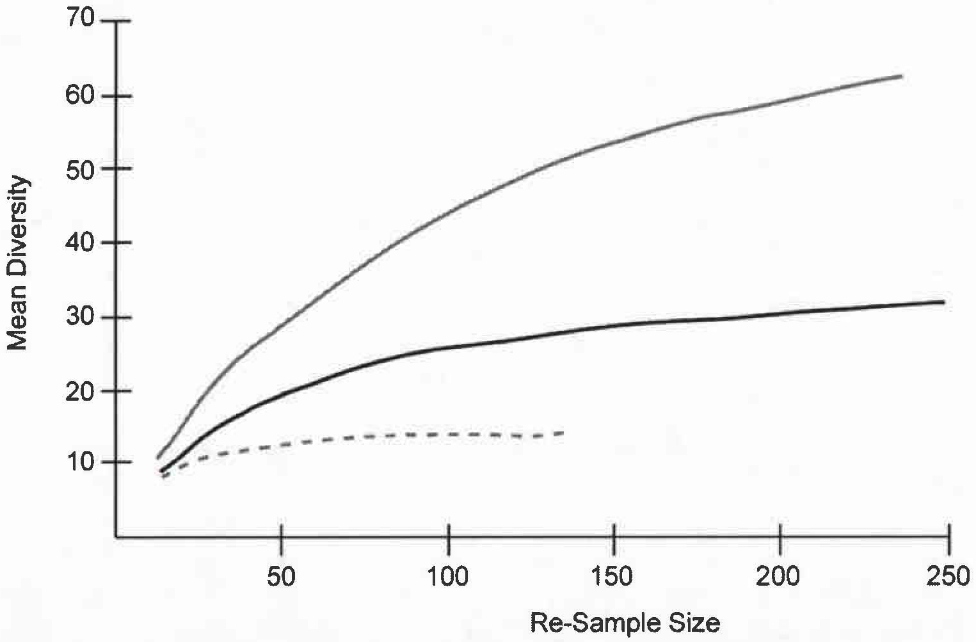

Figure 6.4. Mean richness-sample size curves for five dimension bowl rim classification that incorporates temper (solid gray line), original four dimension classification (solid black line), and five dimension bowl rim classification with fourteen classes used in cladistic analysis (hashed gray line).

Like the jar rim classification, the bowl rim classification used for cladistic analysis is a compromise. By examining classes with multiple members we can be confident that we are tracking those classes that describe similarities transmitted over time and across space. If our analyses do not include all classes with multiple members then we are missing some subset of variation potentially explained by transmission.

A 50% majority rule consensus tree (not shown) generated from 10,000 trees of the 45 bowl rim classes with 2 or more members is not a useful representation of phylogeny. These trees are described by consistency indices of 0.17 and retention indices of 0.36. The consensus tree contains a single clade of 17 classes with the rest of the rim forms tacked on to the tree base as polytomies.

The phylogenetic tree in Figure 6.5 arranges the 14 bowl rim classes with five or more members and one class with four members (class 11121). The outgroup in this tree, class 33121, contains only three members, but it is the only bowl rim class with multiple members present in only the earliest deposits (at the Olo site). Class 33121 is likely our best choice for an outgroup. This 50% majority rule consensus tree is generated from a total of 20,634 equally parsimonious trees of length 14, CI of 0.64 and RI of 0.67.

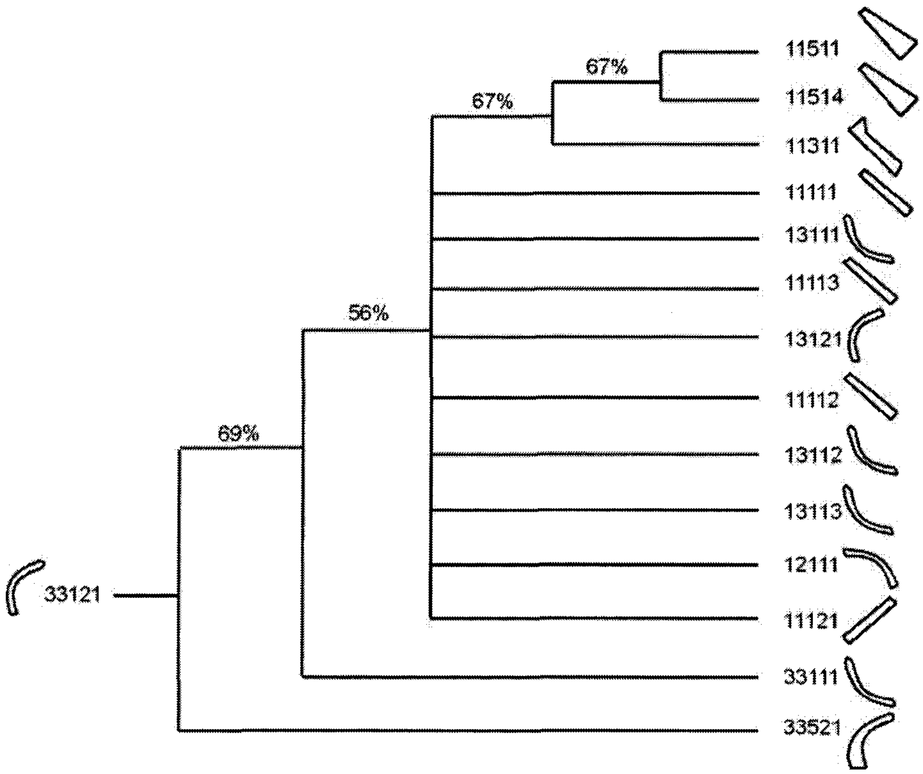

Figure 6.5. Tree representing hypothesized phylogenetic relationships among 14 bowl rim classes with outgroup class 33121. Numbers represent character states (V, C, S, O, and TM1). Percentages indicate the proportion of trees displaying that bipartition out of 20,634 equally parsimonious trees. Rim pictures (interior of vessel to right) convey characteristics of the class and are illustrative only.

The Figure 6.5 tree topology consists of one large clade composed mostly of polytomies related to two other bowl rim classes each separated by nested bifurcations. Class 33521 is separated at the first node in this tree and appears primarily in the earliest deposits in the Yasawas. Nine of the ten sherds in this class are found in the early Olo deposits and one from a surface site on Naviti. Additionally all of the Olo sherds of this bowl class are completely burnished, as are the three sherds of the outgroup, class33121. Thus, of the 19 completely burnished sherds in the Yasawa Islands assemblages, 12 are found within these two classes. Variation in burnishing is non-randomly distributed across bowl rim classes and is found primarily in a transmission lineage connected to other lineages only at the basal node of the phylogenetic tree of bowl rims. In other words, the burnished class 33521 does not share a lengthy transmission history with other classes in the tree. These characteristics suggest some sorting mechanism may explain the burnishing distribution and the transmission history of class 33521. Because burnishing may decrease vessel permeability, as well as increase hardness, this surface treatment may affect the performance of a vessel within specific physical environments (Rice 1987:131,132, 150,151) implicating selection as a possible explanation. Engineering analyses are one possible method for evaluating this hypothesis (e.g., Bronitsky 1986; O'Brien, et al. 1994; Schiffer and Skibo 1987; Schiffer, et al. 1994), but are not further developed here.

The other class related to the large group of polytomies, class 33111, is found only on Waya Island, but in deposits ranging from the earliest occupations at Olo, to the middle of the Qaranicagi sequence, to Waya surface sites. The restricted spatial distribution of the class 33111 transmission lineage may measure spatially structured cultural transmission, but the spatial distribution of this class may also be explained by sample size (n = 5), or as of yet unexamined functional (sensu Dunnell 1978) variation.

The remainder of the bowl rim classes are, for the most part, grouped into a single clade sharing a common pool of ancestral variation, but without any consistent phylogenetic relationships among themselves. Several of these classes are found in discontinuous time periods from the earliest deposits to the most recent surface assemblages and likely track similarities explained as the "re-invention" of particular character states (modes). This can be conceived as a classification problem as our classes are not complex enough to separate temporal changes in transmitted variation. A different classification may remove these homoplasies. Within this group there is one set of three classes with definable phylogenetic relationships. The three bowl rim classes at the top of the tree appear throughout the Yasawas Islands and are present in the earliest to latest deposits.

6.1.4 Summary of Rim Form Cultural Transmission History

Cladistic analysis of rim form variation in both jars and bowls indicates that in the Yasawa Islands we can define clades whose classes span the entire chronology of occupation. It does not appear as though changes in past populations were such that transmission over time was substantially interrupted. In the Figure 6.3 (a) both clades of jar rim classes are related through a common ancestral pool of variation and in the phylogenetic trees of Figures 6.2 and 6.3 (b) the same clade appears containing classes that describe both early and late jar rims. The phylogenetic history of bowl rims (Figure 6.5) is less clear as there are multiple instances of homoplasy across bowl rim evolution as depicted with these classes.

The jar and bowl rim phylogenies also suggest patterns of cultural transmission possibly explained by particular processes. In each of the three jar rim phylogenies (Figure 6.2 and Figure 6.3 (a) and (b)), the set of jar rim classes[33] that occur only in surface deposits throughout the Yasawas comprise a monophyletic group or clade. If this clade is not a product of some analytical bias associated with surface assemblages, what may explain the origins of this group of related classes? In the biological realm clade

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[33] Classes 13351, 13251, 13311, 13312, 13352, 13211

origins and extinctions are typically explained by natural selection when the operation of chance can be dismissed (Gould, et al. 1977; Williams 1992:34). Thus we may develop explanations for the origins of this clade by thinking about particular components that explain sorting of material culture variation. The final section of this chapter looks more closely at explaining the origins of this late clade in Yasawa Islands prehistory.

The pattern of lineage generation and extinction within a clade can also tell us about changing human diversity over time. Figure 6.6 displays one hypothesis of the phylogenetic history of jar rim forms (Figure 6.3 (a)) with lineages plotted horizontally against a temporal scale. The continuous temporal distribution of particular jar rim classes in Figure 6.6 is based on the appearance of these classes in roughly continuous depositional sequences. For example, the top-most class in Figure 6.6 (class 22211) is found in the earliest layers at Olo (Y2-25) dated to c. 2600 BP, at Qaranicagi (Y2-39) in levels 20 and 19 with an estimated date of c. 2300 BP, and at Natia (Y1-15) in level 11 with an estimated date of c. 1900 BP. These separate occurrences of the jar rim class are considered to represent an unbroken temporal sequence, instead of repeated independent occurrences of the same class at close temporal intervals. The only class for which this assumption may be problematic is identified by the question mark in Figure 6.6. This class (22111) is found only in the early deposits at Olo, dated to c. 2600 BP and at Qaranicagi levels 16 and 15 with an estimated date of c. 1700 BP. If this class independently occurs at different times, the calculation of lineage diversity will be affected[34].

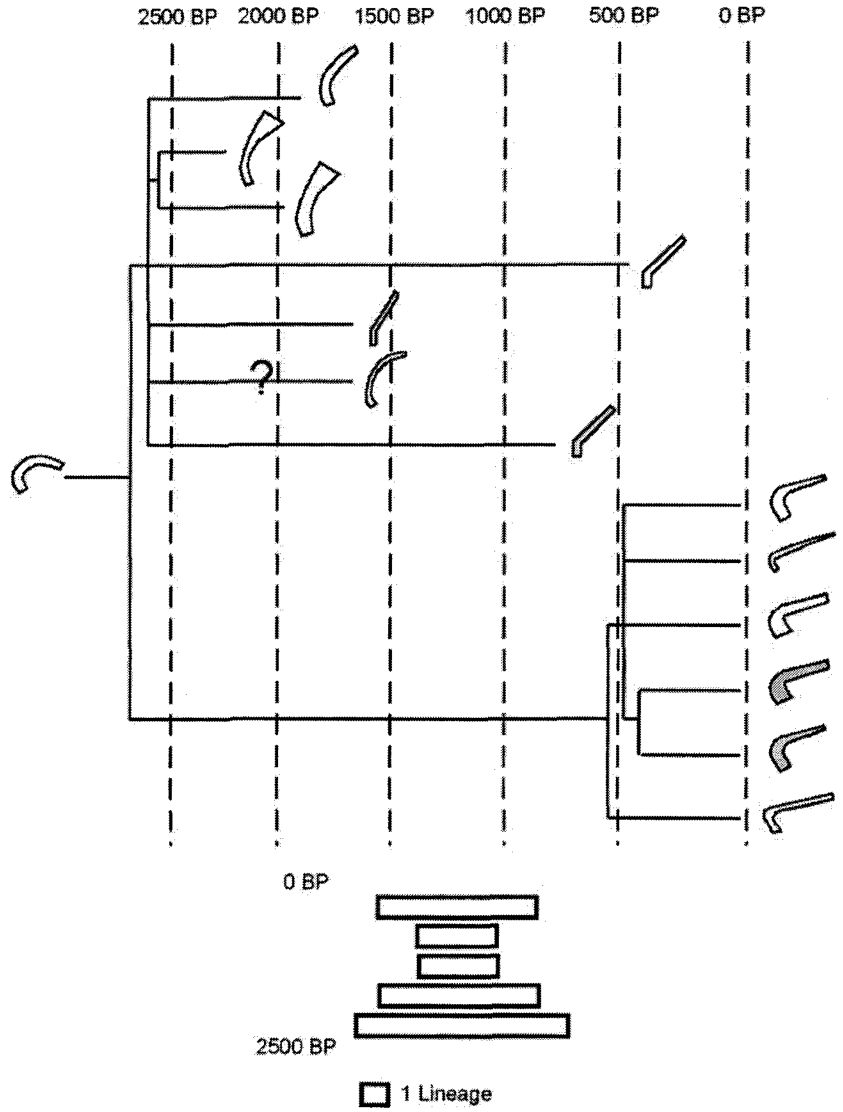

Figure 6.6. Reproduction of Figure 6.3 (a) with jar rim form lineages plotted against temporal scale indicating the approximate time of origin and extinction for each lineage. Question mark indicates possible temporal discontinuity. Clade-diversity diagram at bottom summarizes lineage diversity for each time period. The center of gravity (CG) value is 0.46 and indicates a largely symmetrical clade (after Gould, et al. 1977).

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[34] If the class 22111 is temporally discontinuous, the clade-diversity diagram would show one less lineage in the first temporal period, changing from 8 to 7, but the general character of the diagram would not change and the new CG would be 0.48 describing a symmetrical clade.

Figure 6.6 summarizes lineage diversity over time with a clade diversity diagram at the bottom of the figure. The temporal divisions used to measure diversity are chosen based on the shortest temporal duration of any class in the phylogeny, that is approximately 500 years. Doubling the number of temporal divisions, each representing 250 years, would create the same general diversity pattern (i.e., decreasing over time with a late increase). Lengthening the amount of time in each period would increasingly erode change in measured diversity until, for example with only two time periods, there are equal numbers of transmission lineages in the early half of Yasawas prehistory compared to the more recent half.

Figure 6.6 presents the number of jar rim lineages per 500 year temporal unit and shows that jar rim lineage diversity decreased over time from colonization of the Yasawas up to about 500 BP at which point lineage diversity begins to increase, a pattern in part noted by other researchers in Fiji (e.g., Burley and Clark 2003; Hunt 1987). We may develop different possible explanations for changing lineage diversity that take into account different kinds of theoretically defined similarity. If these classes track variation that conforms to a neutral model, (stylistic classes sensu Dunnell [1978]), then changes in lineage diversity may be explained by changes in the population configuration, geographic space, or other components that structure transmission of equal-cost variants. If these classes track variation that conforms to a functional model (functional classes sensu Dunnell [1978]), then lineage diversity may be explained by changes in environments or other components that affect the relative fitness of variants and thus their availability for transmission.

Currently, only the excavated deposits at Qaranicagi and Natia represent Yasawas prehistory between approximately 1500 and 500 BP. Thus the reduction in jar rim lineage diversity at this time may reflect the poor representativeness of a spatially restricted sample. If there were more assemblages dating to this time period we might find that some of the jar rim classes with members at the early and late ends of the sequence also have members between 1500 and 500 BP and thus change our measurement of lineage diversity over time.

The reduction in jar rim lineage diversity as represented in the Qaranicagi and Natia deposits may also be a result of particular activities during occupation of these areas. The array of artifactual materials at Qaranicagi including a variety ceramic classes, faunal and shellfish remains, and lithic tools (described in section 3.2.1.5.1) suggest the site was used for activities similar to those at the early occupation of Olo representing a time period when jar rim class diversity is relatively high. The inhabitants at Natia also engaged in a variety of domestic activities evidenced by shellfish remains, lithics including formal tools, and at least one piece of shell jewelry (section 3.2.4.1.1). Ceramic deposition at Natia does increase dramatically after approximately 600 BP and this may indicate different activities occurring in the excavation area of the site at this time. In short, there is presently is little evidence that dramatically different activities unique to Qaranicagi or Natia such might explain jar rim diversity between 1500 and 500 BP would be affected.

The jar and bowl rim phylogenies are currently our best hypotheses of cladogenic change in material cultural lineages in the Yasawas Islands. The addition of new samples that change the richness and evenness of classes in the current classification would warrant new cladistic analyses that may render these current hypotheses less parsimonious. A new classification of rim variation may as well produce new cladistic hypotheses judged better than these.

6.2 DEFINING MATERIAL CULTURE LINEAGES USING SURFACE MODIFICATION VARIATION

Rim class variation in the Yasawas demonstrates that continuous transmission over time within the islands can be defined. The spatial and temporal characteristics of lineages suggests changes in cultural diversity in the Yasawa Islands. This section examines transmission related variation in surface modification using seriation. Compared to cladistics, seriation uses a different modes to arrange classes in patterns that represent transmission. While cladistics is built upon a model of cladogenic evolution or bifurcating change, seriation is built upon a model of anagenic evolution where change occurs within a single transmission lineage.

6.2.1 Assessing the Ability of Surface Modification Classes to Measure Transmission

Many surface modification classes appear in multiple sites and across much of Yasawa Islands prehistory (see Table 5.26). To track culturally transmitted variation in this data set, occupations are characterized by the relative abundance (frequency and ordinal variation) of surface modification classes they contain. By using the relative abundances of classes in occupations we can better separate surface modification related similarities in time and space.

Variation in surface modification is first analyzed with by constructing a seriation of the 14 most abundant surface modification classes at Yasawa Islands occupations (Figure 6.7). This frequency seriation was constructed using a Microsoft Excel Macro written by Tim Hunt (Lipo, et al. 1997). The open rectangles represent the relative frequency of each class in an assemblage and the black bars are error terms calculated at 95% confidence intervals. Rows in the seriation are assemblages. Excavated assemblages are divided into groups of approximately equal time periods in an attempt to control for frequency differences due predominantly to the different accumulation histories of deposits (see Dunnell 1981).

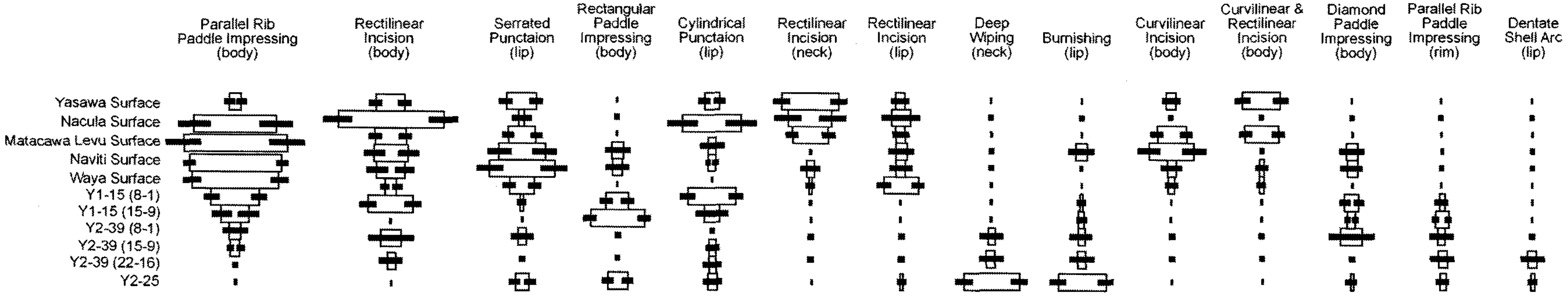

Figure 6.7. Seriation of Yasawa Islands assemblages by surface modification classes. Open rectangles represent class frequency within a particular assemblage. Black bars denote error terms calculated at 95% confidence intervals. Surface modification classes are 13 most abundant classes from right to left, plus the additional dentate class.

The seriation in Figure 6.7 is a first attempt to demonstrate the ability of surface modification classes to measure transmission related similarities across all Yasawa Islands occupations. The seriation does not exhibit all the criteria of a valid frequency seriation (see O'Brien and Lyman 2000b): *all* class distributions are not monotonic within the limits of sample size deviation and there are gaps in the distribution of some classes.

There are several possible reasons for these discrepancies. First, the correlation of surface modification classes and sherd size classes may have an adverse effect. As identified in section 5.2.3.1 sherd size influences the identification of surface modification classes in some assemblages. In particular, sherds from surface assemblages exhibit different size distributions compared to excavated assemblages, therefore the frequency of surface modification classes across surface and excavated assemblages may be more parsimoniously explained by differential breakage patterns and not differences in cultural transmission.

Second, the assemblages ordered may represent different temporal durations. Therefore, differences in the frequency of surface modification classes at occupations may represent differences in duration and not differences explicable by transmission within a population. We can expect some differences in temporal duration between the various excavated and surface assemblages in the Yasawas. Indeed, when the surface assemblages are considered alone, the distribution of classes more closely follows the seriation model (Figure 6.8). The seriation in Figure 6.8, however, may be "better" because fewer assemblages are being ordered and thus there are fewer opportunities for the arrangement to deviate from a model order.

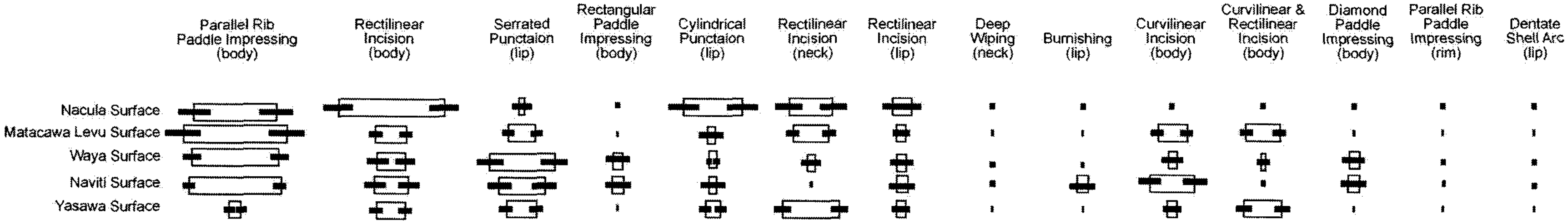

Figure 6.8. Seriation of Yasawa Islands surface assemblages by surface modification classes. Open rectangles represent class frequency within a particular assemblage. Black bars denote error terms calculated at 95% confidence intervals. Surface modification classes are 13 most abundant classes from right to left, plus the additional dentate class.

Before continuing to evaluate the ability of surface modification classes to track transmission across assemblages, we should examine a third possible reason why the original seriation in Figure 6.7 does not follow a model order. The possible effects of sample size on the generation of class frequencies that adequately represent underlying diversity may limit our ability to track variation explained by transmission. Figure 6.9 displays bootstrap mean richness curves for each assemblage in the original seriation order (Figure 6.7). In general, the smaller assemblages, those with sample sizes below 40, do not appear to accurately represent underlying diversity in the ceramic population. The surface assemblages from Matacawa Levu and Yasawa Islands, the upper and lower levels of site Y2-39 (Qaranicagi), and the lower levels of site Y1-15 (Natia) are all likely inaccurate estimates of underlying ceramic variation and this may affect our ability to arrange assemblages in accordance with the seriation model. With these small samples it is difficult to conclusively evaluate the ability of surface modification classes to track transmission.

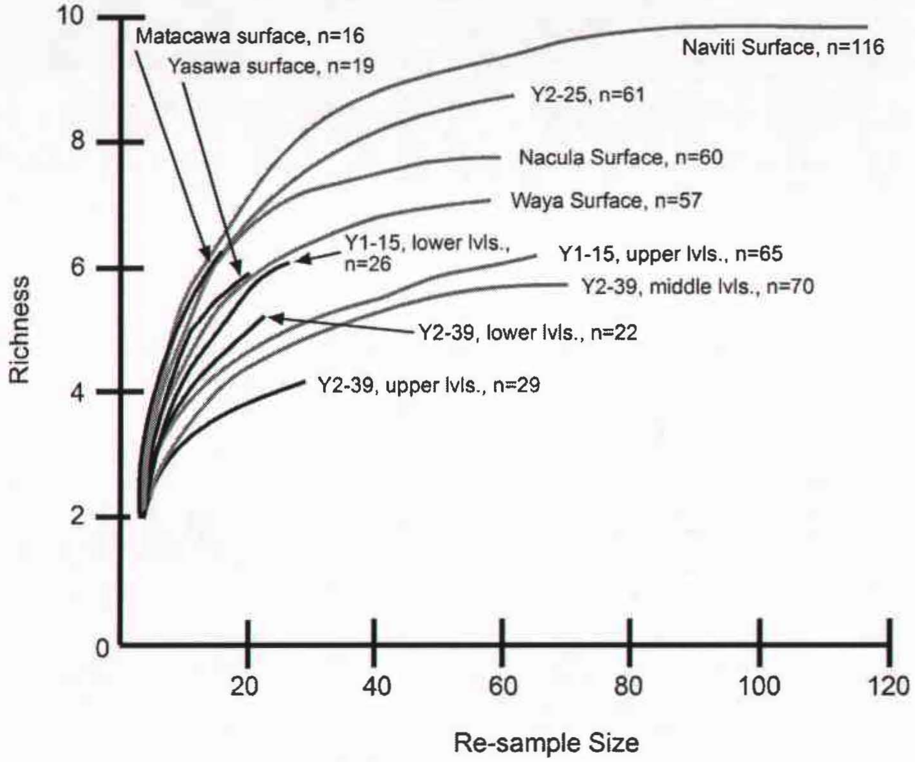

Figure 6.9. Mean richness-sample size curves for eleven ceramic assemblages described by surface modification classes. Gray curves used to construct additional seriations. Curves produced using procedures given in section 5.2.1.1.1.

A seriation comprised of only the assemblages that best represent surface modification diversity (gray curves from Figure 6.9) is presented in Figure 6.10. This order does appear to conform better to the seriation model. Again, as this order consists of only six assemblages instead of the original 11 we can expect there to be fewer opportunities for it to deviate from a perfect seriation. However, as these assemblages are more representative of underlying surface modification diversity, this seriation is likely tracking similarity explained by transmission to a greater degree than the previous seriations in Figures 6.8 and 6.7. If so, this seriation suggests that transmission of surface modification variation occurred in an unbroken lineage from the earliest occupations, such as site Y2-25, to later occupations at sites such as the middle levels of Y2-39 and the upper levels of Y1-15, and including the most recent occupations at surface sites from Nacula Island to Waya Island. It should be noted, however, that these samples are still small and a definitive evaluation of seriations produced from Yasawa Islands assemblages will require larger samples.

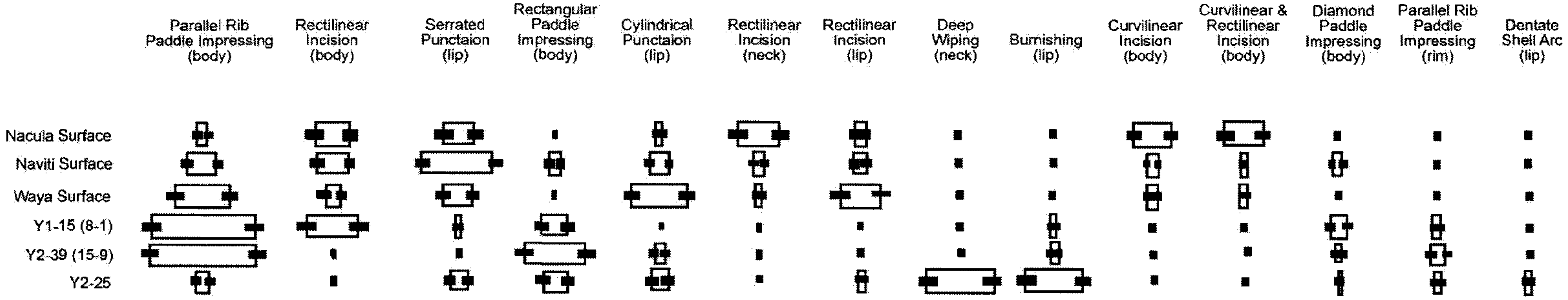

Figure 6.10. Seriation of the six Yasawa Islands assemblages that best represent surface modification diversity. Open rectangles represent class frequency within a particular assemblage. Black bars denote error terms calculated at 95% confidence intervals. Surface modification classes are 13 most abundant classes from right to left, plus the additional dentate class.

Sorting is a fourth possible explanation for similarities in surface modification frequencies across assemblages. Surface modification classes may track variation which is explicable by selection, hitch-hiking, or other sorting mechanisms in addition to transmission. Sorting and transmission may explain the distribution of burnishing on bowl rims. Sorting may also explain surface modification frequencies. If surface modification classes appear on distinct vessel parts (e.g., rims) in a non-random fashion, then seriations may in part be tracking similarity that is a product of the abundance of similar vessel parts in assemblages. This similarity may be explained as functional similarities (sensu Dunnell 1978) across occupations and thus not necessarily a product of transmission within a single population.

To evaluate the possibility that the seriations are tracking variation associated with different vessel parts, a seriation was constructed using only surface modification classes present on body sherds. All assemblages were described by the frequency of the most abundant body sherd surface modification classes listed in Table 5.24 (classes with 12 or more members used). Mean diversity curves used to assess sample representativeness are shown in Figure 6.11. Those curves (in gray) that most closely approach an asymptote are considered more representative of the ceramic population. These assemblages were used to construct the seriation in Figure 6.12.

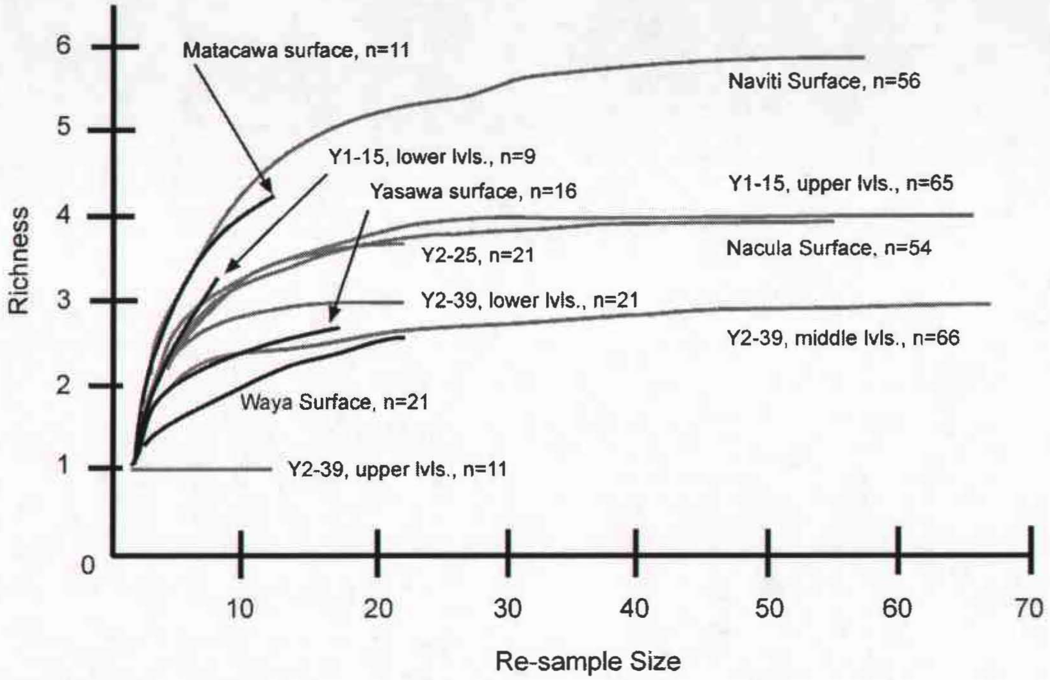

Figure 6.11. Mean richness-sample size curves for eleven ceramic assemblages described by surface modification classes on body sherds. Gray curves used to construct seriation in Figure 6.12. Curves produced using procedures given in section 5.2.1.1.1.

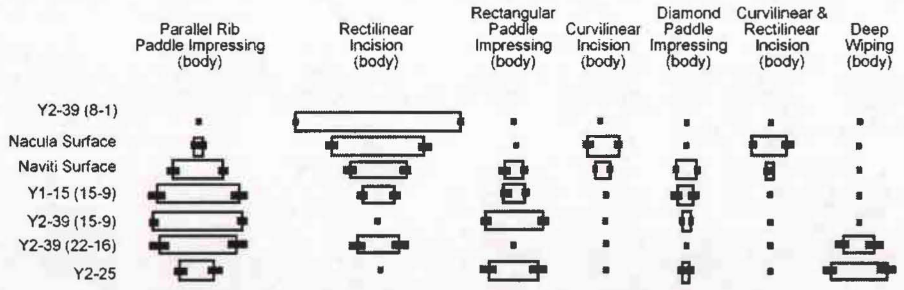

Figure 6.12. Seriation of the seven Yasawa Islands assemblages that best represent surface modification diversity on body sherds. Open rectangles represent class frequency within a particular assemblage. Black bars denote error terms calculated at 95% confidence intervals. Surface modification classes are seven most abundant classes from left to right.

The seriation in Figure 6.12 more closely approximates the frequency seriation model than previous attempts. Again, we may expect this to be a better seriation than other orders, for example Figure 6.10, as this seriation arranges fewer assemblages using fewer classes. With the Figure 6.12 seriation, however, we have removed some similarities across assemblages that may be explained by poor sample representativeness and by possible sorting affects associated with the differential distribution of vessel part classes. Still, there remain additional possible explanations for assemblage similarity as measured by surface modification classes on body sherds. Some similarities may be explained by spatial auto-correlation of sherds, particularly in excavated assemblages. For example, the Parallel Rib Paddle Impressed sherds in the Qaranicagi middle levels, Y2-39 (15-9) in Figure 6.12, could be from one or a few vessels, while the same class of sherds at Nacula surface sites could be derived from many vessels. If so, the similarity of these two assemblages may reflect vessel breakage patterns to an unknown degree. One way to asses this possibility is through sherd re-fitting analyses. If assemblages show similar proportions of re-fitting sherds then this problem may be controlled. Re-fitting analyses were not conducted here.

Finally, the assemblage from the upper levels of Qaranicagi, Y2-39 (8-1), is not described by multiple classes that overlap with other assemblages in this order. Thus, with this seriation we have not demonstrated that frequencies of surface modification classes in the upper levels of Qaranicagi are necessarily related via transmission to other assemblages in the order.

6.2.2 Surface Modification Transmission Lineage

The seriation in Figure 6.12 is problematic, but is thus far our best representation of similarities in surface modification classes that are likely explained by transmission within a population. This seriation indicates that surface modification similarities in the initial human occupations in the Yasawa Islands, latter occupations at Qaranicagi and Natia, as well as the most recent occupations identified as surface assemblages can be explained as the result of cultural transmission within a single material culture lineage. In other words, using surface modification classes applied to body sherds, a single population can be defined for the prehistoric sequence in the Yasawas with spatial boundaries minimally including the islands from Waya in the south to Nacula in the north.

6.3 HOW DO WE EXPLAIN CHANGE IN THE CULTURAL TRANSMISSION HISTORY OF THE YASAWA ISLANDS?

Cladistic and seriation analyses indicate that when ceramic assemblages in the Yasawa Islands are described with particular classifications we can define both monophyletic groups of transmission lineages (i.e., clade) and a single lineage that include multiple classes (i.e., a seriation lineage). Both analyses establish a continuity in cultural transmission throughout Yasawas prehistory. This continuity of transmission is not so readily apparent in the analysis of bowl rims. For bowls, the high incidence of homoplasy in cladistic analysis makes it difficult to define phylogenetic relationships among these classes.

The results of these analyses are complementary. Each method, cladistics and seriation, assumes that evolution occurs predominantly via a particular mode (Lyman and O'Brien 2005). With cladistics, cladogenesis is presumed to be the primary mode of evolutionary change. Cladogenic change is defined by the bifurcation of an ancestral taxon into two sister-taxa. With frequency seriation, anagenesis is presumed to be the primary mode of evolutionary change. Anagenic change is identified by frequency changes across multiple classes describing assemblages. If the frequency changes follow a neutral model, the class distributions define a single transmission lineage that explains change across the assemblages.

The application of both cladistic and seriation methods to the study of transmission in the Yasawas underscores an important point: we may often be able to depict different modes of evolutionary change in the material record of a place and time. The quotation by Woese (2004:179) at the beginning of this chapter describes a similar situation in biological analyses. In some instances, and at some analytical scales, cladogenesis may explain the distributions of similarities and differences. In other instances, and perhaps at different scales change may be explained as anagenic. In the Yasawa Islands assemblages, the cladogenic and anagenic assumptions of change are applied at analytically different scales, artifact classes and assemblages, respectively. Small sample sizes and the classifications generated here preclude the use of both cladistic and seriation methods to the analysis of rim and surface modification variation. The abundance of rim classes in assemblages is too small for valid seriations and the surface modification classification is not complex enough for fruitful cladistic analysis.

6.3.1 Graph Analysis of Rim Forms

A third mode of evolutionary change may be identified as reticulation. Reticulated change occurs when a newly appearing taxon combines the character states (i.e., modes) of two or more ancestral taxa (Levin 2002; Rhymer and Simberloff 1996). Woese (2004) describes reticulated change using the term horizontal gene transfer, synonymous with horizontal transmission, and notes that in particular historical circumstances horizontal transmission may swamp other modes of evolutionary change. Woese (2004:182) summarizes: "evolution at this stage would in essence be communal, not individual . . . the community of . . . evolving entities as a whole as well as the surrounding field of cosmopolitan genes participates in reticulate evolution." Archaeologists as well have argued that reticulation is a mode of change that may explain variation defined by cultural transmission systems (e.g., Dewar 1995; Moore 1994; Terrell, et al. 1997; Terrell 2001; Welsch, et al. 1992).

For any set of artifacts described by classes representing heritable continuity we may define transmission lineages as products of cladogenesis, anagenesis, or reticulation. We can also expect that for some segments of time and space particular modes of evolutionary change may map transmission patterns with greater accuracy than others. Methods for defining cladogenic and anagenic change in cultural transmission systems have been presented in the preceding analyses, but little work has been done to develop methods to define patterns of reticulate change in cultural transmission systems (Terrell, et al. 1997).

One promising method for examining reticulate transmission patterns, graph analysis, has been introduced by Lipo (2005). Graph analysis is a method for presenting data on class similarity and is comparable to the phylogenetic trees produced with cladistics. Both techniques arrange classes based on the number of shared character states. Cladistic techniques attempt to arrange classes so that both the fewest number of character state changes describe a phylogenetic tree and hierarchical class relationships reflect the distribution of ancestral and derived character states. Graph analyses of class similarity are comparable to cladistic analyses in that they too attempt to arrange classes so that the hypothesized relationships between taxa reflect the simplest hypothesis of transmission related similarity.

Graph representations of class similarity include a network of nodes and edges. Nodes are the classes and these are connected by edges describing the quantitative difference between classes. For example, consider a classification with three characters each with three possible character states. There are nine total possible classes. Three of those classes include: class 123, class 223, and class 221. If we arrange these classes in a graph so that edges represent a difference of one character state the graph in Figure 6.13 (a) is generated. If we have developed a theoretical warrant to explain class similarity as a function of relatedness, then class 223 is related to the other two classes by one character state change. We can also state that class 123 and class 221 are related to each other, but their similarity is lower (2 character state changes) than either class's similarity to class 223. With Figure 6.13 (a) we are depicting only the simplest similarity relationships, so classes 123 and 221 are not connected in this graph.

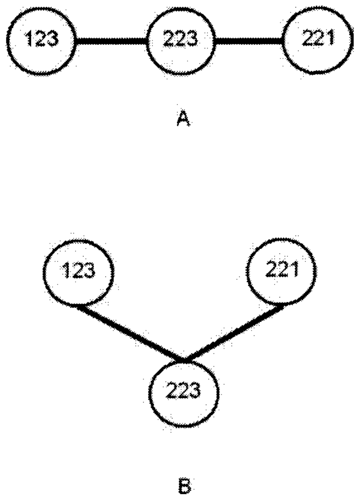

Figure 6.13. Graph relationships between three classes. Circles are classes or nodes with numbers indicating the character states defining each class. Nodes are connected by edges indicating a change of one character state.

Figure 6.13 (a) presents the relationship of the three classes without any assumptions regarding phylogeny. If we assume that character state change occurs through processes such as primarily vertical transmission and innovation in a single lineage (i.e., similarity is homologous), Figure 6.13 (a) may represent a chronology. Although without any additional information we can not determine if a correct chronological order begins with class 221 or class 123.

Figure 6.13 (b) displays the same nodal relationships, but here additional information lets us arrange classes into a hypothesized phylogeny. In Figure 6.13 (b) the second character state is ancestral in both class 123 and class 221 and thus we can depict phylogenetic relationships among the taxa.

Figure 6.13 depicts a simple case of relationships between three classes. When information about character polarity is added to the graph representation a different rendering of historical relationships is created. Note that such information, for example character polarity or chronological position, must be generated by other methods.

The historical relationships between classes used in the cladistic analyses presented in this chapter can also be examined through graph analysis. Figure 6.14 is a graph depiction of the relationships between the 14 jar rim classes presented in the Figure 6.3 (a) phylogenetic tree. Each class or nodes is connected to every other class by which it differs by one character state. Thus each of these connections represents the simplest assumptions regarding the relatedness of classes through cultural transmission. The position of nodes in the network is a result of multi-dimensional scaling of the character state data matrix[35]

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[35] This matrix consists of 14 rows, one for each class, and five columns, one for each character. Stress in the two-dimensional MDS representation of the data matrix is 0.11, an acceptably low number (Kruskal and Wish 1978).

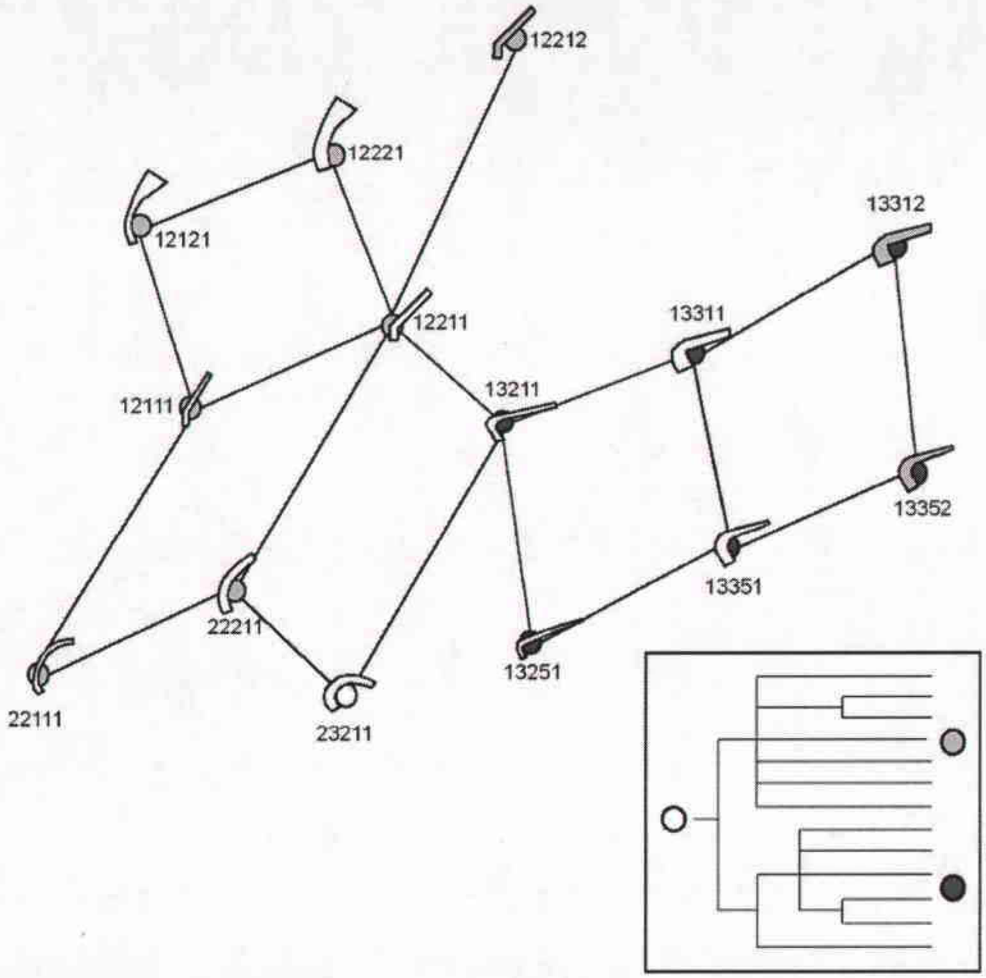

Figure 6.14. Graph representation of jar rim classes from Figure 6.3 (a) (inset). White node is the outgroup from inset phylogeny. Lightly shaded and darkly shaded nodes signify the rim class members of the two largest monophyletic groups in the inset phylogeny.

The graph representation of jar rim similarities provides another perspective on the historical relationships among classes. If each edge represents transmission related change in one character state, then this graph network is the simplest depiction of cultural transmission related similarities among classes. The network has been oriented so that the outgroup of Figure 6.3 (a), class 23211, is at the bottom and is identified by a white node. The outgroup is linked to two classes by one character state change and these classes each belong to one of the two large clades in the Figure 6.3 (a) rim phylogeny.

Like the phylogeny, the graph divides the jar rim classes into two groups of reticulated classes. On the right side of the graph are the highly everted late rims (darkly shaded nodes) that form one of the two large clades in the Figure 6.3 (a) rim phylogeny. On the left side are the early rims (lightly shaded nodes) that form the other clade in the phylogeny. Several of these early rims have extended temporal distributions (see Figure 6.6).

In the graph network the two groups are joined by a pair of rim classes (not including the outgroup): class 12211 and class 13211. Class 13211 is found only on Naviti Island at surface sites Y2-61 and 62. Class 12211 is the long-produced rim class that appears in early deposits at Olo (Y2-25) and Qaranicagi (Y2-39) and from some of the earliest deposits at Natia (Y1-15) up to approximately 500 BP. According to the graph depiction, the early and late clades from Figure 6.3 (a) are related via the long-lived rim class 12211.

The graph depicts a simple hypothesis of transmission relationships among these classes. Where the cladistically derived phylogenies in Figure 6.3 display bifurcating relationships based on the ancestral or derived nature of character states, the graph depicts the reticulate relationships of classes without regard to character polarity. Both depictions of similarity, however, clearly place the late jar rim classes into a group that is related to earlier rim forms. Defining transmission lineages and the relationships between groups of transmission lineages is a first step in explaining past cultural diversity. The next step involves explaining lineage origins and the variation within and between lineages. The next section develops a hypothesis regarding the origin of jar rim lineages late in Fijian prehistory.

6.3.2 Origins of the Late Group of Transmission Lineages in the Yasawa Islands

A clade or group of related transmission lineages develops late in Yasawa Islands prehistory. The earliest dates associated with the late jar rim clade derive from surface deposits at Korowaiwai (Y2-22) and Nasau (Y2-45), dated to 650-460 cal. BP and 630-330 cal. BP, respectively (Table 3.15). Combined, these date ranges suggest a possible origin for the late clade of jar rim classes between 620 – 600 BP and 560 – 480 BP at 2 σ (date ranges combined using OxCal 3.9 [Ramsey 2003]).

Clade origins in biological transmission systems are typically explained by selection where one gene pool becomes separated from another as a result of behavioral, physiological, or other specializations (Harvey and Pagel 1991; Williams 1992:98-100). In cultural transmission systems we should expect that clade origins will not always be explained by selection or other sorting mechanisms as culturally transmitted variation may sometimes be explained as selectively neutral. In these instances, explanations of clade origins will need to account for increased diversity of neutral classes.

6.3.2.1 Roles of Environmental Change in Possible Explanations for Late Diversity

Explanations of clade origins may include environmental changes and changes in population configuration, both situated within particular geographies that may influence the spatial characteristics transmission of transmission systems. Evolutionary ecologists have described relationships between aspects of population configuration and geographic space including the distribution of environmental resources and geographic barriers

(Cashdan 1992; Dyson-Hudson and Smith 1979; Kaplan and Hill 1992). Using these relationships we can begin to develop hypotheses to explain clade origins as a result of selection.

Explanations of human population variation that implicate environmental change have been sporadically offered over the last decades in Oceanic archaeology (e.g., Finney 1985; Kirch 1984:125-127; O'Connell and Allen 1995Hunter-Anderson, 1998 #1154). Most recently, Nunn and colleagues have correlated widespread environmental change, namely the Little Climatic Optimum-Little Ice Age Transition (LCO/LIA) and rapid sea-level fall (Nunn 1997, 1998, 2000a; Nunn 2000b; Nunn and Britton 2001), with changes in human settlement patterns, subsistence strategies, and competitiveness across the Pacific, including Fiji. Based on similar correlations, Field (2002; 2003; 2004) argues that environmental refuges and greater human competition in the Sigatoka Valley on the island of Viti Levu, Fiji develops to cope with El Niño and La Niña generated environmental unpredictability by approximately 650 BP (the El Niño and La Niña cycle is known collectively as the El Niño Southern Oscillation [ENSO]).

Multiple environmental changes beginning approximately 700 BP may have affected many aspects of cultural variability. The rapid sea-level fall, perhaps more than a meter, over the course of 100 years from about 700 to 600 BP, would have devastated the rich near-shore reef systems of the Yasawa Islands and the island populations that likely depended heavily on them[36] (see Nunn 1998, 2000a). The origins of the late clade

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[36] Although Yasawa Islands populations undoubtedly integrated agriculture into their subsistence system, evidence of agriculturally based subsistence has not yet been investigated in the Yasawas Islands. In contrast there is much evidence, although unevenly analyzed, for a subsistence system heavily dependent on marine resources. This evidence include shellfish remains at all excavated and surface sites as well as stone fishtraps surrounding the perimeter of each island in the group (Hunt et al., 1999).

of rim classes appear correlated with this environmental change. Can we craft a hypothesis that that links changes in measured environmental variation to the origins of the late clade of rim classes? As an example, the construction of one possible hypothesis will involve several steps. Environmental change must be convincingly linked to changes in the classes of subsistence remains in the archaeological record of the Yasawas Islands. Engineering analyses (e.g., Braun 1983; Bronitsky 1986; O'Brien, et al. 1994; Schiffer and Skibo 1987) should also be undertaken to determine if variation in late ceramics in the Yasawa Islands is explained by performance differences that may be related to changes in cooking technology. Finally, detailed chronological and spatial distributions of ceramic classes would have to be tested against expectations of a model of selective retention of variation.

6.3.2.2 Role of Population Configuration and Transmission in Possible Explanation for Late Diversity

General spatial patterns of cultural transmission in the Yasawa Islands population may be investigated through both the geographic locations of the classes arranged with cladistics and ceramic compositional variation among Yasawa Islands ceramics. Based on rim form and surface modification variation, the Yasawa Islands populations have always comprised a single related group of lineages. And for the first 1,500 years of Yasawa Islands prehistory, from colonization c. 2760-2470 cal. BP (Y2-25 , Layer II dates) up to c. 1270-920 cal BP (Qaranicagi, level 12 date) this population used ceramics made from clay deposits found throughout the Yasawa and Mamanuca archipelagos. Both northern and southern compositional groups are found in the Yasawa Islands archaeological deposits dating to this period. These findings suggest that when Mamanuca Islands assemblages are collected and analyzed, we will be able to define clades or groups of related lineages that include ceramics from both island groups. These ceramic defined clades should, however, include assemblages and classes dating only from colonization up to approximately 1000 BP. For the first 1,500 years of Yasawas Islands prehistory, the spatial parameters of cultural transmission were broad and included populations from the Mamanucas and possibly others beyond western Fiji.

This spatially broad transmission ended around 1000-900 BP. Beginning at this time (represented by excavation level 11 at Qaranicagi), ceramics found at Qaranicagi on Waya Islands are made almost exclusively from northern clays, or those that likely derive only from the Yasawas and no longer include clays found in the southern Mamanuca Islands (Figure 6.15). The clustered bar chart in Figure 6.15 shows the percentages of different compositional groups in the level assemblages of Qaranicagi, the early assemblages at Olo and Natia, and the surface sites. While sample sizes for the level 14 through level 2 assemblages are low, the pattern over the entire sequence suggests that over time assemblages are increasingly dominated by northern compositional group sherds. The compositional differences in the fairly large samples at either end of the sequence (n = 114, and 37, respectively) reflect this change.

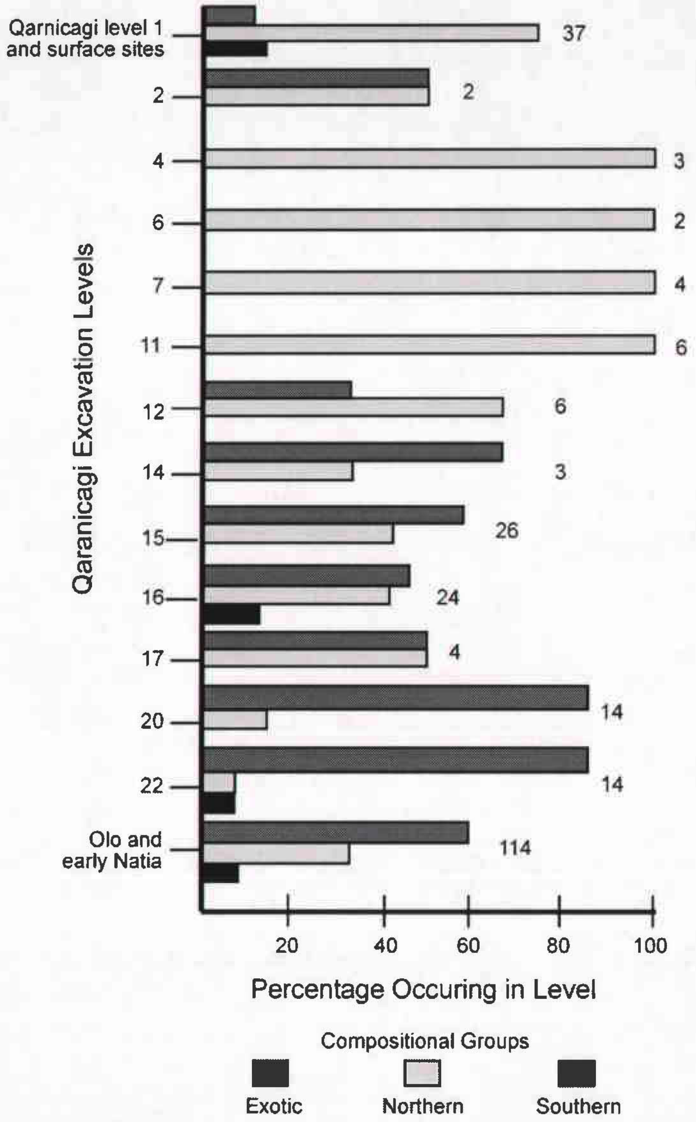


Figure 6.15. Bar chart of compositional group frequencies for Yasawa ceramics assemblages arrayed in chronological order by excavation level and site. Number of analyzed sherds per assemblage is to right of clustered bars.

Clay compositional variation over time in the Yasawas suggests a contraction in the spatial scale of transmission systems. Given the small level assemblages at Qaranicagi it is difficult to determine whether this contraction occurred suddenly at approximately 1000 – 900 BP, or was a gradual contraction over time. Additional compositional analysis should help identify the rate of contraction.

A second hypothesis for the origins of late rim class diversity is suggested by the contraction in the scale of transmission over time. Late occurring cultural diversity in the Yasawas may be explained by increased intra-group transmission. If the probability of transmission is structured predominantly by population configuration, then as population densities increases in local areas, the frequency of intra-group transmission within local areas will increase relative to inter-group transmission between areas (Lipo 2001a; Terrell 1986b:123-127). Neiman (1995) developed population biology based models that demonstrate how diversity increases in such a scenario when culturally transmitted variants are selectively neutral. If the late increase in Yasawa Islands diversity measured by rim classes is a product of increasing intra-group transmission relative to inter-group transmission, then rim class distributions must meet the expectations of the neutral model. Testing this intra-group transmission hypothesis will involve generating distributions of rim class frequencies across time and multiple occupations. For the hypothesis to withstand falsification, we should find that occupations diverge over time relative to frequencies of selectively neutral rim classes they contain. Interestingly, Hunt (1987), using data on Fijian language (i.e., communalect) similarities has argued that increasing population densities late in prehistory may have lead to increasing cultural diversity through a similar process.

6.4 CHAPTER SUMMARY

In this chapter variation in rim classes and assemblages described by surface modification classes was analyzed with cladistics and seriation to generate hypotheses for the transmission history of Yasawa Islands populations. The two favored hypotheses generated to account for jar rim and surface modification variation are similar and both indicate that for the entire prehistoric sequence in the Yasawas, populations belong to a single clade or group of related transmission lineages. The cladistic analyses produced no polytomies at the basal nodes of phylogenies that might suggest an interrupted or lost transmission signal.

Each phylogeny also contains within it multiple monophyletic groups or clades at several hierarchical levels suggesting various events may have shaped cultural transmission histories in the Yasawa Islands. Both jar rim phylogenies and the graph network, depicting cladogenic and reticulate modes of evolution respectively, define a period of early lineage diversity and a period of late lineage diversity likely connected by lesser numbers of transmission lineages for the 1,000 years from 1,500 to 500 BP. Two hypotheses were outlined to account for origins of the late jar rim clade. The late clade may be explained as a product of selective retention of variation related to performance differences in cooking technology. Alternatively, the late clade may be explained by increased intra-group transmission of neutral variation and concomitant increase in between group diversity.

CHAPTER 7. DISCUSSION AND CONCLUSIONS ABOUT FIJIAN POPULATION HISTORY AND DIVERSITY

> Supporters assume that the greatness and importance of a work correlates directly with its stated breadth of achievement: minor papers solve local issues, while great works claim to fathom the general and universal nature of things. But all practicing scientists know in their bones that successful studies require strict limitations. One must specify a particular problem with an accessible solution, and then find a sufficiently simple situation where attainable facts might point to a clear conclusion. Potential greatness then arises from cascading implications toward testable generalities. You don't reach the generality by direct assault without proper tools. One might as well dream about climbing Mount Everest wearing a T-shirt and tennis shoes and carrying a backpack containing only an apple and a bottle of water.
>
> Stephen J. Gould (1998:19)
>
> Writing in the Margins, *Natural History* 107

7.1 THE HISTORY OF HUMAN CULTURAL DIVERSIFICATION IN THE YASAWA ISLANDS

Archaeologist, linguists, biologists, and other scholars have repeatedly identified change in Fijian populations and argued that this change reflects both interaction with nearby archipelagic populations and in situ cultural diversification. Most researchers have attempted to explain Fijian cultural change as it relates to regional problems in prehistory: what are the historical relationships between Fijian populations and those to the west from archipelagos such as New Caledonia and Vanuatu; how is change in Fijian language, culture, and biology related to changes in populations to the east, particularly in the area of Samoa and Tonga, the homeland of Ancestral Polynesian Society conceptualized by Kirch and others (Green 1995; 1984; 1987; 2001)?

In Fiji archaeologists have used ceramic variation to describe and interpret cultural diversity with changing diversity measured across a variety of analytical levels and using various types of material culture. Although it is not his stated goal, Best (2002; 1984) examined material cultural diversity in two different ways. First, Best noted a decrease in diversity within general vessel forms beginning c. 2500 BP. Similar decreases in ceramic diversity have been suggested for the archipelagos of Samoa and Tonga to the west (e.g., Burley and Clark 2003; Dye 1996; Green 1974). Second, Best examined temporal changes in ceramics and argued that there is a distinct change in the overall ceramic repertoire c. 2100 BP. Best interpreted ceramic change at this time to be the result of a migration from Vanuatu into Fiji, thus changing Fijian ceramic assemblages so that they more closely resemble Vanuatu ceramics. If Best is correct, then here is another episode of lessening cultural diversity in Fiji. This time, however, Fiji has become more like populations to the east.

Clark (1999:2) explicitly sought to explain the "development of human diversity in the eastern Melanesian archipelago of Fiji" from c. 2300 to 800 BP. In pursuit of this goal, Clark described ceramic assemblages across several realms of variation including clay composition, temper, decoration, and vessel form and argued that inter-assemblage similarity decreased in the post-Lapita period, c. 2300 BP. Clark suggested that post-Lapita regionalization of ceramic assemblages is a result of large scale changes in subsistence and settlement. While he does not relate this finding to human diversity per se, we might suspect that Clark would equate assemblage regionalization to increased cultural diversity. In contrast, Clark notes increasing inter-assemblage similarity between 1800 and 1000 BP and suggests there is little evidence for sub-regional population differences, in other words, for these 800 years cultural diversity decreases.

While we may speculate about the correctness of Best's and Clark's findings, neither author makes explicit links between their observational and analytical units—how they tabulate archaeological variation—and their explanations. These explicit links are necessary, however, if we are to conclusively evaluate their explanations. Without these links we are left to make educated guesses.

A primary conclusion in Best's work is that contact between Fijian populations and populations to the west, principally in New Caledonia and Vanuatu, account for ceramic change c. 2100 BP, and to a lesser extent at c. 1750 BP. This conclusion is not supported by Best's analyses. Ceramic change c. 2100 BP on Lakeba occurs across a variety of dimensions, including surface modification, temper, and vessel forms (see Table 2.1). If we are going to explain these changes within a scientific framework that links observational units and explanatory processes, then several different processes may account for this variation including selective retention of variation within a population, other sorting processes, and the effects of changing population configuration on cultural transmission. This does not mean that material culture similarities between Fiji, Vanuatu, and New Caledonia can not be explained by interaction and cultural transmission. To craft these explanations, however, we must untangle the various dimensions of ceramic variation and define lineages and lineage groups that include classes present in the ceramic assemblages of these archipelagos.

Clark's primary conclusions are similarly suspect. He suggests that from 2300 BP to 1000 BP Fijian populations first underwent an episode of increasing regionalization where local populations diverged, and then, after about 1800 BP, these populations became more similar to one another. Like Best, Clark has conflated almost all ceramic similarity to equal interaction and transmission between populations. In Chapter 2, a re-analysis of a set of Clark's data suggests that different processes may be used to explain different dimensions of ceramic variation in Clark's assemblages. Moreover, compared to Best's examination of ceramics from a single island, Clark's spatially expansive analyses are more likely to include variation explicable by several processes including selection in different environments, and the influence of geographic variation and different population configurations on cultural transmission. Again, to develop these explanations in a scientific framework we would begin by constructing classifications and defining transmission lineages across Clark's ceramic assemblages.

In this dissertation culture diversity has been measured by the number of ceramic transmission lineages defined through cladistic analysis of rim classes within a particular block of space and time. These transmission lineages represent single lines of descent or pathways of transmission that resulted in the production of rims that are members of a particular rim class. Lineages may also, however, be recognized at different scales. Thus additional research may profitably examine vessel form lineages, or lineages at even larger scales such as lineages of subsistence systems, as long as separate analyses suggest that the classes used track heritable similarity. After charting the temporal origins and demise of these lineages we can quantify changes in diversity over time.

The number of jar rim transmission lineages within the colonizing population of the Yasawa Islands serves as a base line for measuring subsequent changes in diversity (see Figure 6.6). Beginning about 2000 BP, cultural diversity as measured by jar rim classes declines. This early decline in cultural diversity is, as of yet, unexplained. Potential explanations must address variation in rim classes as either selectively neutral or non-neutral homologous similarity. At about this same time Best (2002:28-32) identifies similarities among ceramic assemblages from Lakeba, Vanuatu, and New Caledonia. How Best's findings may relate to this analysis are, for the moment, uncertain.

A more recent group of related transmission lineages, and a concomitant increase in cultural diversity, originate approximately 600 BP in the Yasawa Islands. Two possible hypotheses were offered to explain this late diversity. Late diversity may be explained by selective retention of variation associated with changes in the environment and the performance differences among vessels, or alternatively this diversity may be explained by changes in population configuration and associated increase in the diversity of selectively neutral classes measured across local groups of cultural transmitters. If this second hypothesis withstands repeated evaluation then the origins of late rim class diversity in the Yasawas may also provide a possible date for the origins of communalect differences examined by Hunt (1987) and Geraghty (1983).

Best (2002:71-73) interprets late Fijian ceramic diversity differently, suggesting that the diversity of decoration and vessel forms is explained as the material manifestation of a religious system. There appears to be no way to evaluate this proposition, however, except through ethnographic comparison.

7.2 METHODOLOGICAL CONTRIBUTIONS TO THE STUDY OF CULTURAL SIMILARITIES AND DIFFERENCES IN OCEANIC POPULATIONS

As discussed in Chapters 1 and 2, archaeologists and other scholars of human diversity in Oceania have long been interested in explaining human similarities and differences in the region. A variety of explanations have been offered by early European explorers (e.g., Dumont 1832), western scholars (Diamond 1997; Fornander 1969 [1878-1885]; Sharp 1956; Terrell 1986b), and native peoples (see Beckwith 1970:352-375) to account for similarities in language, biology, and culture.

While the early explanations of explorers or scholars such as Fornander and Sharp are today seen as essentialist and contradicted by empirical evidence, there is no current consensus on how to explain some material culture similarities and differences in Oceania (Spriggs 2004). The majority viewpoint for explaining human diversity, and in part material culture variation in the region, is best described by what Kirch and Green (2001) refer to as historical anthropology combining the data of archaeology, linguistics, biology, ethnography, and ecology into a holistic view of the past (see also Kirch and Green 1987). Proponents of an alternative approach (e.g., Terrell 1988; Terrell, et al. 1997; Terrell and Welsch 1997) argue that using contemporary descriptions of language and biology, for example, to interpret the past conflates contemporary diversity with the time-transgressive data of archaeology (e.g., Gray and Jordan 2000). Aspects of both explanatory frameworks—and the identification of only two is a simplification (Green 2003)—are problematic for historical analyses. The approach championed by Kirch, Green, and others may conflate present patterns with the historical processes that created them and does not often incorporate methods to distinguish homologous and analogous similarity (or rather almost all similarity is treated as homologous). Additionally, it is difficult to recognize when this conflation occurs, thus all answers contain an unknown degree of uncertainty. The approach developed by Terrell and colleagues contains fewer assumptions that might bias the outcome of analyses, but this approach does not include a well-developed set of methods for examining the archaeological record with theoretically informed observational classes.

One contribution of this dissertation is the development of a scientific explanatory framework designed to investigate historical relatedness and evolving human diversity. This cultural transmission framework does not rely upon contemporary patterns of diversity to draw conclusions, indeed, cultural transmission processes can be used to explain contemporary patterns of diversity just as they can explain past patterns. A cultural transmission framework is also well-articulated with the empirical record and thus we can use this framework to develop observational units and produce possible explanations with clear evaluative consequences. The classifications and analytical units used in transmission analysis are not, however, those typically employed by archaeologists in Fiji and Oceania.

By adopting a transmission-based explanatory framework we may also make the theoretical and methodological distinction between homologous and analogous similarity that is necessary to track population relatedness. Without the analytical recognition of different kinds of similarity any analysis of population relatedness and changing diversity over time is suspect. Analogous similarities may be explained as products of separate transmission systems, possibly in separate groups of people, through convergence or parallelism. Such an explanation may be developed for the widespread reduction in vessel forms found in post-Lapita deposits in Fiji, Tonga, and Samoa (Cochrane 2002a:47-48; cf. Kirch 1997-161). Homologous similarities, those that are transmitted within a single system, may be explained as a product of selection or other sorting processes, or simply through chance and the stochastic nature of transmission when class distributions follow a model of neutral variation.

The primary analytical technique used here to establish patterns of relatedness is cladistics. Cladistic analysis establishes hypothetical ancestor-descendant and sister-taxa relationships between classes. The quantitative characteristics of cladistics also allow us to evaluate different phylogenetic hypotheses against one another. The primary benefit of cladistic analysis for archaeologists, however, is the incorporation of ancestral and derived characteristics. After ancestral and derived character states have been independently determined (e.g., through stratigraphy or seriation), cladistic techniques use this information to generate an arrangement of classes that posit historical relationships not possible without designating character polarity. Figure 7.1 demonstrates the difference between a cladistically derived arrangement and an arrangement of the same classes without identifying ancestral and derived characters (i.e., phenetic similarity).

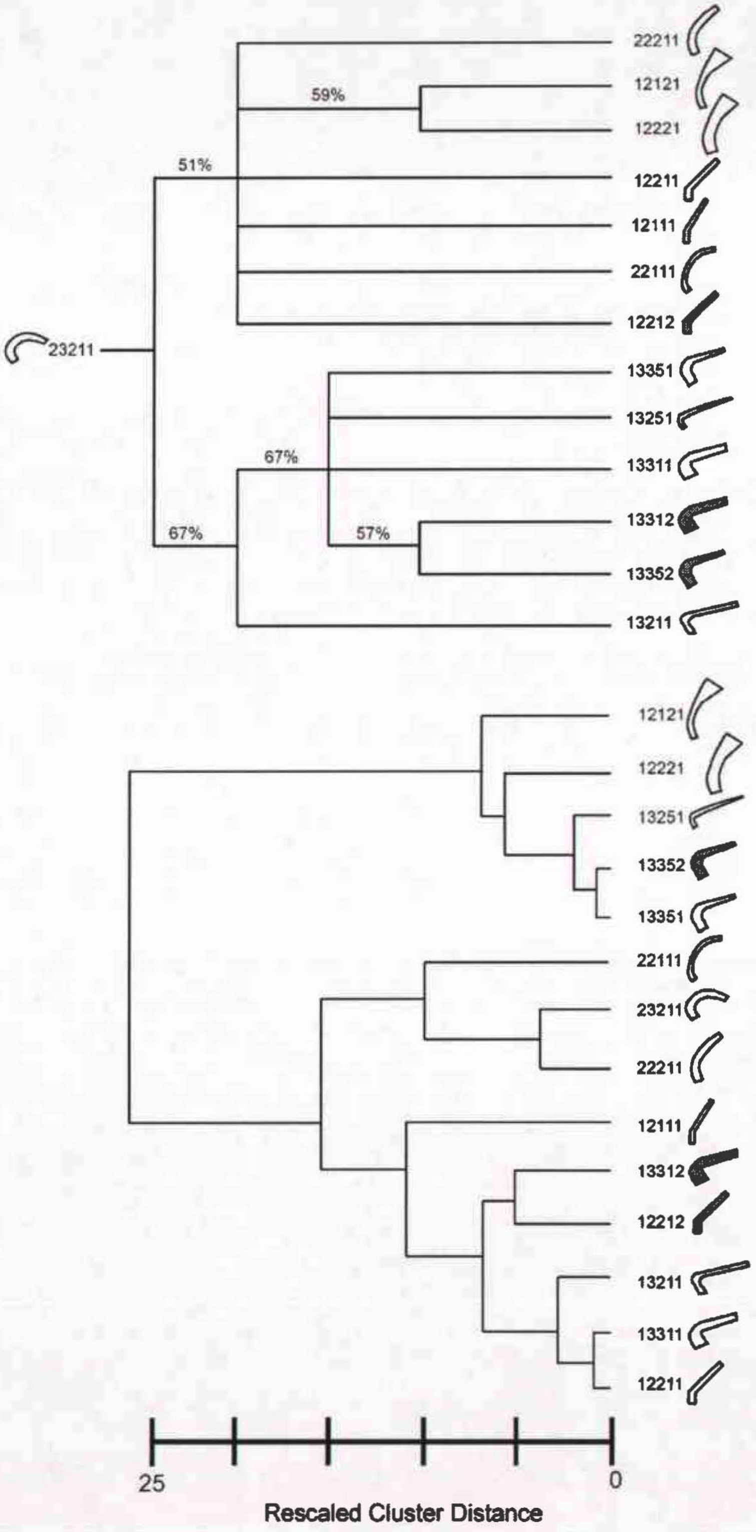


Figure 7.1. Comparison of cladogram, top (from Figure 6.3 (a)), and phenogram, bottom, arrangements of jar rim classes.

The phylogenetic tree of jar rim classes at the top of Figure 7.1 arranges rim classes into two clades differentiated by the Rim Angle character states. This phylogeny, and the others produced in Chapter 6 do contain many instances of homoplasy (i.e., convergent and parallel character state changes), but they still provide clear hypotheses regarding historical relationships in the Yasawa Islands based on ancestral and derived character states. When the temporal distribution of rim classes is noted, this phylogeny suggests chronological changes in the diversity of material culture lineages (Figure 6.6).

The bottom of Figure 7.1 arranges the same rim classes using only phenetic similarity of character states (average linkage between clusters using Pearson's correlation). In the phenogram there are two large clusters joined at a rescaled cluster distance of 25. The phenogram may also present a hypothesis of phylogenetic relationships, but as O'Brien and Lyman (2003:172) point out, "any phylogenetic information that a phenogram projects is strictly a methodological by-product as opposed to a targeted product." If the phenogram portrays phylogenetic relationships between classes we have little idea what aspects of class similarity reflect these relationships.

Cladistic arrangements of classes are hypotheses about phylogenetic relationships between classes and separate cladistic hypotheses may be compared by statistical measurements of character fit such as consistency and retention indices. Cladistic hypotheses may also be evaluated when additional archaeological samples change the richness and evenness of classes describing phenomena. Attempts to explain the historical relationships posited by cladistically derived trees may also lead us to reject particular trees. These useful aspects of cladistic hypotheses depend, however, upon prior classification of the empirical phenomena we are examining. These classes must be constructed for the sole purpose of tracking transmission.

A second contribution of this dissertation is the development of theory-driven classification to the explanation of cultural relatedness and human diversity. The primary problem that drives classification in transmission analyses of cultural relatedness is separation of homologous and analogous similarity. While the need to explicitly recognize these different kinds of similarity has long been discussed in archaeology (e.g., Binford 1968; Dunnell 1978; Kirch 1980), their analytical distinction has seen little use in Oceanic archaeology (exceptions include Allen 1996; Cochrane 2002b; Graves and Cachola-Abad 1996; Pfeffer 2001). This conflation of analogous and homologous similarity is at the center of Oceanic archaeologists' difficulty to conclusively demonstrate historical relatedness between populations at anything but a general level. Among the archipelagos of Fiji, Vanuatu, New Caledonia, Samoa, and Tonga archaeologists repeatedly produce competing scenarios of relatedness with little justification for the way artifact similarity is assessed in terms of homology and analogy (e.g., Bedford and Clark 2000; Best 1984; Burley, et al. 2002; Clark 1999; Clark 1996; Kirch 1988a; Sand 2001).

The evolutionary framework that incorporates cultural transmission includes several methods for the evaluating the efficacy of our classes to track homologous and analogous similarities: seriation (Lipo 2001b), neutral allele models from population biology (Neiman 1995), and engineering analyses (Lyman, J, et al. 1998; O'Brien, et al. 1994; Pierce 1998). These methods can be used as part of a cultural transmission framework to examine population relatedness in Oceania. Areas of fruitful future work include analyses of the paddle-impressed tradition in New Caledonia and Fiji and the incised ceramic tradition in both Fiji and Vanuatu. At larger spatial scales cultural transmission analyses of particular artifact traditions throughout Polynesia may shed light on the complexity likely inherent in the evolution of culture since colonization of these islands.

A final methodological contribution of this dissertation is the recognition that population is an ideational concept. We define populations through distributions of classes that track heritable (homologous) similarity. There is no population in the past the we can empirically discover. This explains why different linguistic, biological, and archaeological analyses often arrive at different conclusions about the spatial and temporal characteristics of Oceanic populations (see Chapter 2). These analyses, when properly constructed, measure different classes of heritable similarity, thus we can expect the distributions of these classes to have different spatial and temporal characteristics.

Ceramics and other artifacts in the Yasawas Islands attest to the presence of humans since approximately 2700 BP. Through cladistic, seriation, and graph techniques this dissertation has defined transmission characteristics within this region that suggest both changes in the diversity of transmission lineages and the unbroken character of transmission over time. Additional analyses using different fields of material culture may define this population differently. Analyses may also expand the spatial and temporal boundaries used here to see if the results of this dissertation are upheld across a larger contiguous space (e.g., the combined Mamanucas-Yasawas region). Additional analyses may also compare the ceramic lineage characteristics that define a Yasawas population with ceramic lineages in other areas such as eastern Fiji to determine if the Yasawas patterns of cultural diversity are widespread.

7.3 PROSPECTUS

The substantive product of this research is small, but as the quote at the beginning of this chapter makes clear, it is the combined results of focused research projects that creates sound scientific knowledge. Cultural transmission has occurred in an unbroken lineage throughout the prehistory of the Yasawa Islands. Temporal changes in the number of jar rim transmission lineages suggests material culture diversity, and thus some aspect of cultural diversity, began to decrease approximately 2000 BP or 700 years after colonization. Relative diversity then increased at approximately 600 BP and the expansion in the number of transmission lineages late in prehistory may be explained via selection and environmental change or as the result of increasing intra-group relative to inter-group transmission.

Perhaps more important than this substantive contribution is the methodological tools this dissertation applies to the study of cultural relatedness in Oceania. Analysis of previous work in Fiji and the south Pacific (Chapter 2) demonstrates that archaeologists and other scholars are interested in explaining why human groups are similar and different across islands and archipelagos and over time. Empirical resolution of this kind of question requires a transmission based framework and associated methods and classifications. This dissertation is the first work in the Pacific to demonstrate the applicability of transmission analyses to long-standing-problems of cultural relatedness.

7.3.1 Addressing Deficiencies in the Current Research

The representativeness of the ceramic samples in this research may call into question the substantive results. Only assemblages from Qaranicagi (Y2-39) and Natia (Y1-15) were sampled for the time period between c. 1500 and 500 BP. During this time, cultural diversity, as measured by the number of jar rim lineages, declines. Thus this decline in diversity could be an artifact of poor sample representativeness.

There are two reasons to suspect that increased sampling may uphold the diversity pattern identified here. First, Qaranicagi and Natia are at the southern and northern ends of the Yasawa chain respectively, thus the sampling of more sites might not increase the richness of jar rim classes that is dependent on spatial variability. Second, the substantive results here generally match diversity patterns identified by others in the region (Best 1984; Burley 2003; Hunt 1987), suggesting that the Yasawa analyses have defined transmission patterns that may be interpreted from the results of others working with larger samples. Regardless, additional ceramic collections and more representative samples are required to substantiate the claims made in this dissertation.

7.3.2 Future Work

Future field work will generate larger ceramic samples throughout the chronological sequence in the Yasawa Islands, but will concentrate on the period between 1500 and 500 BP. Deposits of this age are most often buried and occur in the prograding beach flats and caves throughout the Yasawa Islands.

To continue the research begun here, additional analyses of homologous similarity in Fijian artifacts must be conducted. Transmission-based and cladistic analyses of variation in different artifact types (e.g., house platforms [*yavu*]) may produce similar or contrasting diversity patterns compared to those generated here. These analyses should be conducted using more spatially expansive data sets than in this dissertation to examine the spatial and temporal characteristics of transmission lineages across Fiji and neighboring archipelagos. Also transmission based analyses of single artifact types, but at different analytical scales, will begin to examine the hierarchical nature of cultural transmission and the effects of hierarchical sorting and hitchhiking on cultural diversity.

Finally, the methods and research agenda discussed here are applicable to analyses of cultural relatedness across the vast spatial scale of the Pacific. Even at such large spatial scales, certain sets of material culture, ancient and modern, likely exhibit homologous similarity due to both shared ancestry and continued interaction over time. Homologous similarities in monumental architecture have been examined at an intra-archipelago scale (e.g., Carson 1998; Cochrane 2002b; Graves and Cachola-Abad 1996; Graves and Ladefoged 1995; Kolb 1992) and authors have noted inter-archipelago similarities as well (e.g., Kirch 1990). Transmission-based cladistic, and graph network analyses of monumental architecture across Oceania may add much to our understanding of the historical relationships between island populations. Comparable analyses of other artifacts, for example fishhooks or historic water craft, may also be profitable in this regard.

The approach to explaining cultural similarities and differences employed in this dissertation indicates that prehistoric cultural diversity can be examined using cultural transmission, selection, and innovation to produce empirically testable hypotheses regarding the historical relatedness of populations. The further development of this approach by scholars in the region will do much to answer long-standing questions of cultural similarity in Oceania.

REFERENCES

Aldenderfer, M. and R. K. Blashfield

1978 Cluster Analysis and Archaeological Classification. *American Antiquity* 43:502-505.

Aldenderfer, M. S. and R. K. Blashfield

1984 *Cluster Analysis*. Sage, Beverly Hills, CA.

Allen, M., S

1996 Style and function in East-Polynesian fishhooks. *Antiquity* 70:97-116.

Ambrose, W.

1993 Pottery source materials: source recognition in the Manus Islands. In *A Community of Culture: The People and Prehistory of the Pacific*, edited by M. Spriggs, D. E. Yen, W. Ambrose, R. Jones, A. Thorne and A. Andrews, pp. 206-217. Occasional Papers in Prehistory. vol. 21. Research School of Pacific Studies, Australia National University, Canberra.

Anderson, A., S. Bedford, G. Clark, I. Lilley, C. Sand, G. R. Summerhayes and R. Torrence

2000 An Inventory of Lapita Sites Containing Dentate-Stamped Pottery. In *The Archaeology of Lapita Dispersal in Oceania*, edited by G. A. Clark, A. J. Anderson and T. S. Vunidilo, pp. 1-14. Pandanus Books, Canberra.

Anderson, A. and G. Clark

1999 The age of Lapita settlement in Fiji. *Archaeology in Oceania* 34:31-39.

Arnold, D. E., H. Neff and R. L. Bishop

1991 Compositional Analysis and "Sources" of Pottery: an Ethnoarchaeological Approach. *American Anthropologist* 93:70-90.

Aronson, K. F.

1999 *A Compositional Analysis of Ceramics from the Qaranicagi Rockshelter: Implications for Exchange.* Unpublished Master's Thesis, University of Hawaii.

Aswani, S. and M. W. Graves

1998 Tongan Sociopolitical Evolution. *Asian Perspectives* 37:135-164.

Athens, J. S., H. D. Tuggle, J. V. Ward and D. J. Welch

2002 Avifaunal Extinctions, Vegetation Change and Polynesian Impacts in Prehistoric Hawai`i. *Archaeology in Oceania* 37:57-78.

Babcock, T.
1977 A Re-analysis of Pottery from Fortified Sites on Taveuni, Fiji. *Archaeology and Physical Anthropology in Oceania* 12:112-134.

Ballet, P.
1987 Essai de classification des coupes type "Maidum-Bowl" du sondage nord de 'Ayn-Asil (Oasis de Dakhla): typologie et evolution. In *Cahiers de la Ceramique Egyptienne*, edited by P. Ballet, pp. 1-17. Publications de l'institute Francais d'archaeologie orientale, Cairo.

Bar-Yosef, O. and R. Meadows
1995 The Origins of Agriculture in the Near East. In *First Farmers: New Perspectives on the Prehistoric Transition to Agriculture*, edited by T. D. Price and A. B. Gebauer, pp. 39-94. School for American Research, Sante Fe.

Bauer, J.
2002 Geoarchaeological Analysis of the Qaranicagi Rockshelter, Waya Island, Fiji, Poster presented at the 67th annual meeting of the Society for American Archaeology, Denver, Colorado, March 20-24.

Baxter, M. J.
1994 *Exploratory Multivariate Analysis in Archaeology*. Edinburgh University Press, Edinburgh.

Beckwith, M.
1970 *Hawaiian Mythology*. University of Hawaii Press, Honolulu.

Bedford, S. and G. Clark
2000 The Rise and Rise of the Incised and Applied Relief Tradition: A Review and Assessment. In *The Archaeology of Lapita Dispersal in Oceania*, edited by G. A. Clark, A. J. Anderson and T. S. Vunidilo, pp. 61-74. Pandanus Books, Canberra.

Bell, J. A.
1994 *Reconstructing Prehistory*. Temple University Press, Philadelphia.

Bellwood, P.
1989 The Colonization of the Pacific: Some Current Hypotheses. In *The Colonization of the Pacific: A Genetic Trail*, edited by A. V. S. Hill and S. W. Serjeantson, pp. 1-59. Oxford Scientific Publications. Clarendon Press, Oxford.

Bentley, R. A.
1997 *Pottery Exchange Between Fijian Hillfort Settlements: a Geoarchaeological Study*. Unpublished Master's Thesis, Cornell University.

2000 Provenience analysis of pottery from Fijian hillforts: preliminary implications for exchange within the archipelago. *Archaeology in Oceania* 35:82-91.

Bentley, R. A. and S. J. Shennan
2003 Cultural Transmission and Stochastic Network Growth. *American Antiquity* 68:459-485.

Best, S.
1987 A Preliminary Report on the Sigatoka Burials. *Domodomo* 3:2-15.

1993 At the Halls of the Mountain Kings. Fijian and Samoan Fortifications: Comparison and Analysis. *Journal of the Polynesian Society* 102:385-447.

2002 *Lapita: a View from the East.* New Zealand Archaeological Association Monograph 24. New Zealand Archaeological Association, Auckland.

Best, S. and P. Geraghty
2002 Review of "Hawaiki, Ancestral Polynesia: An Essay in Historical Anthropology." *Journal of the Polynesian Society* 111:171-175.

Best, S., P. Sheppard, R. Green, and R. Parker
1992 Necromancing the Stone: Archaeologists and Adzes in Samoa. *Journal of the Polynesian Society* 101:45-85.

Best, S. B.
1984 *Lakeba: The Prehistory of a Fijian Island.* Unpublished Ph. D. Dissertation, University of Aukland.

Bettinger, R. L. and M. A. Baumhoff
1982 The Numic Spread: Great Basin cultures in competition. *American Antiquity* 47:485-503.

Binford, L. R.
1962 Archaeology as Anthropology. *American Antiquity* 28:217-225.

1964 A Consideration of Archaeological Research Design. *American Antiquity* 29:425-441.

1965 Archaeological Systematics and the Study of Culture Process. *American Antiquity* 31:203-210.

1968 Archaeological Perspectives. In *New Perspectives in Archaeology*, edited by S. R. Binford and L. R. Binford, pp. 5-32. Aldine Publishing Company, Chicago.

1990 Mobility, Housing, and Environment: A Comparative Study. *Journal of Anthropological Research* 46:119-152.

2001 *Constructing frames of reference: an analytical method for archaeological theory building using hunter-gatherer and environmental data sets*. University of California Press, Berkeley.

Birks, L.
1973 *Archaeological Excavations at Sigatoka Dune Site, Fiji*. Bulletin of the Fiji Museum 1. Fiji Museum, Suva, Fiji.

Bishop, R. L. and H. Neff
1989 Compositional Data Analysis in Archaeology. In *Archaeological Chemistry IV*, edited by R. O. Allen, pp. 57-86. Advances in Chemistry Series. vol. 220. American Chemical Society, Washington, DC.

Bishop, R. L., R. L. Rands and G. R. Holley
1982 Ceramic compositional analysis in archaeological perspective. In *Advances in Archaeological Method and Theory*, edited by M. B. Schiffer, pp. 275-330. vol. 5. Academic Press, New York.

Blackmore, S.
1999 *The Meme Machine*. Oxford University Press, Oxford.

Blinman, E. and C. D. Wilson
1992 Ceramic production and exchange in the Northern San Juan region A.D. 600-900. In *Ceramic production and distribution: an integrated approach*, edited by G. J. I. Bey and C. A. Pool, pp. 155-174. Westview Press, Boulder.

Bonner, J. T.
1980 *The Evolution of Culture in Animals*. Princeton University Press, Princeton, New Jersey.

Boone, J. L. and E. A. Smith
1998 Is it Evolution Yet? A Critique of Evolutionary Archaeology. *Current Anthropology* 39:S141-S174.

Boserup, E.
1965 *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. Aldine, Chicago.

Boyd, R. and P. J. Richerson
1985 *Culture and the Evolutionary Process*. University of Chicago Press, Chicago.

Braun, D. P.

1983 Pots as Tools. In *Archaeological Hammers and Theories*, edited by J. Moore and A. Keene, pp. 107-134. Academic Press, New York.

1987 Coevolution of Sedentism, Pottery Technology, and Horticulture in the Central Midwest, 200 B.C. - A.D. 600. In *Emergent Horticultural Economies of the Eastern Woodlands*, edited by W. F. Keegan, pp. 153-181. Occasional Paper. vol. 7. Southern Illinois University, Carbondale.

Brew, J. O.

1946 *The Archaeology of Alkali Ridge, Southeastern Utah*. Papers of the Peabody Museum of Archaeology and Ethnology 21. Harvard University, Cambridge.

Bronitsky, G.

1986 The Use of Materials Science Techniques in the Study of Pottery Construction and Use. In *Advances in Archaeological Method and Theory*, edited by M. B. Schiffer, pp. 206-276. vol. 9. Academic Press, Orlando.

Brown, J. A.

1985 Long-Term Trends to Sedentism and the Emergence of Complexity in the American Midwest. In *The Emergence of Cultural Complexity*, edited by T. D. Price and J. A. Brown, pp. 201-231. Academic Press, New York.

Bruner, E. M.

1956 Cultural Transmission and Cultural Change. *Southwestern Journal of Anthropology* 12:191-199.

Burley, D. V.

2003 Dynamic Landscapes and Episodic Occupations: Archaeological Interpretation and Implications in the Prehistory of the Sigatoka Sand Dunes. In *Pacific Archaeology: assessments and prospects*, edited by C. Sand, pp. 307-315. Les Cahiers de l'Archaéologie en Nouvelle Calédonie. vol. 15. Service des Musées et du Patrimonie de Nouvelle-Calédonie, Nouméa.

Burley, D. V. and J. T. Clark

2003 The Archaeology of Fiji/West Polynesia in the post-Lapita Era. In *Pacific Archaeology: assessments and prospects*, edited by C. Sand, pp. 235-254. Les Cahiers de l'Archaéologie en Nouvelle Calédonie. vol. 15. Service des Musées et du Patrimonie de Nouvelle-Calédonie, Nouméa.

Burley, D. V. and W. R. Dickinson

2004 Late Laptia occupation and its ceramic assemblage at the Sigatoka Sand Dune site, Fiji, and their place in Oceanic prehistory. *Archaeology in Oceania* 39:12-25.

Burley, D. V., A. Storey and J. Witt
2002 On the Definition and Implication of Eastern Lapita Ceramics in Tonga. In *Fifty Years in the Field. Essays in Honour and Celebration of Richard Shutler Jr's Archaeological Career*, edited by S. Bedford, C. Sand and D. V. Burley, pp. 213-226. New Zealand Archaeological Association Monograph. vol. 25. New Zealand Archaeological Association, Auckland.

Burton, J. H. and A. W. Simon
1993 Acid extraction as a simple and inexpensive method for compositional characterization of archaeological ceramics. *American Antiquity* 58:45-59.

Caldwell, J. R.
1964 Interaction Spheres in Prehistory. In *Hopewellian Studies*, edited by J. R. Caldwell and R. L. Hall, pp. 135-143. Illinois State Museum Scientific Papers. vol. 12. Illinois State Museum, Chicago.

Capell, A., and R. H. Lester
1940-41 Local Divisions and Movements in Fiji. *Oceania* 4-5:313-341, 21-48.

Caramelli, D., C. Lalueza-Fox, C. Vernesi, M. Lari, A. Casoli, F. Mallegni, B. Chiarelli, I. Dupanloup, J. Bertranpetit, G. Barbujani and G. Bertorelle
2003 Evidence for a genetic discontinuity between Neandertals and 24,000-year-old anatomically modern Europeans. *PNAS* 100:6593-6597.

Carpenter, A. J. and G. M. Feinman
1999 The Effects of Behaviour on Ceramic Composition: Implications fo rthe Defintion of Production Locations. *Journal of Archaeological Science* 26:783-796.

Carson, M. T.
1998 Cultural Affinities of Monumental Architecture in the Phoenix Islands. *Journal of the Polynesian Society* 107:61-77.

Cashdan, E.
1992 Spatial Organization and Habitat Use. In *Evolutionary Ecology and Human Behavior*, edited by E. A. Smith and B. Winterhalder, pp. 237-268. Foundations of Human Behavior, S. H. Blaffer, general editor. Aldine De Gruyter, New York.

Cavalli-Sforza, L. L. and M. W. Feldman
1981 *Cultural Transmission and Evolution: A Quantitative Approach*. Monographs in Population Biology 16. Princeton University Press, Princeton.

Cavalli-Sforza, L. L. and E. E. Minch
1997 Paleolithic and Neolithic lineages in the European Mitochondrial Gene Pool. *American Journal of Human Genetics* 61:247-251.

Clark, G.
2000 Mid-Sequence Isolation in Fiji 2500-1000 BP. In *Indo-Pacific Prehistory: The Melaka Papers*, edited by P. Bellwood, D. Bowdery, D. Bulbeck, D. Baer, V. Shinde, R. Shutler and G. Summerhayes, pp. 152-158. Bulletin of the Indo-Pacific Prehistory Association. vol. 19. Australian National University, Canberra.

2002 Adzes of Interaction: Samoan Basalt Artefacts in Fiji. In *Fifty Years in the Field: Essays in Honour and Celebration of Richard Shutler Jr's Archaeological Career*, edited by S. Bedford, C. Sand and D. V. Burley, pp. 227-238. vol. 25. New Zealand Archaeological Association, Auckland.

Clark, G. and A. Anderson
2001 The Pattern of Lapita Settlement in Fiji. *Archaeology in Oceania* 36:77-88.

Clark, G., A. Anderson and S. Matararaba
2001 The Lapita Site of Votua, northern Lau Islands, Fiji. *Archaeology in Oceania* 36:146-152.

Clark, G. and G. Hope
2001 Archaeological and Palaeoenvironmental Investigations on Yacuta Island, Northern Lau, Fiji Islands. *Domodomo* 13:29-47.

Clark, G.
2003 Dumont d'Urville's Oceania. *Journal of Pacific History* 38:155-167.

Clark, G. A. and M. Barton
1997 Rediscovering Darwin. In *Rediscovering Darwin: Evolutionary Theory in Archaeological Explanation*, edited by M. Barton and G. Clark, pp. 309-319. vol. 7. American Anthropological Association, Arlington.

Clark, G.
1999 *Post-Lapita Fiji: cultural transformation in the mid-sequence.* Unpublished Ph. D. dissertation, Australian National University.

Clark, J. T.
1996 Samoan Prehistory in Review. In *Oceanic Culture History: Essays in Honour of Roger Green*, edited by J. Davidson, G. Irwin, F. Leach, A. K. Pawley and D. Brown, pp. 445-460. New Zealand Journal of Archaeology Special Publication. New Zealand Archaeological Association, Dunedin.

Clunie, F.

2003 *Fijian Weapons and Warfare*. 2nd ed. Quality Print Limited, Suva, Fiji.

Cochrane, E. E.

2001 Style, Function, and Systematic Empiricism: The Conflation of Process and Pattern. In *Style and Function: Conceptual Issues in Evolutionary Archaeology*, edited by T. D. Hurt and G. F. M. Rakita, pp. 183-202. Bergin and Garvey, Westport, Conn.

2002a Explaining the Prehistory of Ceramic Technology on Waya Island, Fiji. *Archaeology in Oceania* 37:37-50.

2002b Separating Time and Space in Archaeological Landscapes: An Example from Windward Society Islands Ceremonial Architecture. In *Pacific Landscapes: Archaeological Approaches*, edited by T. N. Ladefoged and M. W. Graves, pp. 189-209. Easter Island Foundation Press, Los Osos, CA.

Cochrane, E. E. and T. L. Hunt

2004 When Seriation is Chronological: An Evaluation of the Method from the Fiji Islands. Manuscript in possession of authors.

Cochrane, E. E., M. Pietrusewsky and M. T. Douglas

2004 Culturally Modified Human Remains Recovered from an Earth-oven Interment on Waya Island, Fiji. *Archaeology in Oceania* 39:54-59.

Cochrane, G. W.

2003 Artefact attribute richness and sample size adequacy. *Journal of Archaeological Science* 30:837-848.

Collard, M. and S. Shennan

2000 Processes of Culture Change in Prehistory: a Case Study from the European Neolithic. In *Archaeogenetics: DNA and the population prehistory of Europe*, edited by C. Renfrew and K. Boyle, pp. 89-97. McDonald Institute for Archaeological Research, Oxford.

Conkey, M.

1990a Experimenting with Style in Archaeology. In *The Uses of Style in Archaeology*, edited by M. Conkey and C. Hastorf, pp. 5-17. Cambridge University Press, Cambridge.

1990b Experimenting with style in archaeology: some historical and theoretical issues. In *The Uses of Style in Archaeology*, edited by M. Conkey and C. Hastorf, pp. 5-17. New Directions in Archaeology. Cambridge University Press, Cambridge, England; New York.

Cowgill, G. L.
1972 Models, Methods, and Techniques for Seriation. In *Models in Archaeology*, edited by D. Clarke, pp. 381-424. Methuen and Company, London.

Crosby, A.
1988 *Beqa: Archaeology, Structure and History in Fiji.* Masters, University of Auckland.

Crown, P. L.
1994 *Ceramics and Ideology: Salado Polychrome Pottery.* University of New Mexico Press, Albuquerque.

Cruz, M. J., D. J. Kennett, A. Anderson and G. Summerhayes
2001 Reconstructing Trade and Interaction in Oceania with Inductively Coupled Plasma Mass Spectrometry (ICP-MS) of Lapita Ceramics, Paper presented at the 66th Annual Meeting of the Society for American Archaeology, New Orleans, Louisiana.

Cullen, R. S. B.
1996 Cultural Virus Theory and the Eusocial Pottery Assemblage. In *Darwinian Archaeologies*, edited by H. D. G. Maschner, pp. 43-60. Plenum Press, New York.

Davidson, J. and F. Leach
1993 The Chronology of the Natunuku Site, Fiji. *New Zealand Journal of Archaeology* 15:99-105.

Davis, P. H. and V. H. Heywood
1963 *Principles of Angiosperm Taxonomy.* Oliver & Boyd, Edinburgh.

Dawkins, R.
1982 *The Extended Phenotype: The Long Reach of the Gene.* 2nd ed. Oxford University Press, Oxford.

de Queiroz, K.
1998 The General Lineage Concept of Species, Species Criteria, and the Process of Speciation: A Conceptual Unification and Terminological Recommendations. In *Endless Forms: Species and Speciation*, edited by D. J. Howard and S. H. Berlocher, pp. 57-75. Oxford University Press, Oxford.

Deetz, J.
1965 *The Dynamics of Stylistic Change in Arikara Ceramics.* Illinois Studies in Anthropology, Urbana.

Derrick, R.

1968 *A History of Fiji*. Print and Stationary Department, Suva.

1957 *The Fiji Islands*. Government Press, Suva.

Dewar, R. E.

1995 Of Nets and Trees: Untangling the Reticulate and Dendritic in Madagascar's Prehistory. *World Archaeology* 26:301-318.

Diamond, J.

1997 *Guns, Germs, and Steel: The Fates of Human Societies*. W. W. Norton & Company, New York.

Diamond, J. M.

1988 Express Train to Polynesia. *Nature* 336:307-308.

Dickinson, W. R.

1997a *Sand tempers in prehistoric sherds from Kulu Bay, Beqa, Fiji*. Petrographic Report WRD-161.

1997b *Sand tempers in sherds from Ugaga Island (off Beqa in Fiji)*. Petrographic Report WRD-163.

1998a Petrographic Temper Provinces of Prehistoric Pottery in Oceania. *Records of the Australian Museum* 50:263-276.

1998b *Sand temper in prehistoric sherds from Navatu, Viti Levu, Fiji*. Petrographic Report WRD-171.

1998c *Temper sands in sherds from prehistoric post-Lapita Fijian double-spouted water jars from Natunuku, Navatu, Sigatoka, and Ugaga*. Petrographic Report WRD-165.

1999a *Petrographic appraisal of temper sands in selected prehistoric sherds from Navatu, Karobo, and Ugaga sites on or near Viti Levu in Fiji*. Petrographic Report WRD-188.

1999b *Reappraisal of quartz-rich volcanic sand temper in Ugaga sherds*. Petrographic Report WRD-191.

Dickinson, W. R., D. V. Burley, P. D. Nunn, A. Anderson, G. Hope, A. De Biran, C. Burke, and S. Matararaba

1998d Geomorphic and Archaeological Landscapes of the Sigatoka Dunes Site, Viti Levu, Fiji: Interdisciplinary Investigations. *Asian Perspectives* 37:1-31.

Doran, J. E. and F. R. Hodson

1975 *Mathematics and Computers in Archaeology.* Edinburgh University Press, Edinburgh.

Drennan, R. L.

1996 *Statistics for Archaeologists: a Commonsense Approach.* Interdisciplinary Contributions to Archaeology. Plenum Press, New York.

Duff, A., I

1996 Ceramic micro-seriation: Types or Attributes. *American Antiquity* 61:89-101.

Dumont, d. U.

1832 Notice sur les îles du Grand Océan et sur l'origine des peuples quie les habitent. *Société de Géographie Bulletin* 17.

Dunnell, R. C.

1970 Seriation Method and its Evaluation. *American Antiquity* 35:305-319.

1971 *Systematics in Prehistory.* The Free Press, New York.

1978 Style and Function: A Fundamental Dichotomy. *American Antiquity* 43:192-202.

1981 Seriation, Groups, and Measurement. In *Manejos de Datos Y Methods Mathematicos de Arqualogia*, edited by G. L. Cowgill, R. Whallon and B. S. Ottaway, pp. 67-90. Union Internacional de Ciences Prehistoricas y Protohistoricas, Mexico City.

1982 Science, Social Science and Common Sense: The Agonizing Dilemma of Modern Archaeology38:1-25.

1986 Methodological Issues in Americanist Artifact Classification. In *Advances in Archaeological Method and Theory*, edited by M. B. Schiffer, pp. 149-207. vol. 9. Academic Press, New York.

1992 Archaeology and Evolutionary Science. In *Quandaries and Quests: Visions of Archaeology's Future*, edited by L. Wandsnider, pp. 209-224. Center for Archaeological Investigations, Occasional Paper No. 20. Southern Illinois University Press, Carbondale.

1995 What Is It That Actually Evolves? In *Evolutionary Archaeology: Methodological Issues*, edited by P. A. Teltser, pp. 33-50. University of Arizona Press, Tucson.

Dunnell, R. C. and J. K. Feathers

1990 Later Woodland Manifestations of the Malden Plain, Southeast Missouri. In *Stability, Transformation, and Variation: The Late Woodland Southeast*, edited by M. S. Nassaney and C. S. Cobb, pp. 21-45. Plenum Press, New York.

Dunnell, R. C. and D. M. Greenlee

1999 Late Woodland Period "Waste" Reduction in the Ohio River Valley. *Journal of Anthropological Archaeology* 18:376-395.

Dunnell, R. C. and R. J. Wenke

1980 An Evolutionary Model of the Development of Complex Societies. Paper presented at the Paper presented at the annual meeting of the American Association for the Advancement of Science, San Francisco, January.

Durham, W. H.

1992 Applications of Evolutionary Culture Theory. *Annual Review of Anthropology* 21:331-355.

Dye, T.

1996 Early Eastern Lapita to Polynesian Plainware at Tongatapu and Lifuka: An Exploratory Data Analysis and Comparison. In *Oceanic Culture History: Essays in Honour of Roger Green*, edited by J. Davidson, G. Irwin, F. Leach, A. K. Pawley and D. Brown, pp. 461-473. New Zealand Journal of Archaeology Special Publication. New Zealand Archaeological Association, Dunedin.

Dyson-Hudson, R. and E. A. Smith

1979 Human Territoriality: an Ecological Reassessment. *American Anthropologist* 80:21-41.

Efron, B. and R. Tibshirani

1993 *An Introduction to the Bootstrap*. Chapman and Hall, New York.

Emory, K. P.

1933 *Stone Remains in the Society Islands*. Bernice P. Bishop Museum Bulletin 53. Bernice P. Bishop Museum, Honolulu.

Feathers, J. K.

1990 *An Evolutionary Explanation for Prehistoric Ceramic Change in Southeast Missouri.* Ph. D. dissertation, University of Washington.

Feinman, G. M., S. A. Kowalewski, S. Banker and L. M. Nicholas

1992 Ceramic production and distribution in Late Postclassic Oaxaca: stylistic and petrographic perspectives. In *Ceramic production and distribution: an integrated approach*, edited by G. J. I. Bey and C. A. Pool, pp. 235-260. Westview Press, Boulder.

Field, J.

1998 Natural and Constructed Defenses in Fijian Fortifications. *Asian Perspectives* 37:32-58.

2002 GIS-based analyses of agricultural production and habitation in the Sigatoka Valley, Fiji. In *Pacific Landscapes: Archaeological Approaches*, edited by T. N. Ladefoged and M. W. Graves, pp. 97-124. Easter Island Foundation Press, Los Osos, CA.

2003 *The Evolution of Competition and Cooperation in Fijian Prehistory: Archaeological Research in the Sigatoka Valley, Fiji.* Unpublished Ph.D. dissertation, University of Hawaii.

2004 Environmental and climatic considerations: a hypothesis for conflict and the emergence of social complexity in Fijian prehistory. *Journal of Anthropological Archaeology* 23:79-99.

Finney, B.

1985 Anomalous Westerlies, El Nino, and the Colonization of Polynesia. *American Anthropologist* 87:9-26.

Fitzhugh, B.

2001 Risk and Invention in Human Technological Evolution. *Journal of Anthropological Archaeology* 20:125-167.

Flannery, K. V.

1986 *Guila Naquitz: Archaic Foraging and Early Agriculture in Oaxaca, Mexico*. Academic Press, Orlando.

Folk, R. L.

1974 *Petrology of Sedimentary Rocks*. Hemphill Publishing Company, Austin, Texas.

Ford, J. A.

1938 A Chronological Method Applicable to the Southeast. *American Antiquity* 3:260-264.

1949 Cultural Dating of Prehistoric Sites in Viru Valley, Peru. *American Museum of Natural History, Anthropological Papers* 43:29-89.

1952 Measurements of Some Prehistoric Design Developments in the Southeastern States. *American Museum of Natural History Anthropological Papers* 43:313-384.

1954a Comment on A.C. Spaulding's "Statistical Techniques for the Discovery of Artifact Types". *American Antiquity* 19.

1954b On the Concept of Types: The Type Concept Revisited. *American Anthropologist* 56:42-53.

1954c Spaulding's Review of Ford. *American Anthropologist* 56:109-112.

Forey, P. L., C. Humphries, J, I. J. Kitching, R. W. Scotland, D. J. Siebert and D. M. Williams (editors)

1992 *Cladistics: a Practical Course in Systematics*. 10. Claredon Press, Oxford.

Fornander, A.

1969 [1878-1885] *An Account of the Polynesian Race, Its Origin and Migrations and the Ancient History of the Hawaiian People to the Times of Kamehameha I.* Charles E. Tuttle Co., Rutland, VT.

Fox, G. L.

1998 An Examination of Mississippian-Period Phases in Southeastern Missouri. In *Changing Perspectives on the Archaeology of the Central Mississippi Valley*, edited by M. J. O'Brien and R. C. Dunnell, pp. 31-58. University of Alabama Press, Tuscaloosa.

Frost, E. L.

1974 *Archaeological Excavations of Fortified Sites on Tavenuni, Fiji*. Asia and Pacific Archaeology Series 6. Social Science Research Institute, Honolulu.

1979 Fiji. In *The Prehistory of Polynesia*, edited by J. D. Jennings, pp. 61-81. Harvard University Press, Cambridge.

Geraghty, P. A.

1983 *The History of the Fijian Languages*. Oceanic Linguistics Special Publication 19. University of Hawaii Press, Honolulu.

Geraghty, P. A., and A. Pawley

1981 The Relative Chronology of Some Innovations in the Fijian Languages. In *Studies in Pacific Languages and Cultures, in Honour of Bruce Biggs*, edited by a. A. P. J. Hollyman. Linguistic Society of New Zealand, Auckland.

Gifford, E. W.

1949 Excavations in Viti Levu. *Journal of the Polynesian Society* 58:83-90.

1951 Archaeological Excavations in Fiji, pp. 189-288. *Anthropological Records*. vol. 13, University of California Press, Los Angeles.

Gilboa, A., A. Karasik, I. Sharon and U. Smilansky
2004 Towards Computerized Typology and Classification of Ceramics. *Journal of Archaeological Science* 31:681-694.

Glascock, M. D.
1999 An inter-laboratory comparison of element compositions for two obsidian sources. IAOS Special Report. *International Association for Obsidian Studies Bulletin* 23.

Golson, J.
1961 Report on New Zealand, Western Polynesia, New Caledonia, and Fiji. *Asian Perspectives* 5:166-180.

Goodenough, W. H.
2002 Anthropology in the 20th Century and Beyond. *American Anthropologist* 104:423-440.

Gould, S. J.
1998 Writing in the Margins. *Natural History* 107:16-20.

Gould, S. J., D. M. Raup, J. J. Sepkoski, T. J. M. Schopf and D. S. Simberloff
1977 The shape of evolution: a comparison of real and random clades. *Paleobiology* 3:23-40.

Grant, P. and R. Grant
1996 Cultural Inheritance of Song and its Role in the Evolution of Darwin's Finches. *Evolution* 50:2471-487.

Gratuze, B., M. Blet-Lemarquand and J. N. Barrandon
2000 Mass spectrometry with laser sampling: A new tool to characterize archaeological materials. *Journal of Radioanalytical and Nuclear Chemistry* 247:645-656.

Graves, M. W. and C. K. Cachola-Abad
1996 Seriation as a method of chronologically ordering architectural design traits: an example from Hawai`i. *Archaeology in Oceania* 31:19-32.

Graves, M. W. and T. N. Ladefoged
1995 The Evolutionary Significance of Ceremonial Architecture. In *Evolutionary Archaeology: Methodological Issues*, edited by P. A. Teltser, pp. 149-174. University of Arizona Press, Tucson.

Gray, R. D. and F. M. Jordan

2000 Language Trees Support the Express-Train Sequence of Austronesian Expansion. *Nature* 405.

Green, R. C.

1963 A Suggested Revision of the Fijian Sequence. *Journal of the Polynesian Society* 72:235-253.

1966 Linguistic Subgrouping within Polynesia: The Implications for Prehistoric Settlement. *Journal of the Polynesian Society* 75:6-38.

1971 The chronology and age of sites at South Point, Hawaii. *Archaeology and Physical Anthropology in Oceania* 6.

1974 A Review of Portable Artifacts from Western Samoa. In *Archaeology in Western Samoa*, edited by R. C. Green and J. M. Davidson, pp. 245-275. vol. II. 2 vols. The Auckland Institute and Museum, Auckland.

1979 Lapita. In *The Prehistor yof Polynesia*, edited by J. D. Jennings, pp. 27-60. Harvard University Press, Cambridge.

1981 Location of the Polynesian Homeland: A Continuing Problem. In *Studies in Pacific Languages and Cultures in Honour of Bruce Biggs*, edited by J. Hollyman and A. K. Pawley, pp. 133-158. Linguistic Society of New Zealand, Auckland.

1991 Near and Remote Oceania: Disestablishing 'Melanesia' in Culture History. In *Man and a Half: Essays in Pacific Anthropology and Ethnobiology in Honour of Ralph Bulmer*, edited by A. K. Pawley, pp. 491-502. Polynesian Society, Auckland.

1994 Changes Over Time: Recent Advances in Dating Human Colonization of the Pacific Basin Area. In *The Origins of the First New Zealanders*, edited by D. G. Sutton, pp. 19-52. University of Auckland Press, Auckland.

1995 Linguistic, Biological, and Cultural Origins of the Original Inhabitants of Remote Oceania. *New Zealand Journal of Archaeology* 17:5-27.

1999 Integrating Historical Linguistics with Archaeology: Insights from Research in Remote Oceania. *Bulletin of the Indo-Pacific Prehistory Association* 18:3-16.

2003 The Lapita Horizon and Traditions--Signature for One Set of Oceanic Migrations. In *Pacific Archaeology: assessments and prospects*, edited by C. Sand, pp. 95-120. Les Cahiers de l'Archaéologie en Nouvelle Calédonie. vol. 15. Service des Musées et du Patrimonie de Nouvelle-Calédonie, Nouméa.

Green, R. C. and P. V. Kirch
1997 Lapita Exchange Systems and Their Polynesian Transformations: Seeking Explanatory Models. In *Prehistoric Long-Distance Interaction in Oceania: An Interdisciplinary Approach*, edited by M. I. Weisler, pp. 19-37. New Zealand Archaeological Association Monograph. vol. 21. New Zealand Archaeological Association, Auckland, New Zealand.

Hagelberg, E.
1994 Ancient DNA Studies. *Evolutionary Anthropology* 2:199-207.

Harvey, P. H. and M. D. Pagel
1991 *The Comparative Method in Evolutionary Biology*. Oxford University Press, Oxford.

Hathway, B. and H. Colley
1994 Eocene to Miocene Geology of Southwest Viti Levu, Fiji. In *Geology and Submarine Resources of the Tonga-Lau-Fiji Region*, edited by A. J. Stevenson, R. H. Herzer and P. F. Ballance, pp. 153-169. SOPAC Technical Bulletin. vol. 8. SOPAC Secretariat, Suva.

Hegmon, M.
1992 Archaeological Research on Style. *Annual Reviews in Anthropology* 21:517-536.

1995 *Style as a Social Strategy in the Early Puebloan Southwest*. Occasional Papers 5. Crow Canyon Archaeological Center, Cortez.

2003 Setting Theoretical Egos Aside: Issues and Theory in North American Archaeology. *American Antiquity* 68:213-244.

Hennig, W.
1950 *Grundzüge einer Theorie der Phylogenetischen Systematik*. Deutscher Zentralverlag, Berlin.

1966 *Phylogenetic Systematics*. University of Illinois Press, Urbana.

Herdrich, D. J. and J. T. Clark

1993 Samoan Tia `Ave and Social Structure: Methodological and Theoretical Considerations. In *The Evolution and Organization of Prehistoric Society in Polynesia*, edited by M. W. Graves and R. C. Green, pp. 52-63. New Zealand Archaeological Association Monograph. vol. 19. New Zealand Archaeological Association, Auckland.

Hertzberg, M., K. N. P. Mickleson, S. W. Serjeantson, P. J. F and T. R. J

1989 An Asian-Specific 9bp Deletion of Mitochondrial DNA is Frequently Found in Polynesians. *American Journal of Human Genetics* 44:504-510.

Hill, J. N.

1970 *Broken K Pueblo: Prehistoric Social Organization in the American Southwest.* Anthropological Papers 18. University of Arizona, Tuscon.

HIll, J. N.

1972 The Methodological Debate in Contemporary Archaeology: a Model. In *Models in Archaeology*, edited by D. Clarke, pp. 61-107. Methuen and Company, London.

Hoard, R. J., M. J. O'Brien, M. G. Khorasgany and V. S. Gopalaratnam

1995 A Materials-Science Approach to Understanding Limestone-Tempered Pottery from the Midwest. *Journal of Archaeological Science* 22:823-832.

Hodder, I. and C. Orton

1976 *Spatial Analysis in Archaeology.* Cambridge University Press, Cambridge.

Holliday, V. T.

1992 Soil Formation, Time, and Archaeology. In *Soils in Archaeology*, edited by V. T. Holliday, pp. 101-118. Smithsonian Institution Press, Washington, D. C.

Holmes, W. H.

1903 *Aboriginal Pottery of the Eastern United States.* 20th Annual Report of the Bureau of American Ethnology ed, Washington D.C.

Hommon, R.

1986 Social Evolution in Ancient Hawaii. In *Island Societies: Archaeological Approaches to Evolution and Transformation*, edited by P. V. Kirch, pp. 55-68. Cambridge University Press, Cambridge.

Houghton, P.

1989 The Lapita-Associated Human Skeletal Material from Lakeba, Fiji. *Records of the Australian Museum* 41:223-233.

Hull, D. L.

1988a *Science as a Process.* University of Chicago Press, Chicago.

1988b Interactors versus Vehicles. In *The Role of Behavior in Evolution*, edited by H. C. Plotkin, pp. 19-50. MIT Press, Cambridge, Massachusetts.

Hunt, T. L.

1980 *Toward Fiji's Past: Archaeological Research on Southwestern Viti Levu.* Masters, University of Auckland.

1981 New Evidence for Early Horticulture in Fiji. *Journal of the Polynesian Society* 90:259-266.

1986 Conceptual and Substantive Issues in Fijian Prehistory. In *Island Societies: Archaeological Approaches to Evolution and Transformation*, edited by P. V. Kirch, pp. 20-32. Cambridge University Press, Cambridge.

1987 Patterns of Human Interaction and Evolutionary Divergence in the Fiji Islands. *Journal of the Polynesian Society* 96:299-334.

1988 Graph Theoretic Network Models for Lapita Exchange: A Trial Application. In *Archaeology of the Lapita Cultural Complex: A Critical Review*, edited by P. V. Kirch and T. L. Hunt, pp. 135-156. Thomas Burke Memorial Washington State Museum Research Report. vol. 5. Burke Museum, Seattle.

1989 *Lapita Ceramic Exchange in the Mussau Islands, Papua New Guinea.* Unpublished Ph. D. Dissertation, University of Washington.

Hunt, T. L., K. A. Aronson, E. E. Cochrane, F. J. S, L. Humphrey and T. M. Rieth

1999 A Preliminary Report on Archaeological Research in the Yasawa Islands, Fiji. *Domodomo* 12:5-43.

Hunt, T. L., C. P. Lipo and S. L. Sterling (editors)

2001 *Posing Questions for a Scientific Archaeology.* Bergin and Garvey, Westport, Conn.

Hurles, M. E., M.-S. Elizabeth, R. D. Gray and D. Penny

2003 Untangling Oceanic Settlement: the edge of the knowable. *Trends in Ecology and Evolution* 18:531-540.

Hurles, M. E., J. Nicholson, E. Bosch, C. Renfrew, B. Sykes and M. A. Jobling

2002 Y Chromosomal Evidence for the Origins of Oceanic Speaking Peoples. *Genetics* 160:289-303.

Hurt, T. D., T. L. VanPool, G. F. M. Rakita and R. D. Leonard
2001 Explaining the Co-occurrence of Traits in the Archaeological Record: A Further Consideration of Replicative Success. In *Style and Function: Conceptual Issues in Evolutionary Archaeology*, edited by T. D. Hurt and G. F. M. Rakita, pp. 51-68. Bergin and Garvey, Westport, Connecticut.

Ingold, T.
2000 Introduction to Culture. In *Companion Encyclopedia of Anthropology*, edited by T. Ingold, pp. 329-349. Routledge, New York.

Irwin, G.
1990 Human colonization and change in the remote Pacific. *Current Anthropology* 31:90-94.

1992 *The prehistoric exploration and colonization of the Pacific*. Cambridge University Press, Cambridge.

Jordan, P. and S. Shennan
2003 Cultural transmission, language, and basketry traditions amongst the California Indians. *Journal of Anthropological Archaeology* 22:42-74.

Kaestle, F. A. and D. G. Smith
2001 Ancient mitochondrial DNA evidence for prehistoric population movement: The Numic expansion. *American Journal of Physical Anthropology* 115:1-12.

Kaplan, H. and K. Hill
1992 The Evolutionary Ecology of Food Acquistion. In *Evolutionary Ecology and Human Behavior*, edited by E. A. Smith and B. Winterhalder, pp. 167-202. Foundations of Human Behavior, S. H. Blaffer, general editor. Aldine De Gruyter, New York.

Kelley, J. H. and M. P. Hanen
1988 *Archaeology and the methodology of science*. University of New Mexico Press, Albuquerque.

Kelly, K. M.
1996 The End of the Trail: The Genetic Basis for Deriving the Polynesian Peoples from Austronesian Speaking Palaeopopulations of Melanesian Near Oceania. In *Oceanic Culture History: Essays in Honour of Roger Green*, edited by J. Davidson, G. Irwin, F. Leach, A. K. Pawley and D. Brown, pp. 355-364. New Zealand Journal of Archaeology Special Publication. New Zealand Archaeological Association, Dunedin.

2002 Population. In *Darwin and Archaeology: a Handbook of Key Concepts*, edited by J. P. Hart and J. E. Terrell, pp. 243-256. Bergin and Garvey, Westport, CT.

Kennett, D. J., A. Anderson, M. J. Cruz, G. A. Clark and G. R. Summerhayes
2004 Geochemical Characterization of Lapita Pottery Via Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). *Archaeometry* 46:35-46.

Kennett, D. J., S. Sachiko, H. Neff, R. Gossett and D. O. Larson
2002 Compositional Characterization of Prehistoric Ceramics: A New Approach. *Journal of Archaeological Science* 29:443-455.

Kirch, P.
1997 *The Lapita peoples*. The Peoples of South-East Asia and The Pacific. Blackwell, Cambridge.

1980 The Archaeological Study of Adaptation: Theoretical and Methodological Issues. In *Advances in Archaeological Method and Theory*, edited by M. B. Schiffer, pp. 101-156. vol. 3. Academic Press, New York.

1984 *The Evolution of the Polynesian Chiefdoms*. Cambridge University Press, Cambridge.

1988a *Niuatoputapu, the Prehistory of a Polynesian Chiefdom*. Thomas Burke Memorial Washington State Museum Monograph 5. Thomas Burke Memorial Washington State Museum, Seattle.

1990 Monumental Architecture and Power in Polynesian Chiefdoms: A Comparison of Tonga and Hawaii. *World Archaeology* 22:206-222.

1991 Prehistoric Exchange in Western Melanesia. *Annual Review of Anthropology*:141-165.

1994 Paleoenvironmental Evidence for Human Colonization of Remote Oceanic Islands. *Antiquity* 68:310-321.

2000 *On the Road of the Winds: An Archaeological History of the Pacific Islands before European Contact*. University of California Press, Berkeley.

Kirch, P. V. and R. C. Green
1987 History, Phylogeny, and Evolution in Polynesia. *Current Anthropology* 28:431-456.

2001 *Hawaiki, Ancestral Polynesia: an Essay in Historical Anthropology*. Cambridge University Press, Cambridge.

Kirk, R. L.

1988 Fiji - Ancient Melting Pot in the Pacific? Perspectives in Human Biology. *Proceedings of the Australasian Society for Human Biology 1.*

1989 Population Genetic Studies in the Pacific: Red Cell Antigen, Serum Protein, and Enzyme Systems. In *The Colonization of the Pacific: a Genetic Trail*, edited by V. S. Hill and S. W. Serjeantson, pp. 60-119. Clarendon Press, Oxford.

Kirk, R. L., N. M. Blake and J. U. Mataika

1987 Red Cell Enzyme and Serum Protein Gene Markers in Fijians. *Gene Geography* 1:41-46.

Kirkendall, M.

1998 *Demographic change on Matuku Island, Fiji, in response to infectious diseases introduced at European contact.* Unpublished Ph.D. dissertation, University of Hawaii.

Kitching, I. J.

1992a The Determination of Character Polarity. In *Cladistics: a Practical Course in Systematics*, edited by P. L. Forey, C. Humphries, J, I. J. Kitching, R. W. Scotland, D. J. Siebert and D. M. Williams, pp. 22-43. Systematics Association Publication. vol. 10. Claredon Press, Oxford.

1992b Tree-Building Techniques. In *Cladistics: a Practical Course in Systematics*, edited by P. L. Forey, C. Humphries, J, I. J. Kitching, R. W. Scotland, D. J. Siebert and D. M. Williams, pp. 44-71. Systematics Association Publication. vol. 10. Claredon Press, Oxford.

Kitching, I. J., P. L. Forey, C. Humphries, J and D. M. Williams

1998 *Cladistics: The Theory and Practice of Parsimony Analysis.* Oxford University Press, Oxford.

Kohler, T. A., S. Van Buskirk and S. Ruscavage-Barz

2004 Vessels and Villages: evidence for conformist transmission in early village aggregations on the Pajarito Plateau, New Mexico. *Journal of Anthropological Archaeology* 23:100-118.

Kolb, M., J

1992 Diachronic Design Changes in Heiau Temple Architecture on the Island of Maui, Hawai`i. *Asian Perspectives* 31:11-37.

Krieger, A. D.

1944 The Typological Concept. *American Antiquity* 9:271-288.

Kroeber, A. L.
1931 The Culture-Area and Age-Area Concepts of Clark Wissler. In *Methods in Social Science*, edited by S. A. Rice, pp. 248-265. University of Chicago Press, Chicago.

Kruskal, J. B. and M. Wish
1978 *Multidimensional Scaling*. Sage University Paper series on Quantitative Applications in the Social Sciences series no. 07-011. Sage Publications, London.

Ladefoged, T. N. and M. W. Graves
2000 Evolutionary Theory and the Historical Development of Dry-Land Agriculture in North Kohala, Hawaii. *American Antiquity* 65:423-428.

Leach, B. F., C. J. Quinn, G. L. Lyon, H. A and M. D. B
2000 Evidence of Prehistoric Lapita Diet at Watom Island, Papua New Guinea, Using Stable Isotopes. *New Zealand Journal of Archaeology* 20(1998).

Leonard, R. D. and G. T. Jones
1989 *Quantifying diversity in archaeology*. Cambridge University Press, Cambridge; New York.

Levin, D. A.
2002 Hybridization and Extinction. *American Scientist* 90:254-261.

Lewontin, R. C.
1974 *The Genetic Basis of Evolutionary Change*. Columbia University Press, New York.

Lightfoot, K. G. and R. Jewett
1984 Late prehistoric ceramic distributions in east-central Arizona: an examination of Cibola whiteware, White Mountain redware, and Salado redware. In *Regional analysis of prehistoric ceramic variation: contemporary studies of the Cibola whitewares*, edited by A. P. Sullivan and J. L. Hantman, pp. 36-73. Anthropological Research Papers. vol. 31. Arizona State University, Tempe.

Lipo, C. and M. Madsen
2001 Neutrality, "Style," and Drift: Building Methods for Studying Cultural Transmission in the Archaeological Record. In *Style and Function: Conceptual Issues in Evolutionary Archaeology*, edited by T. D. Hurt and G. F. M. Rakita, pp. 91-118. Bergin and Garvey, Westport, Connecticut.

Lipo, C. P.

2001a Community Structures among Late Mississippian Populations of the Central Mississippi River Valley. In *Posing Questions for a Scientific Archaeology*, edited by T. L. Hunt, C. P. Lipo and S. L. Sterling, pp. 175-216. Scientific Archaeology for the Third Millenium, J. L. Lantana, M. Aldenderfer and H. Neff, general editor. Bergin and Garvey, Westport, Conn.

2001b *Science, Style, and the Study of Community Structure: An Example from the Central Mississippi River Valley*. British Archaeological Reports, International Series 918. Hadrian Books Ltd., Oxford.

2005 The Resolution of Cultural Phylogenies Using Graphs. In *Mapping Our Ancestors: Phylogenetic Methods in Anthropology and Prehistory*, edited by C. P. Lipo, M. J. O'Brien, S. Shennan and M. Collard. Aldine de Gruyter, New York (in press).

Lipo, C. P., M. Madsen, R. C. Dunnell and T. Hunt

1997 Population Structure, Cultural Transmission, and Frequency Seriation. *Journal of Anthropological Archaeology* 16:301-333.

Lipo, C. P., M. J. O'Brien, M. Collard and S. Shennan (editors)

2005 *Mapping Our Ancestors: Phylogenetic Methods in Anthropology and Prehistory*. Aldine de Gruyter, New York (in press).

Longacre, W. A.

1970 *Archaeology as Anthropology: A Case Study*. Anthropological Papers 17. University of Arizona, Tuscon.

Lum, J. K., L. B. Jorde and W. Schiefenhovel

2002 Affinities among Melanesians, Micronesians, and Polynesians: a Neutral, Biparental, Genetic Perspective. *Human Biology* 74:413-430.

Lum, K. J.

1998 Central and Eastern Micronesia: Genetics, the Overnight Voyage, and Linguistic Divergence. *Man and Culture in Oceania* 14:69-80.

Lum, K. J., O. Rickards, C. Ching and R. L. Cann

1994 Polynesian Mitochondrial DNAs Reveal Three Deep Maternal Lineage Clusters. *Human Biology* 66:567-590.

Lyman, R. L., O. B. M. J and V. Hayes

1998 A Mechanical and Functional Study of Bone Rods from the Richey-Roberts Clovis Cache, Washington, U.S.A. *Journal of Archaeological Science* 25:887-906.

Lyman, R. L. and M. J. O'Brien

1998 The Goals of Evolutionary Archaeology: History and Explanation. *Current Anthropology* 39:615-652.

2000 Measuring and Explaining Change in Artifact Variation with Clade-Diversity Diagrams. *Journal of Anthropological Archaeology* 19:39-74.

2003 Cultural Traits: Units of Analysis in Early Twentieth-Century Anthropology. *Journal of Anthropological Research* 59:225-250.

2005 Seriation and Cladistics: The Difference Between Anagenic and Cladogenic Evolution. In *Mapping Our Ancestors: Phylogenetic Methods in Anthropology and Prehistory*, edited by C. P. Lipo, M. J. O'Brien, S. Shennan and M. Collard. Aldine de Gruyter, New York (in press).

Lyman, R. L., M. J. O'Brien and R. C. Dunnell

1997 *The Rise and Fall of Culture History*. Plenum Press, New York.

Lyman, R. L., S. Wolverton and M. J. O'Brien

1998 Seriation, Superposition, and Interdigitation: A History of Americanist Graphic Depictions of Culture Change. *American Antiquity* 63:239.

Lynch, A.

1996 The Population Memetics of Birdsong. In *Ecology and evolution of acoustic communication in birds*, edited by D. E. Kroodsma and E. H. Miller, pp. 181-197. Cornell University Press, Ithaca.

MacDonald, D. H.

1998 Subsistence, Sex, and Cultural Transmission in Folsom Culture. *Journal of Anthropological Archaeology* 17:217-239.

Mace, R. and M. Pagel

1994 The Comparative Method in Anthropology. *Current Anthropology* 35:549-564.

MacEachern, S.

2000 Genes, Tribes, and African History. *Current Anthropology* 41:357-384.

Mallory-Greenough, L. M. and J. D. Greenough

1998 New Data for Old Pots: Trace-Element Characterization of Ancient Egyptian Pottery Using ICP-MS. *Journal of Archaeological Science* 25:85-97.

Margolis, M.

2004 Jungle Economics. *Newsweek*. vol. 143.

Marks, J.
2002 *What it means to be 98% chimpanzee: apes, people, and their genes.* University of California Press, Berkeley.

Marshall, Y., A. Crosby, S. Matararaba and S. Wood
2000 *Sigatoka: the Shifting Sands of Fijian Prehistory.* University of Southampton Department of Archaeology Monograph 1. Oxbow Books, Oxford.

Mayr, E.
1981 Biological Classification: Toward a Synthesis of Opposing Methodologies. *Science* 214:510-516.

1982 The Growth of Biological Thought: Diversity, Evolution, and Inheritance. Belknap Press, Cambridge, Massachusetts.

McBride, M. B.
1994 *Environmental Chemistry of Soils.* Oxford University Press, Oxford.

McCutcheon, P. T.
1996 *Stone Tool Heat Treatment Technology on the Malden Plain, Southeast Missouri: An Experimental Approach.* Ph. D Dissertation, University of Washington.

Meggers, B. J.
1955 The Coming of Age of American Archaeology. In *New Interpretations of Aboriginal American Culture History*, edited by B. J. Meggers and C. Evans, pp. 116-129. Anthropological Society of Washington, Washington, D. C.

Melton, T., R. Peterson, A. J. Redd, N. Saha, A. S. M. Sofro, J. Martinson and M. Stoneking
1994 Polynesian Genetic Affinities as Identified by mtDNA Analysis. *American Journal of Human Genetics* 57:403-414.

Meltzer, D., J
1981 A Study of Style and Function in a Class of Tools. *Journal of Field Archaeology* 8:313-326.

Mesoudi, A., A. Whiten and K. N. Laland
2004 Perspective: Is Human Cultural Evolution Darwinian? Evidence Reviewed from the Perspective of The Origin of Species. *Evolutionary Anthropology* 58:1-11.

Moore, J. D.
1997 *Visions of Culture.* Alta Mira Press, Walnut Creek, California.

Moore, J. H.
1994 Putting Anthropology Back Together Again: The Ethnogenetic Critique of Cladistic Theory. *American Anthropologist* 96:925-948.

Morrison, A.
2003 Analysis of Shellfish Remains from Natia (Y1-15), Nacula Island, Fiji, Manuscript in possession of author.

Neff, H.
1993 Theory, Sampling, and Analytical Techniques in the Archaeological Study of Prehistoric Ceramics. *American Antiquity* 58:23-44.

1995 A Role for "Sourcing" in Evolutionary Archaeology. In *Evolutionary Archaeology: Methodological Issues*, edited by P. A. Teltser, pp. 69-112. University of Arizona Press, Tucson.

2001 Differential Persistence of What? The Scale of Selection Issue in Evolutionary Archaeology. In *Style and Function: Conceptual Issues in Evolutionary Archaeology*, edited by T. D. Hurt and G. F. M. Rakita, pp. 25-40. Bergin and Garvey, Westport, Conn.

2002 Quantitative Techniques for Analyzing Ceramic Compositional Data. In *Ceramic Production and Circulation in the Greater Southwest: Source Determination by INAA and Complementary Mineralogical Investigations*, edited by D. M. Glowacki and H. Neff, pp. 15-36. Monograph 44. The Costen Institute of Archaeology, Los Angeles.

2003 Analysis of Mesoamerican Plumbate Pottery Surfaces by Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS). *Journal of Archaeological Science* 30:21-35.

Neff, H. and R. L. Bishop
1988 Reconstructing ceramic production from ceramic compositional data: an example from Guatemala. *Journal of Field Archaeology* 15.

Neff, H., R. L. Bishop and E. V. Sayre
1989 More Observations on the Problem of Tempering in Compositional Studies of Archaeological Ceramics. *Journal of Archaeological Science* 16:57-69.

Neiman, F.
1995 Stylistic Variation in Evolutionary Perspective: Inferences from Decorative Diversity and Interassemblage Distance in Illinois Woodland Ceramic Assemblages. *American Antiquity* 60:7-36.

Nettle, D.

1996 Language Diversity in West Africa: An Ecological Approach. *Journal of Anthropological Archaeology* 15:403-438.

Nunn, P. D.

1994 *Oceanic Islands.* Blackwell, Cambridge.

1997 Late Quaternary environmental changes on Pacific islands: controversy, certainty and conjecture. *Journal of Quaternary Science* 12:443-450.

1998 Sea-Level Changes Over the Past 1,000 Years in the Pacific. *Journal of Coastal Research* 14:23-30.

2000a Environmental Catastrophe in the Pacific Islands around A.D. 1300. *Geoarchaeology* 15:715-740.

2000b Illuminating sea-level fall around AD 1220-1510 (730-440 cal yr BP) in the Pacific Islands: implications for environmental change and cultural transformation. *New Zealand Geographer* 56:46-54.

Nunn, P. D. and J. M. R. Britton

2001 Human-Environment Relationships in the Pacific Islands around A.D. 1300. *Environment and History* 7:3-22.

Nunn, P. D., R. Kumar, S. Matararaba, T. Ishimura, J. Seeto, S. Rayawa, S. Kuruyawa, A. Nasila, B. Oloni, A. R. Ram, P. Saunivalu, P. Singh and E. Tegu

2004 Early Lapita Settlement at Bourewa, southwest Viti Levu Island, Fiji. *Archaeology in Oceania* 39:139-143.

Nunn, P. D., C. Ollier, G. Hope, P. Rodda, A. Omura and W. R. Peltier

2002 Late Quaternary sea-level and tectonic changes in northeast Fiji. *Marine Geology* 187:299-311.

O'Brien, M. J., J. Darwent and R. L. Lyman

2001 Cladistics is Useful for Reconstructing Archaeological Phylogenies: Palaeoindian Points from the Southeastern United States. *Journal of Archaeological Science* 28:1115-1136.

O'Brien, M. J. and T. D. Holland

1990 Variation, Selection, and the Archaeological Record. *Archaeological Method and Theory* 2:31-79.

1992 The Role of Adaptation in Archaeological Explanation. *American Antiquity* 57:36-59.

O'Brien, M. J., T. D. Holland, R. J. Hoard and G. L. Fox
1994 Evolutionary Implications of Design and Performance Characteristics of Prehistoric Pottery. *Journal of Archaeological Method and Theory* 1:259-304.

O'Brien, M. J. and R. L. Lyman
2000a *Applying Evolutionary Archaeology: A Systematic Approach*. Kluwer Academic/Plenum Publishers, New York.

2000b *Seriation, Stratigraphy, and Index Fossils: the Backbone of Archaeological Dating*. Kluwer Academic/Plenum Publishers, New York.

2003 *Cladistics and Archaeology*. University of Utah Press, Salt Lake City.

O'Brien, M. J., R. L. Lyman, Y. Saab, E. Saab, J. Darwent and D. S. Glover
2002 Two Issues in Archaeological Phylogenetics: Taxon Construction and Outgroup Selection. *Journal of Theoretical Biology* 215:133-150.

O'Brien, M. J. and H. C. Wilson
1988 A Paradigmatic Shift in the Search for the Origin of Agriculture. *American Anthropologist* 90:958-965.

O'Connell, J. and J. Allen
1995 Human Reactions to the Pleistocene-Holocene Transition in Greater Australia: a Summary. *Antiquity* 69:855-862.

Osgood, C.
1951 Culture: Its Empirical and Non-empirical Character. *Southwestern Journal of Anthropology* 7:202-214.

Palmer, B.

1965 Excavations at Karobo, Viti Levu. *New Zealand Archaeological Association Newsletter* 8:26-33.

1969a Ring-Ditch Fortifications on Windward Viti Levu, Fiji. *Archaeology and Physical Anthropology in Oceania* 4:181-197.

1971a Fijian Pottery Technologies: their relevance to certain problems of southwest Pacific history. In *Studies in Oceanic Culture History Volume 2*, edited by R. C. Green and M. Keelly, pp. 77-103. Pacific Anthropological Records. vol. 12. Bishop Museum, Honolulu.

1971b Naga Ceremonial Site in Navosa Upper Sigatoka Valley. Final Report No. 1. In *Sigatoka Research Project Miscellaneous Papers*, pp. 92-106. vol. 1. Fiji Museum, Suva, Fiji.

Palmer, B. and E. Shaw

1968 Pottery Making in Nasama Village. *Records of the Fiji Museum* 1:48-67.

1969b Fortified Sites on Ridge Junctions, Fiji. *New Zealand Archaeological Association Newsletter* 12:15-19.

Parke, A. L.

2003 Late Lapita site on Yacata, Fiji. In *Pacific Archaeology: assessments and prospects*, edited by C. Sand, pp. 187-190. Les Cahiers de l'Archaéologie en Nouvelle Calédonie. vol. 15. Service des Musées et du Patrimonie de Nouvelle-Calédonie, Nouméa.

Parry, J. T.

1977 *Ring-Ditch Fortification in the Rewa Delta, Fiji: Air Photo Interpretation and Analysis*. Bulletin of the Fiji Museum 3. The Fiji Museum, Suva, Fiji.

1982 *Ring-Ditch Fortification in the Navua Delta, Fiji: Air Photo Interpretation and Analysis*. Bulletin of the Fiji Museum 7. The Fiji Museum, Suva, Fiji.

1987 *The Sigatoka Valley: Pathway Into Prehistory*. Bulletin of the Fiji Museum 9. The Fiji Museum, Suva, Fiji.

1997 *The North Coast of Viti Levu Ba to Ra Air Photo Archaeology and Ethnohistory*. Bulletin of the Fiji Museum 10. The Fiji Museum, Suva, Fiji.

Pawley, A., and T. R. Sayaba

1971 Fijian Dialect Divisions: Eastern and Western Fijian. *Journal of the Polynesian Society*:405-436.

Pawley, A. K.

1981 Melanesian Diversity and Polynesian Homogeneity: A Unified Explanation for Language. In *Studies in Pacific Languages and Cultures in Honour of Bruce Biggs*, edited by J. Hollyman and A. K. Pawley, pp. 269-309. Linguistic Society of New Zealand, Auckland.

1996 On the Polynesian Subgroup as a Problem for Irwin's Continuous Settlement Hypothesis. In *Oceanic Culture History: Essays in Honour of Roger Green*, edited by J. Davidson, G. Irwin, F. Leach, A. K. Pawley and D. Brown, pp. 387-410. New Zealand Journal of Archaeology Special Publication. New Zealand Archaeological Association, Dunedin.

Pawley, A. K. and R. C. Green

1973 Dating the dispersal of the Oceanic Languages. *Oceanic Linguistics* 12:1-67.

1984 The Proto-Oceanic Language Community. *Journal of Pacific History* 29:123-146.

Pawley, A. K. and M. Ross

1993 Austronesian Historical Linguistics and Culture History. *Annual Review of Anthropology* 22:425-459.

Payne, R. B.

1996 Song traditions in Indigo Buntings: Origin, improvisation, dispersal, and extinction in cultural evolution. In *Ecology and evolution of acoustic communication in birds*, edited by D. E. Kroodsma and E. H. Miller, pp. 198-220. Cornell University Press, Ithaca.

Pfeffer, M. T.

2001 The Engineering and Evolution of Hawaiian Fishhooks. In *Posing Questions for a Scientific Archaeology*, edited by T. L. Hunt, C. P. Lipo and S. L. Sterling, pp. 73-96. Bergin and Garvey, Westport, Conn.

Philips, P., J. A. Ford and J. B. Griffin

1951 *Archaeological Survey in the Lower Mississippi Valley, 1940-1947.* Papers of the Peabody Museum of Archaeology and Ethnology 25. Harvard University, Cambridge.

Phillips, P.

1958 Application of the Wheat-Gifford-Wasley Taxonomy to Eastern Ceramics. *American Antiquity* 24:117-125.

Pierce, C.

1998 Theory, Measurement, and Explanation, Variable Shapes in Poverty Point Objects. In *Unit Issues in Archaeology: Measuring Time, Space, and Material*, edited by A. Ramenofsky, F and A. Steffen, pp. 163-190. University of Utah Press, Salt Lake City.

Pietrusewsky, M.

1989 A Lapita-Associated Skeleton from Natunuku, Fiji. *Records of the Australian Museum* 41:297-325.

1994 Pacific-Asian Relationships: A Physical Anthropology Perspective. *Oceanic Linguistics* 33:407-429.

Pietrusewsky, M., M. T. Douglas, E. E. Cochrane and S. Reinke

2004 Cultural Modifications in an Adolescent Earth-Oven Interment from Fiji: Sorting out Mortuary Practice. *International Journal of Osteoarchaeology* (in review).

Pietrusewsky, M., M. T. Douglas and I.-Q. R

1994 *The Human Osteology of the Sigatoka Dune Burials (Site VL 16/1), Viti Levu, Fiji Islands*. Unpublished report on file at the University of Hawaii.

Pietrusewsky, M., T. L. Hunt, and R. Ichihara-Quebral

1997 A New Lapita-Associated Skeleton from Fiji. *Journal of the Polynesian Society* 106:284-295.

Plog, F.

1976 Measurement of Prehistoric Interaction Between Communities. In *The Mesoamerican Village*, edited by K. V. Flannery, pp. 255-272. Academic Press, New York.

Plog, S.

1980 *Stylistic Variation in Prehistoric Ceramics: Design Analysis in the American Southwest*. Cambridge University Press, Cambridge.

1983 Analysis of Style in Artifacts. *Annual Review of Anthropology* 12:125-142.

Pocklington, R. and M. L. Best

1997 Cultural Evolution and Units of Selection in Replicating Text. *Journal of Theoretical Biology* 188:79-87.

Ramenofsky, A. F. and A. Steffen (editors)

1997 *Unit Issues in Archaeology : Measuring Time, Space, and Material*. University of Utah Press, Salt Lake City.

Ramsey, C. B.

2003 OxCal 3.9. Program available at: http://units.ox.ac.uk/departments/rlaha/orau/06_01.htm.

Rands, R. L. and R. L. Bishop

1980 Resource procurement zones and patterns of ceramic exchange in the Palenque region, Mexico. In *Models and methods in regional exchange*, edited by R. E. Fry, pp. 19-46. SAA Papers. vol. 1. Society for American Archaeology, Washington, D.C.

Rechtman, R. B.
1992 *The Evolution of Sociopolitical Complexity in the Fiji Islands.* PhD dissertation, The University of California, Los Angeles.

Renfrew, C.
1977 Alternative Models for Exchange and Spatial Distribution. In *Exchange Systems in Prehistory*, edited by T. K. Earle and J. E. Ericson, pp. 71-90. Academic Press, New York.

1997 World linguistic diversity and farming dispersals.

Renfrew, C. and K. Boyle
2000 *Archaeogenetics: DNA and the Population Prehistory of Europe.* McDonald Institute for Archaeological Research, Cambridge.

Rhode, D.
1988 Measurement of Archaeological Diversity and the Sample-size Effect. *American Antiquity* 53:708-716.

Rhymer, J. and D. Simberloff
1996 Extinction by Hybridization and Introgression. *Annual Review of Ecology and Systematics* 27:83-109.

Rice, P. M.
1987 *Pottery Analysis: A Sourcebook.* University of Chicago Press, Chicago.

Richerson, P. J. and R. Boyd
1992 Cultural Inheritance and Evolutionary Ecology. In *Evolutionary Ecology and Human Behavior*, edited by E. A. Smith and B. Winterhalder, pp. 61-94. Foundations of Human Behavior, S. H. Blaffer, general editor. Aldine De Gruyter, New York.

Ridley, M.
1986 *Evolution and Classification: the Reformation of Cladism.* Longman, New York.

Rindos, D.
1984 *The Origins of Agriculture: An Evolutionary Approach.* Academic Press, Orlando.

Robinson, W. S.
1951 A Method for Chronologically Ordering Archaeological Deposits. *American Antiquity* 16:293-301.

Rodda, P.

1990a *Geology of Nacula, Yasawa Group*. Ministry of Lands and Mineral Resources. Submitted to Mineral Resources Department Note BP1/93.

1990b *Geology of Tokoriki (Mamanuca Group), Malolo*. Ministry of Lands adn Mineral Resources. Submitted to Mineral Resources Department Note BP1/83.

1994 Geology of Fiji. In *Geology and Submarine Resources of the Tonga-Lau-Fiji Region*, edited by A. J. Stevenson, R. H. Herzer and P. F. Ballance, pp. 131-151. SOPAC Technical Bulletin. vol. 8. SOPAC Secretariat, Suva.

Rodda, P. and J. Lum

1990 Geological Evolution and Mineral Deposits of Fiji. *Geologisches Jahrbuch* 92:37-66.

Roscoe, P.

2002 Culture. In *Darwin and Archaeology: A Handbook of Key Concepts*, edited by J. P. Hart and J. E. Terrell, pp. 107-124. Bergin and Garvey, Westport, Connecticut.

Rosenberg, M.

1994 Pattern, Process, and Hierarchy in the Evolution of Culture. *Journal of Anthropological Archaeology* 13:307-340.

Rossitto, R.

1989a Stylistic Change in Fijian Pottery, Part II: Decoration. *Domodomo* 1-4:48-69.

1989b Stylistic Change of Fijian Pottery, Part 1: Form. *Domodomo* 1-4:1-47.

Rouse, I.

1939 *Prehistory in Haiti*. Yale University Publications in Anthropology 21.

Sagan, C.

1997 *The Demon-Haunted World : Science As a Candle in the Dark*. Ballantine Books, New York.

Sand, C.

2001 Evolutions in the Lapita Cultural Complex: a View from the Southern Lapita Province. *Archaeology in Oceania* 36:65-76.

Sand, C., F. Valentin, T. Sorovi-Vunidilo, J. Bole, A. Ouetcho, S. Matararaba, J. Naucabablavu, D. Baret and L. Lagarde

1999 *Cikobia-i-Ra*. Service de Musees et du Patrimonie, Noumea, New Caledonia.

Sassaman, K. E.

1993 *Early Pottery in the Southeast: Tradition and Innovation in Cooking Technology*. University of Alabama Press, Tuscaloosa.

Saunders, A. D.

1984 The Rare Earth Element Characteristics of Igneous Rocks from the Ocean Basins. In *Rare Earth Element Geochemistry*, edited by P. Henderson, pp. 205-236. Elsevier, New York.

Sayre, E. V. and R. W. Dodson

1957 Neutron activation study of Mediterranean potsherds. *American Journal of Archaeology* 61:35-41.

Schiffer, M. B.

1987 *Formation processes of the archaeological record*. 1st ed ed. University of New Mexico Press, Albuquerque, NM.

1992 *Technological Perspectives on Behavioral Change*. University of Arizona Press, Tucson.

1996 Some Relationships Between Behavioral and Evolutionary Archaeologies. *American Antiquity* 61:643-662.

Schiffer, M. B. and J. M. Skibo

1987 Theory and Experiment in the Study of Technological Change. *Current Anthropology* 28:595-622.

Schiffer, M. B., J. M. Skibo, T. C. Boelke, M. A. Neupert and M. Aronson

1994 New Perspectives on Experimental Archaeology: Surface Treatments and Thermal Response of the Clay Cooking Pot. *American Antiquity* 59:197-218.

Scotland, R. W.

1992 Character Coding. In *Cladistics: a Practical Course in Systematics*, edited by P. L. Forey, C. Humphries, J, I. J. Kitching, R. W. Scotland, D. J. Siebert and D. M. Williams, pp. 14-21. Systematics Association Publication. vol. 10. Claredon Press, Oxford.

Sellars, W.

1962 Philosophy and the Scientific Image of Man. In *Frontiers of Science and Philosophy*, edited by R. Colodny. University of Pittsburgh Press, Pittsburgh.

Sharp, A.

1956 *Ancient Voyagers in the Pacific*. Polynesian Society, Wellington, New Zealand.

Shaw, E.

1967 *A Reanalysis of Pottery from Navatu and Vuda, Fiji.* PhD, University of Auckland.

Shennan, S.

1989 Cultural transmission and cultural change. In *What's new? A closer look at the process of innovation*, edited by S. E. van der Leeuw and R. Torrence, pp. 330-346. Unwin Hyman, London.

1997 *Quantifying Archaeology*. 2nd ed. Edinburgh University Press, Edinburgh.

2002 Learning. In *Darwin and Archaeology: a Handbook of Key Concepts*, edited by J. P. Hart and J. E. Terrell, pp. 183-200. Bergin and Garvey, Westport, Connecticutt.

2003 *Genes, Memes, and Human History: Darwinian Archaeology and Cultural Evolution.* Thames and Hudson, London.

Shennan, S. J. and J. R. Wilkinson

2001 Ceramic Style Change and Neutral Evolution: A Case Study from Neolithic Europe. *American Antiquity* 66:577-593.

Shepard, A. O.

1964 Temper Identification: "Technological Sherd-Splitting" or an Unanswered Challenge. *American Antiquity* 29:518-520.

Siebert, D. J.

1992 Tree Statistics; Trees and 'Confidence'; Consensus Trees; Alternatives to Parsimony; Character Weighting; Character Conflict and its Resolution. In *Cladistics: a Practical Course in Systematics*, edited by P. L. Forey, C. Humphries, J, I. J. Kitching, R. W. Scotland, D. J. Siebert and D. M. Williams, pp. 72-88. Systematics Association Publication. vol. 10. Claredon Press, Oxford.

Simpson, G. G.

1963 Historical Science. In *The Fabric of Geology*, edited by C. C. Albritton Jr., pp. 24-48. Freeman, Cooper, Stanford, California.

1970 Uniformitarianism: An Inquiry into Principle, Theory, and Method in Geohistory and Biohistory. In *Essays in Evolution and Genetics in Honor Of Theodosius Dobzhansky*, edited by M. K. Hecht and W. C. Steere, pp. 43-96. Appleton, New York.

Smith, B.

1994 *The Emergence of Agriculture.* W. H. Freeman, San Francisco.

Sober, E.

1984 *The Nature of Selection*. MIT Press, Cambridge, MA.

1988 *Reconstructing the Past: Parsimony, Evolution, and Inference*. MIT Press, Cambridge, Massachusettes.

1992 Models of Cultural Evolution. In *Trees of Life*, edited by P. Griffiths, pp. 17-39. Kluwer, Dordrecht.

Sokal, R. R. and P. H. A. Sneath

1963 *Principles of Numerical Taxonomy*. W. H. Freeman, Lodon.

Spaulding, A. C.

1953a Review of "Measurements of Some Prehistoric Design Developments in the Southeastern States" by J. A. Ford. *American Anthropologist* 55:588-591.

1953b Statistical Techniques for the Discovery of Artifact Types. *American Antiquity* 18:305-313.

1954a Reply (to Ford). *American Anthropologist* 56:112-114.

1954b Reply to Ford. *American Antiquity* 19:391-393.

Spriggs, M.

1984 The Lapita Cultural Complex: Origins, Distribution, Contemporaries, and Successors. *Journal of Pacific History* 19:202-223.

1997 *The Island Melanesians*. Blackwell, Oxford.

2003 Post-Lapita Evolutions in Island Melanesia. In *Pacific Archaeology: assessments and prospects*, edited by C. Sand, pp. 205-212. Les Cahiers de l'Archaéologie en Nouvelle Calédonie. vol. 15. Service des Musées et du Patrimonie de Nouvelle-Calédonie, Nouméa.

2004 Is There Life After Lapita, and Do You Remember the 60s? The Post-Lapita Sequences of the Western Pacific. *Records of the Australian Museum* Supplement 29:139-144.

Stannard, D. E.

1989 *Before the Horror: The Population of Hawai`i on the Eve of Western Contact*. University of Hawai`i Press, Honolulu.

Sterling, S., L

2001 Social Complexity in Ancient Egypt: Functional Differentiation Reflected in the Distribution of Standardized Ceramics. In *Posing Questions for a Scientific Archaeology*, edited by T. Hunt, L, C. Lipo, P and S. Sterling, L, pp. 145-174. Scientific Archaeology for the Third Millennium. Bergin and Garvey, Westport, Conn.

Stuiver, M., P. J. Reimer, E. Bard, W. J. Beck, G. S. Burr, K. A. Hughen, B. Kromer, G. McCormac, J. van der Plicht and M. Spurk

1998 INTCAL98 Radiocarbon Age Calibration, 24,000-0 cal BP. *Radiocarbon* 40:1041-1084.

Summerhayes, G. R.

2001 Far Western, Western, and Eastern Lapita: A Re-Evaluation. *Asian Perspectives* 39:109-138.

Swofford, D. L.

2001 PAUP*: Phylogenetic Analysis Using Parsimony And Other Methods. 4.0 ed. Computer program distributed by Sinaur Associates, Sunderland, MA.

Szabó, K.

2000 The Reef, the Beach, and the Rocks: An Environmental Anlaysis of Mollusc Remains from Natunuku, Viti Levu, Fiji. In *The Archaeology of Lapita Dispersal in Oceania*, edited by G. A. Clark, A. J. Anderson and T. S. Vunidilo, pp. 159-166. Pandanus Books, Canberra.

Tehrani, J. and M. Collard

2002 Investigating cultural evolution through biological phylogenetic analyses of Turkmen textiles. *Journal of Anthropological Archaeology* 21:443-463.

Teltser, P., A

1995 Culture History, Evolutionary Theory, and Frequency Seriation. In *Evolutionary Archaeology: Methodological Issues*, edited by P. A. Teltser, pp. 51-68. University of Arizona Press, Tucson.

Terrell, J.

1986a Causal Pathways and Causal Processes: Studying the Evolutoinary Prehistory of Human Diversity in Language, Customs, and Biology. *Journal of Anthropological Archaeology* 5:187-198.

1986b *Prehistory in the Pacific Islands*. Cambridge University Press, New York.

1988 History as a Family Tree, History as an Entangled Bank: Constructing Images and Interpretations of Prehistory in the South Pacific. *Antiquity* 62:642-657.

2001 Introduction. In *Archaeology, Language and History*, edited by J. E. Terrell, pp. 1-10. Scientific Archaeology for the Third Millenium, J. L. Lantana, M. Aldenderfer and H. Neff, general editor. Bergin and Garvey, Westport, Connecticut.

Terrell, J., T. L. Hunt and C. Gosden
1997 The Dimensions of Social Life in the Pacific: Human Diversity and the Myth of the Primitive Isolate. *Current Anthropology* 38:155-195.

Terrell, J. E., T. L. Hunt and J. Bradshaw
2002 On the Location of the Proto-Oceanic Homeland. *Pacific Studies* 25:57-93.

Terrell, J. E. and R. L. Welsch
1997 Lapita and the Temporal Geography of Prehistory. *Antiquity* 71:548-572.

Thomas, N.
1989 The Force of Ethnology: Origins and Significance of the Melanesia/Polynesia Division. *Current Anthropology* 30:27-41.

Thompson, R. H.
1956 An Archaeological Approach to the Study of Cultural Stability. In *Seminars in Archaeology:1955*, pp. 31-57. Society for American Archaeology Memoirs. vol. 11. Society for American Archaeology.

Toggweiler, J. R., K. Dixon and K. Bryan
1989 Simulations of radiocarbon in a coarse-resolution world ocean model 1. Steady state prebomb distributions. *Journal of Geophysical Research* 94:8217-8242.

Upham, S., K. G. Lightfoot and G. M. Feinman
1981 Explaining Socially Determined Ceramic Distribution in the Prehistoric Plateau Southwest. *American Antiquity* 46:822-833.

Vayda, A. P. and R. A. Rappaport
1963 Ecology, Cultural and Noncultural. In *Introduction to Cultural Anthropology: Essays in the Scope and Methods of the Science of Man*, edited by J. Clifton, pp. 477-497. Houghton Mifflin, Boston.

Vierra, R. K.
1982 Typology, Classification, and Theory Building. In *Essays on Archaeological Typology*, edited by R. Whallon and J. A. Brown. Center for American Archaeology Press, Evanston, Illinois.

Visser, E.
1994 *The Prehistoric People from Sigatoka: An Analysis of the Skeletal and Dental Traits as Evidence of Adaptation.* Unpublished Ph. D. dissertation, University of Otago.

Vrba, E. S. and S. J. Gould
1986 The hierarchical expansion of sorting and selection: Sorting and selection cannot be equated. *Paleobiology* 12:217-228.

Waterhouse, J.
1866 *The King and People of Fiji.* Wesleyan Conference Office, London.

Watson, P. J., S. A. LeBlanc and C. L. Redman
1971 *Explanation in Archaeology: an Explicitly Scientific Approach.* Columbia University Press, New York.

Welsch, R. L., J. Terrell and J. Nadolski
1992 Language and Culture on the North Coast of New Guinea. *American Anthropologist* 94:568-600.

Whallon, R.
1972 A New Approach to Pottery Typology. *American Antiquity* 37:13-33.

Whallon, R. and J. A. Brown
1982 *Essays on Archaeological Typology.* Center for American Archaeology, Evanston, Illinois.

Wheat, J. B., J. C. Gifford and W. W. Wasley
1958 Ceramic Variety, Type Cluster, and Ceramic System in Southwestern Pottery Analysis. *American Antiquity* 24:34-47.

Wiessner, P.
1983 Style and Social Information in Kalahari San Projectile Points. *American Antiquity* 49:253-276.

Wilkes, C.
1845 *Narrative of the U.S. Exploring Expedition during the Years 1838-1842.* Lea & Blanchard, Philadelphia.

Willer, D. and J. Willer
1974 *Systematic Empiricism: Critique of a Pseudoscience*. Prentice-Hall, Englewood Cliffs, N.J.

Willey, G. R.
1945 Horizon Styles and Pottery Traditions in Peruvian Archaeology. *American Antiquity* 10:49-56.

1953 Archaeological Theories and Interpretation: New World. In *Anthropology Today*, edited by A. L. Kroeber, pp. 361-385. University of Chicago Press, Chicago.

Willey, G. R. and P. Phillips
1958 *Method and Theory in American Archaeology*. University of Chicago Press, Chicago.

Williams, G. C.
1992 *Natural Selection: Domains, Levels, and Challenges*. Oxford Series in Ecology and Evolution 4. Oxford University Press, New York.

Wilson, E. O.
1998 *Consilience: The Unity of Knowledge*. Alfred A. Knoph, New York.

Winterhalder, B. and E. A. Smith
1992 Evolutionary Ecology and the Social Sciences. In *Evolutionary Ecology and Human Behavior*, edited by E. A. Smith and B. Winterhalder, pp. 3-24. Foundations of Human Behavior, S. H. Blaffer, general editor. Aldine De Gruyter, New York.

Wobst, H. M.
1977 Stylistic Behavior and Information Exchange. In *For the Director: Research Essays in Honor of James B. Griffin*, edited by C. Cleland, pp. 317-342. Anthropological Papers. vol. 61. University of Michigan, Ann Arbor.

Woese, C. R.
2004 A New Biology for a New Century. *Microbiology and Molecular Biology Reviews* 68:173-186.

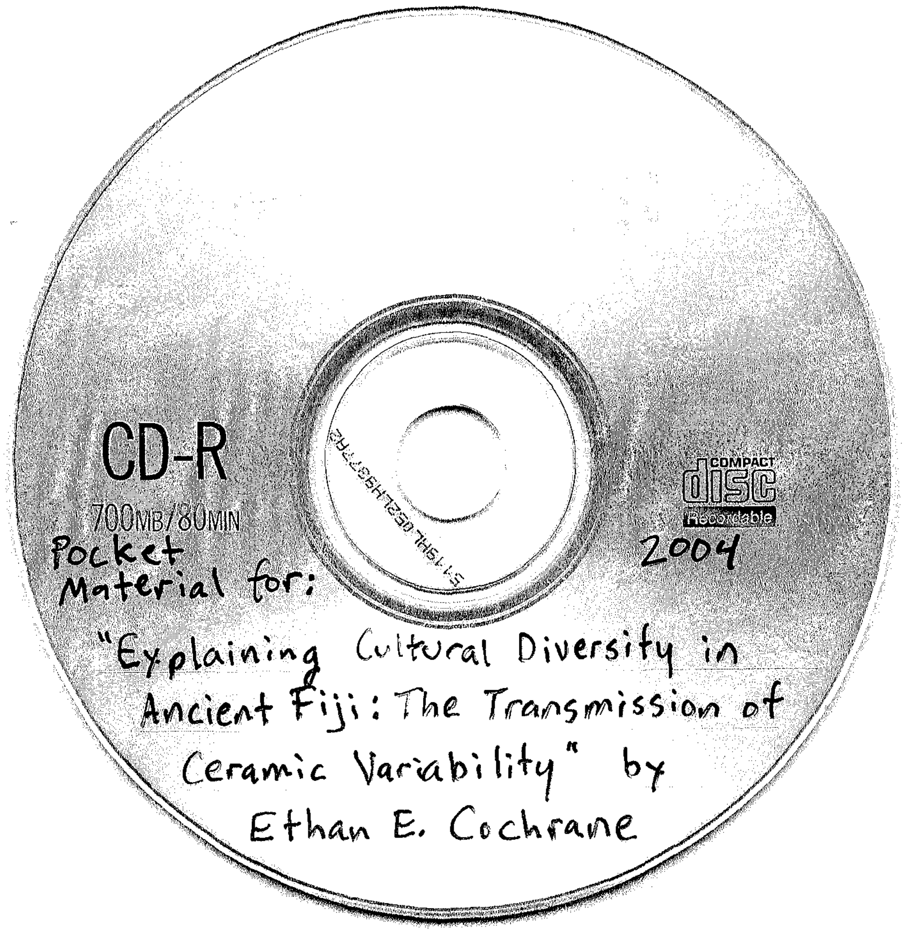
Wylie, A.
2000 Questions of Evidence, Legitimacy, and the (Dis)Union of Science. *American Antiquity* 65:227-237.

Zedeño, M. N.

1994 *Sourcing Prehistoric Ceramics at Chodistaas Pueblo, Arizona: The Circulation of People and Pots in the Grasshopper Region.* Anthropological Papers of the University of Arizona 58. University of Arizona Press, Tuscon.

Zvelebil, M.

1995 At the Interface of Archaeology, Linguistics, and Genetics: Indo-European Dispersals and the Agricultural Transition in Europe. *Journal of European Archaeology* 3:33-70.



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