

**Dynamics of Agricultural Development in Prehistoric Samoa:
The Case of Ofu Island**

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in
Anthropology, The University of Auckland, 2015

Abstract

Agricultural development is intimately tied to the environment and cultural practices, specifically socio-political change. Nowhere are these relationships more clear than on Polynesian islands. Many sequences of agricultural change have now been documented in the region, and their relationships with the environment and cultural change assessed. Most, if not all, of these identified sequences have been described as processes of intensification. Samoan agricultural systems, however, are vastly under researched archaeologically, creating a serious gap in archaeological knowledge of the archipelago. Land use practices in the archipelago are often thought to have been non-intensive, and the assumed prehistoric sequence, built using ethnographic analogy, has been utilized to argue that the process of intensification was not inevitable on all Polynesian high islands. To address this gap, and to determine the nature of agricultural development in the Samoan Archipelago, this thesis examines agricultural development on Ofu Island in the Manu'a Group of American Samoa.

Archaeological research was carried out over the course of two field seasons at three locations on the island, two in the interior uplands (A'ofa and Tufu) and one of the coast (Ofu Village). Results of this field work were utilized to critically explore questions relating to agricultural development on Ofu, specifically how that development can be described and which factors influenced the development. These results suggest that agricultural intensification did occur on the island at some scales of analysis, but alternative processes, such as expansion and innovation, were of great importance. The development of production was impacted by multiple factors, including landscape evolution, the spatial variability of the environment, and socio-political change. This thesis documents how, on one small island, agricultural change resulted in complex socio-political negotiations beyond individual producers, which resulted in a small-scale political economy.

This research contributes at three levels, the local, regional, and theoretical. At the local level, this research fills a serious gap by documenting an agricultural sequence in the Samoan archipelago. At the regional level, this research provides another case study as to the different factors that influence agricultural development in Polynesia. At the theoretical level, this research highlights the multiple paths of agricultural development. Agricultural development is a process imbedded in history, impacted by multiple factors, individuals, and groups.

Acknowledgements

Several individuals contribute to the research process that creates one person's Ph.D. Through the rollercoaster that is graduate studies, I have been particularly lucky to have had the sustained support of my supervisors, family, and friends. I will surely leave out individuals that deserve to be thanked, but I will try to cover the various ways in which I have been helped along the way.

I wish to thank my mom Kris, my dad Terry, my brother Brennan, and my sister Mariah. You never wavered in the support of my aspirations to be an archaeologist, and you always motivated me to do the best I could do, especially in academics. Living in a family of teachers has also helped me find my place. I was lucky to have your support through this whole process, especially when I needed people to talk to during the more stressful periods of graduate studies.

This research would not have been possible without the advice, support, encouragement, and dedicated hard work of Melinda Allen, Thegn Ladefoged, and Jeffrey Clark. I know I was incredibly lucky to have three very supportive and successful advisors who would make time to talk to me about archaeology. They put up with my unbridled energy and excitement during the positive swings in the process, and built me up through the more negative events. I learned how to be a successful researcher through their constant questioning of my interpretations and underlying assumptions. They constantly asked me to go beyond good enough, which meshed with my desire and ambition. The hours of reading and editing that they spent on my work truly paid off for my professional development, and for that I will be eternally grateful. Somehow, Jeff, you have stayed with me since my first year as an undergraduate. Thank you all for believing in me.

For support in the field and permissions to work on the island of Ofu and their land specifically, I extend my thanks to High Chief Misa'alefua Hudson, Manu'a Rep. Toeaina Faufano Autele, Eleloi Misa'alefua, Apelu Malae, Alisana Malae, and Ele'ele Utuone. I also acknowledge the efforts and help of American Samoa Historic Preservation officer David Herdrich, National Park Service ranger Carlo Caruso, and the Malae family of the Va'oto Lodge (Marjorie Malae, Jim Malae, Debra Malae, and Ben McDonough). Fieldwork would not have been possible without the aid of many archaeologists, particularly those from the island and those who took part in field schools: Wayne (So'o) Eliu, Nouata Malae, Ricky Misa'alefua, Carrie Fagerland, Nathan Smith, Allison Aakre, Clayton Knudson,

Amber Schneider, Visessio Gogo Hope Sakaria, Rachel Giesler, and Jeremy Ahlers. Not only did these individuals make the project feasible, but they made it much more fun.

The ideas expressed in this document are an outcome of conversations with many people. Peter Sheppard, Stephanie Day, Donald Schwert, Judith Huntsman, Janet Davidson, David Addison, Alex Morrison, and Ethan Cochrane all aided to improve the quality of this thesis through advice and discussion. The support I received from these individuals is something that will be very difficult to give back. Special mention must be made of my fellow Ph.D. students, who helped me through the ups and downs of the process. While not all can be mentioned by name, special acknowledgement must be made to a few. Gerard O'Regan kept me balanced through very long conversations about connections between historical anthropology and archaeology. Maybe now that I am gone, you can get some work done. Mara Mulrooney and Charlotte Warner helped me through the Ph.D. process with their gracious friendship and constant encouragement.

Finally, this work would not have been possible without the financial support of the University of Auckland through the Doctoral Research Fund (PReSS), the Doctoral Scholarship, and the Faculty of Arts Doctoral Research Fund. Minor funding was also provided by grants from the National Science Foundation (BCS-1260909) and NASA.

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Chapter 1: Introduction

Agricultural development is a complex process where production systems change in tandem with other cultural practices and the environment. The increasing complexity of political systems has long been accepted to co-occur with changing cultivation strategies (e.g., Earle 1978, 1997; Kirch 2010; Morehart and Eisenberg 2010; Stanish 2003, 2004, 2006). Human population fluctuations, either increases or decreases, may accompany changes to strategies of food production (Boserup 1965), and modern environments are known to be the result of long-term changes to agricultural systems (e.g., Balée and Erickson 2006; Lincoln and Ladefoged 2014; Terrell et al. 2003). Given the interconnectedness between agricultural systems, other cultural practices, demography, and environmental contexts, the documentation and explanation of courses of agricultural change is an important research objective for archaeologists throughout the world.

Polynesian islands serve as useful case studies to consider the nature of agricultural development because these island environments can be used as model systems to examine long term ecological and human development (e.g., Kirch 2007a,b; Vitousek 2002) (Fig. 1.1). Polynesian agricultural systems have long been of interest to archaeologists (e.g., Clark 1986; Kirch 1975, 1977, 1982, 1984; Kirch and Yen 1982; Leach 1976, 1979; Riley 1973; Rosendaul 1972; Yen et al. 1972). Indeed, the regional examination of agricultural development and changing cultivation strategies has grown substantially in the past two decades. Renewed interest has resulted in research projects that have explicitly explored questions relating to agricultural development and subsistence change in previously unexamined or less understood islands and archipelagos, such as in the Marquesas, Cooks, New Zealand, and Society Islands (e.g., Addison 2006, 2008; Allen and Craig 2009; Barber 1984, 1989, 2001, 2004, 2010, 2013; Campbell 2001; Lepofsky 1994, 1995; Lepofsky and Kahn 2011), and the re-examination of agriculture on islands where prehistoric sequences had been established, most notably Hawai'i (e.g., Allen 2001, 2004; Field et al. 2010, 2011; Kirch 1994, 2007b; Kirch and Sahlins 1992; Kirch et al. 2004; Ladefoged and Graves 2000, 2008; Ladefoged et al. 2009, 2011; McCoy 2006; McCoy and Graves 2010; McElroy 2007, 2012; Spriggs and Kirch 1992; Vitousek et al. 2004, 2010, 2014).

Strides have been made to understand the variability of agricultural change in Polynesia, but important time periods and archipelagos remain poorly understood.

Specifically, the nature of agricultural change in Samoa is largely unknown. Ethnohistoric evidence has been used to argue that there was continuity in Samoan subsistence practices “particularly from the last half of the first millennium BC until A.D. 1840” (Green 2002:148). Such a situation, if valid, has implications for our understanding of the nature of subsistence change in the region. Though fragmentary evidence is available suggesting that such continuity was not necessarily the case (e.g., Addison and Gurr 2008; Carson 2006; Pearl 2006; Valentin et al. 2011), this study addresses these questions using empirical evidence to critically evaluate the course and nature of agricultural development on the island of Ofu in the Manu’a Group of American Samoa (Fig. 1.2).

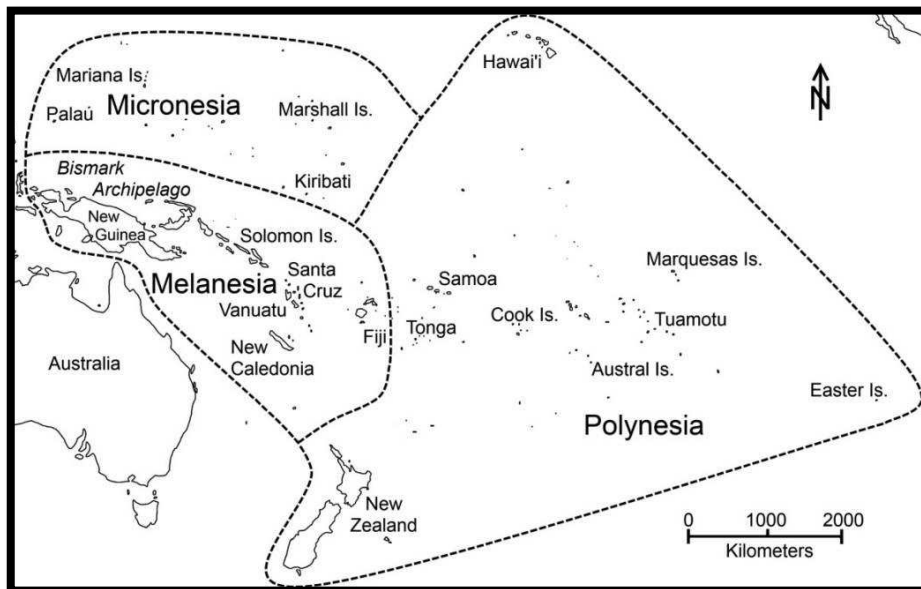


Figure 1.1 Map of the Pacific with major geographical divisions outlined and major archipelagos labelled (from Burley 2013:437, Fig. 1)

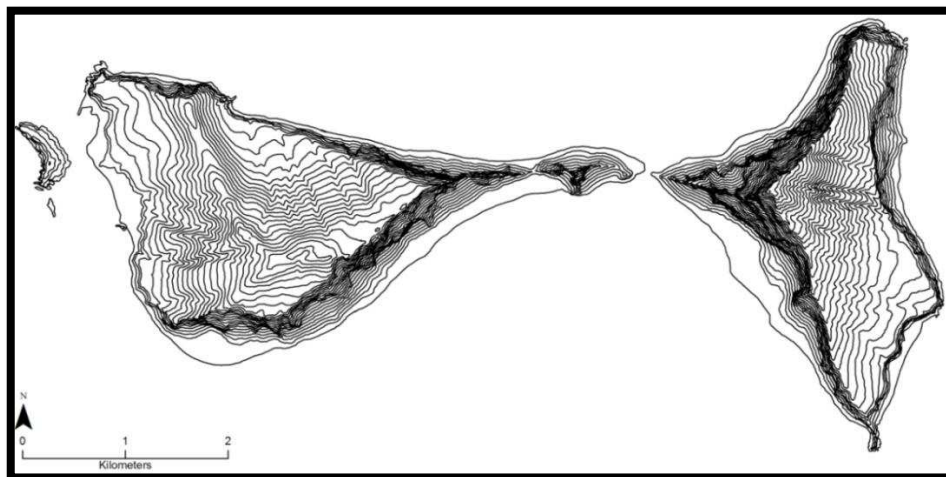


Figure 1.2 Ofu and Olosega of the Manu’a Group of American Samoa (20 m contours)

Agricultural Development

Addressing why cultivation strategies change has been a focus of scientific research since Boserup (1965) originally proposed the concept of agricultural intensification. Defined as the replacement of less labour intensive techniques by more intensive techniques, she argued that the impetus for intensification was population growth. In the classic case, intensification was equated with shortening fallow time that eventually resulted in permanent cultivation. Supplementing Boserup, Brookfield (1972, 1984) and Sahlins (1972) have suggested that social demands led to attempts to increase production. Elite class demands may force farmers to attempt to increase production to fund community level labour projects and their own political ambitions (e.g., Earle 1997; Kirch 1984, 1994; Stanish 1992, 1994, 2003, 2004).

More recently, Morrison (1994, 1995, 1996, 2006, 2007) and Leach (1999) have argued that courses of agricultural change reflect the composite working of multiple processes, not just intensification, at different spatial and temporal scales. The expansion of cultivation strategies at set levels of intensity may be a viable way to increase production or mitigate the chances of subsistence shortfall (Ladefoged and Graves 2008), and individual cultivation strategies are directed toward the accomplishment of different aims. Some aid to increase production while others reduce the variability of resource acquisition, the latter referred to as risk management (Allen 2004; Marston 2011). The recent re-evaluation of the nature of course of agricultural development has led to recognition that the process is complex and historically contingent (Morrison 2006, 2007). In this context, Polynesian islands have served as cogent study areas.

Polynesian Islands as Case Studies

The development of agricultural systems in Polynesia exemplifies the plasticity of human cultural practices, and has been suggested to “represent a case of adaptive radiation” (Kirch 1982:1). Kirch (2006:192) suggested that,

the prehistoric sequences of many Polynesian islands and archipelagos offer a series of “comparative experiments” in which the outcomes of agricultural change may be compared and contrasted with respect to similarity and difference in a range of potentially significant variables.

Colonists to newly discovered islands, which were environmentally varied, initially used a similar suite of crops, techniques, and ideas. This suite, which is referred to as a “transported

landscape” (Kirch 1982), included several cultivation techniques including 1) rain-fed, 2) flooded, 3) irrigated, and 4) tree cropping. From this set, each island developed unique production systems dictated in part by local environmental and cultural conditions.

Vitousek et al. (2004) noted that “by the time of significant European contact...many Polynesian economies were highly intensive, with short-fallow or irrigated agricultural systems supporting dense populations”. These agricultural systems were of such importance in Polynesia that Kirch (2006:192) has asserted that “politically complex social formations...all owed their existence to agricultural economies more often than not highly intensive in the use of both landscape and labor.” Numerous archaeological projects have investigated how individual cultivation systems have developed on islands throughout Polynesia (see Addison 2006; Allen 2001, 2004; Barber 1989, 2004; Clark 1986; Kirch 1994; Kirch and Sahlins 1992; Kirch and Yen 1982; Lidefeged and Graves 2000, 2008; Leach 1979; Lepofsky 1994, 1995; Riley 1973; Yen 1973). These various researchers have examined several components of each agricultural sequence, but most, if not all, of these sequences are defined by a trend of increased labour input and assumed product output within a given land area. This has resulted in the characterisation of these agricultural trajectories as processes of intensification. In fact, Kirch (1984:160, 2006:209) has argued that the intensification of food production was a consistent trend in Polynesia.

However, multiple processes of agricultural development (e.g., Lidefeged and Graves 2008) and many consequences of those changes (e.g., Allen 2004; Lepofsky and Kahn 2011; Lincoln and Lidefeged 2014) have also been documented in the region. Each case study demonstrates the ability of island populations to respond to local environmental and cultural characteristics by changing cultivation strategies. In all cases, environmental variability, whether spatial or temporal, influenced the nature of production systems. Social mechanisms in the form of reproductive norms or political hierarchy interact with the impacts of landscape change and history to result in unique developments. Though knowledge of agricultural development in the region is increasing, key gaps in our knowledge exist that may compromise our understanding of the general processes and unique historic circumstances of agricultural change in the Pacific and beyond. In order to close some of these gaps, this study explores agricultural development in the Samoan Archipelago.

The Research Problem

Unlike most islands in Polynesia, few archaeological examples of agricultural systems have been identified in the Samoan Archipelago (but see Addison and Gurr 2008; Carson 2006; Davidson 1974a; Ishizuki 1974; Quintus 2012). This paucity of data has resulted in a failure to establish a sequence of agricultural change for the archipelago. This is not to say that there is an absence of archaeological evidence, just that there is a lack of research on the topic. Instead of documented processes of change, practices recorded in the historic period, which have been described as non-intensive (Buck 1930:545), have served as an indicator of the prehistoric situation (Green 2002). Carson (2006:6) has argued that “Samoan plant food production systems involve neither intensive labour nor large-scale capital investment...Samoan farmers exercise a degree of planning for low-labour input strategies”. Likewise, Leach (1999:320) stated: “Samoans practised shifting cultivation for three millennia without deforesting their islands or failing to meet their social obligations. They made only minor experiments with wetland ditching (Hiroa [Buck] 1930:547; Davidson 1974:157)”. The inference that the post-contact situation extends back into the prehistoric period, in the absence of archaeological evidence to the contrary, has played an important role in our understanding of Polynesian agricultural systems. Samoa, for instance, has been cited to argue that the intensification of food production was not inevitable in the Pacific (Leach 1999), and may be evidence that the general pattern of intensification was not as widespread as previously thought. Still, it remains to be demonstrated with archaeological evidence that practices documented in the 19th and 20th century AD extend into prehistory in Samoa.

Aims of this Study

This study seeks to contribute at three scales, the local, regional, and global. At the local scale, this is the first study to empirically analyse the historical development of a Samoan agronomic system. The lack of documentation of changing subsistence strategies in Samoa has affected our understanding of the prehistory of the region. Other researchers have echoed this view. Burley and Clark (2003:39), referring to all of West Polynesia, have suggested that the “evolution of subsistence economies have yet to receive the kind of attention they deserve”. For Samoa in particular, Kirch (1999:328) has stated that the lack of documentation of agricultural development is “a serious gap in our knowledge of that [Samoan] archipelago,” and Leach (1999:333) has urged that “a research programme

concentrating on the prehistory of Samoan subsistence would be desirable”. Very little is known of prehistoric subsistence systems and basic questions remain to be answered. Specifically, this study will address whether agricultural intensification occurred in Samoa, what other processes were influential, and what factors caused changes in agricultural systems.

At the regional scale, this thesis will address the differences and similarities between agricultural systems of Samoa and other islands in Polynesia through comparison. Answering this question contributes to our understanding of variability, specifically of what general processes were shared and what factors contribute to differences throughout the region. Ofu Island adds important temporal depth to our knowledge of Polynesian agricultural systems as the eastern extent of Lapita-era island colonisation in Oceania.

The study of Ofu Island also addresses issues surrounding the causes and consequences of agricultural development at a global scale. Specifically, this thesis examines agricultural development as long-term landscape history, providing an opportunity to study historical contingency. The chapters in this thesis are geared toward understanding how agricultural development shaped and was shaped by environmental and cultural variables. This case study considers the role of predictable environmental variability (e.g., cyclones, landslides, and drought), and assesses how such variability impacted the course of agricultural development. Additionally, the presence of a simple chiefdom on the island in the 19th century AD raises the possibility that political change factored into the process of agricultural change. Exploring the role of environment and cultural variables in tandem contributes to our understanding of the processes of agricultural development by studying the multiple aims, outcomes, and consequences of cultivation strategies.

In sum, in examining agricultural development in Samoa, this study seeks to document a course of agricultural development, the general processes that characterise that course (e.g., intensification, expansion), and the aims or consequences of cultivation strategies (e.g., risk management, increased production). I build on the work of Allen (2004), Kirch and Zimmerman (2010), and Ladefoged and Graves (2000, 2008) in attempting to understand and evaluate the variable agronomic practices that developed in locations in response to local environmental and cultural characteristics. This goal takes into account Morrison’s (2006, 2007) suggestion to examine agriculture as a situated process and Leach’s (1999) advice to consider alternative concepts and terms to evaluate variability.

Structure of Thesis

Chapter 2 considers past perspectives on the study of agriculture, expanding on the discussion that began in this chapter. Multiple theoretical concepts useful in understanding alternative cultivation strategies are discussed, including intensification, expansion, risk management. Because these strategies are often affected by the degree or scale of management, relevant literature on the social relations of production is presented. This general discussion then turns to the examination of agriculture and agricultural development in Polynesia, discussing the diversity of cultivation strategies practiced in the islands. The final section of the chapter presents the research design used to study the development of agriculture on Ofu Island.

Chapter 3 presents a summary of the geographical and cultural context of this study, first examining the entire archipelago then focusing on Manu'a. A brief review of Samoan cultural history is presented focussing on the timing of major cultural changes. This is followed by a synthesis of the ethnohistoric and ethnographic political situation in the Samoan archipelago. The next section examines the historic and modern production system of the archipelago. Important crops are discussed and the impacts of hazards (i.e., cyclones, landslides, and drought) are evaluated.

Chapter 4 presents the methods that were employed to collect and analyse data. The field, laboratory, and analysis methods are discussed. Additionally, feature definitions used to classify remains identified in the interior uplands of Ofu are included here.

Chapter 5 presents the results of subsurface investigations conducted on the coast. Results of coring are presented first before discussing controlled unit excavation and backhoe trenches. For each subsurface unit, the results of the particle size analysis are discussed in terms of the depositional history of each area. Radiocarbon dates of each unit are introduced in this section, but a full discussion of the coastal chronology is provided in a single section near the end of the chapter. The implications of these coastal investigations are summarised in the final section with reference to coastal landscape evolution and the use of the coastal flats throughout the cultural sequence.

Chapter 6 presents the results of field work undertaken in the interior uplands. The first section discusses the results of two remote sensing strategies that examined the distribution of archaeological remains at the island scale. The next sections summarise the

results of survey, separating the archaeology of two interior zones, and include information regarding the number, variability, and distribution of archaeological features. The function of feature classes is assessed after the presentation of the archaeology of both areas. The next section summarises results of interior excavation of features, and the final section presents the results of radiocarbon dating.

Chapter 7 synthesises the results of field work on the coast and interior uplands, and discusses the course of agricultural development on the island. This discussion is framed in terms of the changing location, timing, and scale of management of agricultural activities on the island. The final section situates agricultural development on Ofu within relevant environmental and social parameters.

Chapter 8 evaluates the research problem of Samoan agricultural development by addressing the modes of agricultural development on Ofu. The outcomes of agricultural change are addressed, highlighting risk management and the social relations of production on the island. This is followed by a comparison between the sequence of agricultural development on Ofu and sequences documented elsewhere in Polynesia. The final section presents a summary of how this study addressed the aims of the thesis.

Chapter 2: Understanding Agricultural Development

The documented variability of courses of agricultural development has led to the use of several theoretical and conceptual models to study how and why populations employ and change cultivation strategies (e.g., Allen 2004; Erickson 1993, 1999, 2006; Field 2003, 2004, 2005; Kirch 1994, 2007a,b; Kirch and Yen 1982; Ladefoged and Graves 2000, 2008; Marston 2011; Morehart and Eisenberg 2010; Stanish 1992, 1994, 2003, 2004). What this research has identified are general processes that occur in many sequences of agricultural development (e.g., intensification, expansion, disintensification), the multiple consequences or aims of cultivation strategies (e.g., risk management and short-term product increase), and the role of cultural and environmental factors in the creation of unique characteristics of production systems (e.g., political change, environment variability, population fluctuation).

This chapter summarises these different perspectives and discusses important concepts and issues relevant to any study of agricultural development. The first section examines the general processes involved as well as the consequences and outcomes of those processes. These concepts are then linked to the study of agricultural change in Polynesia. A set of general cultivation techniques were employed by all populations in Polynesia, and archaeologists have highlighted causal factors that resulted in changes to those cultivation techniques. The final section outlines the research design used in this study to document and explain the course of agricultural development on Ofu Island.

Perspectives on Changing Agricultural Systems

No concept has been more important in the study of agriculture than intensification. The continual critique of the concept since its inception has led to a greater understanding of the underlying conditions which lead to intensification and the alternative processes that characterise courses of agricultural change.

Intensification and Process

The explicit examination of changing agricultural systems began in the 1960s with the work of Boserup (1965) and Geertz (1963). Boserup (1965) argued for a unilinear progression of agriculture from long-fallow shifting cultivation systems to short-fallow systems with high labour input per unit of land. This process of increased cropping frequency and labour input was termed intensification. Eventually, this would lead to multi-cropped

plots with permanent field boundaries and the more intensified land use practices documented throughout the world, such as irrigation and agricultural terracing. The study of agricultural systems by Boserup led to a new explanation of why and how cultivation strategies changed. In contrast to Malthus (1798), who had argued that changing cultivation systems resulted in population growth, Boserup argued that population growth was the cause of agricultural intensification. To Boserup, population growth acted as a tipping point, in which the response of the society was to develop technologies and strategies that would alleviate population pressures. However, Boserup argued that increased labour input would eventually result in less efficient labour use with declining yields. Kirch (1984:162-165) describes this as an inflection point where yield increases decline relative to increases in labour input. As population increased and as the agricultural system was intensified, output per labour unit was reduced.

Building upon the work and models of Boserup, Brookfield (1972) made explicit the connection between demographic carrying capacity and subsistence change. However, given that lack of congruence between population growth and increased production in some societies, he further proposed that social production, in the form of surplus demanded for ritual or political ends, influenced agricultural development. In a similar vein, Sahlins (1972) argued that the intensification of production was in part the result of changes in the social relations of production by which the domestic mode of production was modified. For both Brookfield and Sahlins, changes to cultivation systems were still based on perceived need, but that perceived need included production for a variety of activities (e.g., subsistence, surplus, and trade). Intensification was the process by which cultivators increased the concentration of production against constant land for different purposes. The seminal definition of intensification by Brookfield (1972:31) is:

Intensification of production describes the addition of inputs up to the economic margin, and is logically linked to the concept of efficiency through consideration of marginal and average productivity obtained by such additional inputs. In regard to land, or to any natural resource complex, intensification must be measured by inputs only of capital, labor, and skills against constant land. The primary purpose of intensification is the substitution of these inputs for land, so as to gain more production from a given area, use it more frequently, and hence make possible a greater concentration of production.

Brookfield (1984) further made distinctions between innovation and intensification. This differentiation was made to distinguish between intensification, which was “burdensome”, and innovation, which “offers the hope of advantage” (Brookfield 1984:35). Genetic changes

to plants or technological inventions that enhance production can be termed innovation (Kirch 1994:19), as they do not require extra labour input to create higher yields. On the other hand, intensification is gaining higher output through existing technologies. Intensification in the classic sense often involved more individuals working a set land area or individuals working harder on the land.

Kirch (1994, 2006) has expanded our understanding of agricultural intensification by including what he calls cropping cycle intensification and landesque capital intensification, the latter originally proposed by Blaike and Brookfield (1987; see also Brookfield 1984). Cropping cycle intensification is intensification in the Boserupian sense of decreasing fallow periods; landesque capital intensification is labour inputs that result in permanently modified environments that increase production over time in fixed land areas (Kirch 2006:194). The investment in landscape modification that increases production over the *long term* is a way to reduce labour, as this creates a more productive system that can be worked and maintained with less labour input in the future. In some ways, landesque modification is similar to the concept of agricultural involution (Geertz 1963), in which an initial investment in labour reduces the need for future systemic change because the system is built to incorporate continued strategies of intensification. The decision to invest in either mode of intensification has implications for future development, which can impact the trajectory of agricultural change.

The development of the intensification concept and subsequent critiques has led to recognition that unilinear models of agricultural development are untenable (Brookfield 2001; Kirch 1994; Leach 1999; Morrison 1994, 1996, 2006, 2007). Multiple courses of agricultural development are possible, not just the unilinear short to long fallow sequence documented by Boserup; in essence, what Morrison (2007:244) referred to as “lived trajectories of change”. In order to document the different courses of agricultural development, Morrison (2006:72) has argued that the process must be placed into historical and cultural context. This historical and contextual approach is particularly relevant because agricultural practices are part of larger landscape histories. Landscapes accumulate the past efforts of human populations, and options for change are limited by historical contingency and what is possible within the system structure (Lansing 2007; van der Leeuw 2013; van der Leeuw and Aschan-Leygonie 2000). The modification of the environment, through niche construction, can change the selective pressures working on human populations (Day et al. 2003; Laland and O’Brien 2010; Lewontin 1982; Odling-Smee et al. 2003). The biological

concepts of developmental constraints, genetic hitchhiking, and cooptation developed by Gould and Lewontin (1979) and Gould and Vrba (1982) may have profound effects on agronomic trajectories. For instance, the modification of existing cultivation strategies is often geared toward a certain goal, but there are always unforeseen consequences as circumstances change. The function(s) of agricultural technologies, for instance, is not static. It is dependent on the environment in which the technology is used, an environment that is dynamic. Relating this back to courses of agricultural development, the consequences of any change to the agricultural system “immediately ramify and create new conditions for production” (Morrison 2007:238; see also Lansing 2007); some over long temporal spans.

Critiques have illustrated that agricultural systems are constituted by several strategies, not all of them the result of intensification. Leach (1999), for instance, has challenged the view that techniques viewed as non-intensive, specifically shifting cultivation, were replaced with more intensive practices over sequences of agricultural change in the Pacific. Nor can intensification be inferred from the presence of intensive cultivation strategies (Leach 1999), since these may have been the first techniques utilised in the location. The characterisation of agricultural development as intensification can only be accomplished by documenting a process of increased labour investment at a set spatial scale.

The documentation of the different courses, causes, and consequences of intensification has led Leach (1999:311) to question “whether the multiple trajectories that intensification has been shown to follow dilute its value to the point that it should be replaced by more precisely defined terms”. While the term remains useful (Allen and Ballard 2001), Brookfield (2001:190) warns that “intensification is only part of the story, and its reductionist explanation can lead away from understanding”. He (2001) has argued that more attention needs to be paid to the other processes of agricultural development, such as diversification, specialisation, disintensification and expansion. These sentiments echo similar arguments made by Morrison (1994, 1995), especially as they relate to expansion. For instance, expansion, the spatial extension of cultivation techniques at a set level of intensity, was a political strategy to increase surplus in both India and Hawai’i, which occurred at the same time that other parts of the production system were being intensified (Ladefoged and Graves 2008; Morrison 1995).

The distinction between intensification and expansion is dependent on the scale of analysis. For a sequence to be labelled agricultural intensification, increased labour input

must be demonstrated at a fixed spatial scale. If this is not demonstrated, only intensive cultivation practices can be identified. Perspectives from different scales can be complementary. Often the scale of analysis is equated with individual plots of land, and analysis at this scale has successfully documented the intensification based on field segmentation (Ladefoged and Graves 2008). In contrast, Stanish (1994) views intensification from a social perspective and has argued that individual polities should be used as the unit of analysis, with increased labour investment into lands owned and worked by a single population viewed as intensification. Populations often occupy a fixed region, which may also be the unit of analysis, as it is for Athen's (1999) land use intensification. This is similar to the definition of diversification used by Morrison (1995), which she argued was a mode of intensification. For islands, this means that one scale of analysis could be the island as a whole. Any increased input of labour across the island can be defined as land use intensification, and when the island is small (less than 10 km²), this analytical scale may be especially relevant. A multi-scalar approach that enables different patterns of increased labour investment to be highlighted at multiple levels is useful, building from the smallest scale up.

Taking into consideration of the discussion above, it is important to define terms. In this study, intensity is defined as the amount of labour necessary to cultivate land employing a specific technique. Agricultural intensification is defined as the *process* of increased labour input into agricultural activities at a fixed spatial and temporal scale. Multiple modes of intensification exist, such as diversification, specialisation, or technological innovation. Agricultural development also includes expansion, the spatial extension of a cultivation technique at a set level of intensity, and disintensification, reduced labour input into agricultural activities at a set spatial and temporal scale. These processes lead to the development of different cultivation strategies. Cultivation strategies are outcomes of agricultural development that may or may not have been explicit aims of producers, specifically stabilised and increased production. These aims and outcomes can be better understood by considering risk management and the social relations of production.

Risk management

Allen (2004) has remarked that the study of agricultural change has, at times, privileged the identification of techniques that increase production over the short-term. Some studies of agricultural development ignore the temporal fluctuation of resource production

(Morrison 1994:139). Depending on the range of variation in production, populations that experience fluctuations might employ cultivation strategies that stabilise instead of enhance yields. Such strategies are usually a response to risk (Halstead and O'Shea 1989). The usage of risk in anthropological discourse is diverse (e.g., Baksh and Johnson 1990; Boholm 2003; Carter 1997; Cashdan 1990:2; Halstead and O'Shea 1989; Hardaker et al. 2004; Henrich and McElreath 2002:172; Kealhofer 2002; Larson et al. 1996; Marston 2011; Mishra et al. 2003; Torrence 2012; Winterhalder 1986), but the term has been defined as the variance of resource acquisition (Winterhalder et al. 1999), or the probability of an undesirable event or a shortfall occurring (Cashdan 1990:3). In essence, agricultural risk management strategies can buffer against shortfalls or reduce the variance of resource production.

Buffers take a variety of forms, but can be grouped into four types: mobility, diversification, physical storage, and exchange (Halstead and O'Shea 1989). In all four cases, these buffer strategies help "lessen the effects of resource variability" (Halstead and O'Shea 1989:3). Populations that employ a mobility strategy, more commonly practiced by hunter-gatherers and pastoralists, seek unexploited patches after a period of exploitation of a prior patch that has resulted in at least some resource deficiency. There are several types of diversification. Spatial diversification is the use of spaced planting areas that may or may not be located within different microenvironments, and can be equated with expansion in some situations (Morrison 1995). Crop diversification refers to the use of multiple crops within the same cultivation regime to guard against crop specific hazards. Technique diversification is employed to exploit multiple niches utilising more than one cultivation technique. Physical storage, which can also be referred to as temporal diversification, is a method of saving portions of harvests for future use. This is particularly effective when the population can overproduce in good years (Marston 2011). Finally, exchange enables the use of resources from a large geographic area at different times of year. It is similar to mobility, but instead of moving from place to place individuals exchange their resources for the resources of others.

Some risk management techniques directly reduce the temporal fluctuation of resource production by limiting sources of variability in the environment. This can be accomplished through the construction of agricultural infrastructure. Studies that define risk management as decreased variance in resource production involve the examination of subsistence acquisition strategies as rational decisions that affect evolutionary fitness and long term survivability (Allen 2004). This can be illustrated using examples from evolutionary ecology. Frank and Slatkin (1990:244) have noted, "that it is not just good

performance, on the average, that matters...but that variation in performance also plays an important role in determining long-term evolutionary trends”. In this perspective, risk is defined as “variation in the outcome of behaviour” (Winterhalder et al. 1999:302). With risk, the probability of any one outcome occurring is known, and the sources of variation (e.g., environmental and cultural hazards) are also commonly recognised. Risk is distinguished from uncertainty in that uncertainty develops when the probability of any outcome occurring is unknown. Uncertainty can impact the ability of organisms to make decisions, but it is rare that humans have total uncertainty as probability estimates are within our mental capabilities and multiple estimates can be analysed to isolate the best action (Cashdan 1990:2; Henrich and McElreath 2002:173; Real and Caraco 1986:373).

Risk prone groups are those that favour “behaviors linked to unpredictable over more certain outcomes” while risk averse individuals avoid unfavourable behaviours in favour of certain ones (Winterhalder et al. 1999:303). The empirical analysis of these concepts in evolutionary ecology is structured to present experimental organisms (e.g., *individual* hummingbirds or rats) with two options, one that provides a variable food source and another that provides a constant amount of food. The yield of the variable choice ranges from well above the minimum daily need to below that survival threshold. The yield of the control is never as high as the maximum yield provided by the high variance choice, but always provides enough for survival.

Researchers have proposed numerous models based on results of experiments, but the most widely utilised is the Z-score model or equation (Caraco 1980; Stephens 1981; Stephens and Charnoz 1982; Stephens and Paton 1986). The z-score model can be graphically displayed as the following, where R_{\min} is the survival threshold, μ is the mean of resource acquisition, and σ is the standard deviation:

$$Z = (\mu - R_{\min})/\sigma$$

The z-score model predicts that the benefits of being risk prone and risk averse are dependent on context (Caraco 1980; Real and Caraco 1986). The model is built on the assumption that all organisms act to limit the chances of falling below a survival threshold. The variance and the mean of resource acquisition interact through time, and it is the interaction that influences decision making. These assumptions are supported by experimental results (summarised in Real and Caraco 1986). When given the choice between a high variance return that can fall below requirements and one with a low variance return

that always meets nutritional requirements, most animals choose the low variance option. However, as the mean of the high variance return is increased, to the point where the lowest or close to lowest return meets daily requirements, animals tend to favour the high variance option. The model is very simplistic and limitations have been noted (Winterhalder et al. 1999:309), but it has substantial explanatory power. Based on experimental results, Marston (2011) has argued that the model has implications for the use of different agronomic strategies (Fig. 2.1).

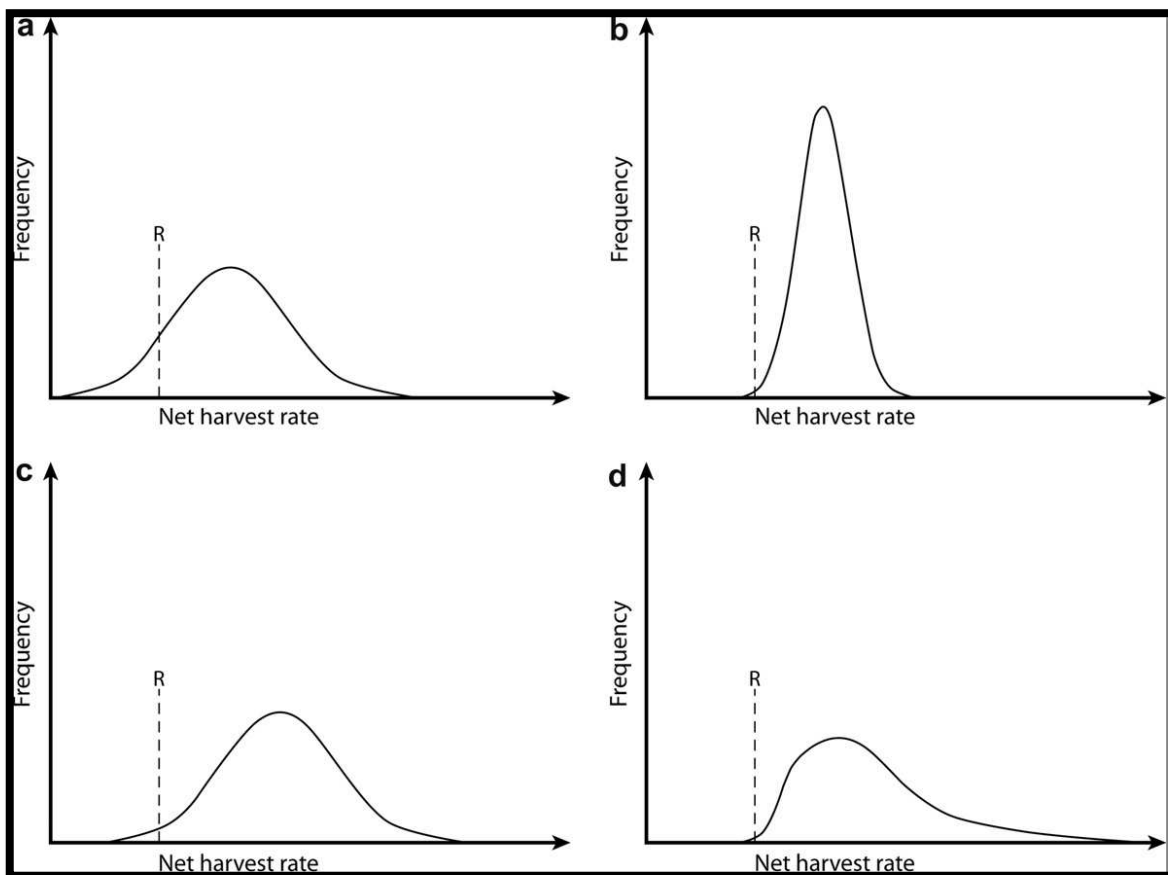


Figure 2.1 Z-score implications of different agronomic strategies (From Marston 2011:192). R represents the starvation threshold of a population where a) a strategy with moderate kurtosis, a mean higher than the survival threshold, but a range that extends below that threshold (base case), b) reduced variance strategy with high kurtosis and a mean above the starvation threshold (variance minimisation), c) a strategy with a large range but the range is greater than the starvation threshold (e.g., overproduction), and d) a strategy with a high mean and low kurtosis with a positive skew (e.g., irrigation)

Along similar lines, explicitly using principles of bet-hedging (see Hunt and Lipo 2011; Madsen et al. 1999), Allen (2004) used the assessment of risk to study agricultural development in Hawai'i. She has argued that strategies of short-term increased production, or

product maximisation, can be beneficial when the environment is stable or when the population is significantly below the carrying capacity of the environment and technology. When the environment is stable, the probability of a yield shortfall is low, which enables the practice of risky behaviour. Variance minimisation strategies are beneficial in variable environments when a population is in danger of exceeding carrying capacity. These strategies act to limit sources of variation in the environment such as drought, cyclones, or flooding, thereby reducing the probability of yield shortfall. Without variance minimisation that stabilises the food supply from year-to-year, sufficient resources are only acquired in good years. Production can fall below carrying capacity when “lean” years occur and hazards result in decreased yield. This might result in population decline or complete extirpation. Put another way, decisions to invest in techniques that stabilise yield reduce food available relative to other strategies that would have maximised productivity over the short term. This limits population growth and maintains a population level that can be supported by the production system (Allen 2004:206-207). The intersection of these two outcomes (i.e., yield stability and sustainable population levels) means that over the long term the probability of population sustainability is increased.

Social Relations of Production

As noted above, the aims or outcomes of agricultural development are tied to social relations. Cultivation is often implemented by households in the domestic mode of production (Stanish 2004:10). In Sahlins’ (1972) view, based on work of Chayanov (1966), this domestic mode of production is one characterised by household underproduction centred on the cultivation of food for subsistence, as opposed to social purposes. Strategies that increase production at the level of the household, whether by expansion or intensification, may be a response to population growth (à la Boserup 1965).

Still, there is little doubt of the influence of domestic modes of production on courses of agricultural change (Lepofsky and Kahn 2011), and evidence points to the ability of small-scale producers to create and maintain complex production systems (Earle 1978; Erickson 1993, 2006; Feinman 2006; Lansing 2007, Netting 1993). The household farmer may not attempt to produce surpluses beyond subsistence needs, but he or she will try to minimise costs of food acquisition. The minimisation of costs may include capital investments in the landscape, even if only to satisfy household subsistence (Netting 1993:299). The farmers themselves hold valuable ecological knowledge that may be important for efficient and

sustainable land management (Lepofsky and Kahn 2011). The appreciation of domestic modes of production in courses of agricultural development is important because, as Morehart and Eisenberg (2010) discuss, the practice of cultivation is undertaken at a local scale and in the hands of the farmer.

Even so, individual farmers or households are situated within wider socio-political matrices. Though highlighting the organizational and managerial capabilities of farmers in Bali, Lansing (2007) clearly illustrated the connection between production and social negotiation. In some instances, these matrices of social relations can result in economic negotiations between elites and households. Interest in the control of wealth by leaders can be traced to Marx and Marxist approaches (see McGuire 1992). Most archaeological studies of the influence of social complexity on courses of agricultural development highlight the influence of staple finance systems that extract resources for political purposes (Earle 1997; Johnson and Earle 2000). Sahlins (1972:140) recognised that “the development of rank and chieftainship becomes, *parsi passu*, development of productive forces”, creating a political economy. Hirth (1996:205) defined the political economy “as that sector of the economy that extracts surplus from subsistence households and that is used to finance social, political and religious institutions” (see also Johnson and Earle 2000:24-27). From the political economy perspective of Stanish (2003:22), “the key process is one in which control of some wealth shifts from domestic groups to larger and stronger organizations”.

While technologically complex agricultural systems might have been constructed by households or individual farmers, certain technologies (e.g., walls, irrigation systems, terraces, or even storage facilities) may have enabled future management by elites (e.g., D’Altroy and Earle 1985; Earle 1978, 1997:85; Ladefoged and Graves 2008). Morehart (2010:78) noted that “intensive strategies and capital investments of local groups create conditions in which they can more easily be controlled by power-holders seeking to finance the political economy”, and “smallholders can establish the conditions for their own potential exploitation” (Morehart 2010:89). For instance, water control technology can be constructed without elite management (Lansing 2007), but such engineered landscapes *present opportunities for* management. When different cultivation techniques have different productive capacities, social bottlenecks may be created that can be appropriated and controlled by leaders, creating a system of unequal access to more productive lands (Earle 2011a,b). The control of water can be a particularly significant bottleneck in societies practicing large scale irrigation. When water is restricted by the working of channels and the

spatial variation in stream systems, the configuration presents an opportunity for the control of a resource that enables high resource productivity (Morehart 2010:88). The appropriation and control of production systems or resources can be the source of wealth and power that contributes to the ability of leaders to retain influence (Earle 1997). The significance of the high priests of the Balinese water temples owes much to their role in managing water used in agricultural production through the agricultural calendar, even though farmers themselves managed and worked the land on a daily basis (Lansing 2007).

The development and use of more intensive agricultural systems enable an elite class to control and extract surplus, funding political ambition or mitigating group risk (e.g., Earle 1997; Kirch 1984; Ladefoged and Graves 2008; Spencer et al. 1994; Stanish 1994, 2003, 2004, 2006, 2007; Wittfogel 1957). Control of labour for construction and cultivation was made possible by social factors ranging from ideology to force (Earle 1997). Surpluses generated and then controlled by elites could be funnelled into political action, such as corvée labour projects for temple construction or expansive warfare. The cultivation of land conquered by groups, and appropriated by warriors to elites, could then become avenues for increased production through the expansion of cultivation techniques at set levels of intensity (Kirch and Sahlins 1992).

Therefore, in courses of agricultural development, it is important to recognize that the motivations behind changing cultivation strategies are complex, influenced by multiple parties (e.g., Janusek and Kolata 2004; Lepofsky and Kahn 2011; Morehart 2010; Morehart and Eisenberg 2010). Cultivation is an activity that is socially embedded in economic negotiation. Farmers work within social constraints created by elites, and elites rely on farmers to cultivate the land. The accumulation of wealth and power via agricultural production not only relies on a leader's ability to control systems of production, but also on the ability of farmers to actually produce beyond subsistence needs. Certain cultivation strategies or techniques also persist beyond a single political regime that had, at one historic moment, taken control, and these strategies or techniques can be coopted by future groups for subsistence or political reasons. This creates "historical flexibility" in production systems (Morehart and Eisenberg 2010:16). An exclusive focus on farmers or elites elides the importance of social interactions that occur during courses of agricultural development. Such a view is recognised by Erickson (1993:411) in the case of raised field systems in South America, wedding aspects of household production and social control:

What raised fields and other landscape capital systems did was to tie farmers to the land, making them relatively immobile and subject to labor taxes and tribute. Such a situation is beneficial to the state in that such farmers can easily be controlled and labour and goods can easily be expropriated for the elite's purposes. As long as the tribute flowed from the local communities, it would not be in the state's best interest to meddle with well-established and efficiently functioning raised field agriculture.

Summary

As Allen (2004:206) notes, the process of agricultural development:

may take a variety of forms (e.g., increased labour and capital inputs, specialisation, diversification, and...expansion), may be directed to different purposes (e.g., basic subsistence, generation of surplus, risk management), and may have varied outcomes (e.g., productive increases, enhanced stability, or even agronomic failure).

Because of its complexity, agricultural development can be most productively studied as a process that is situated within a wider ecological and cultural framework. The process and outcomes of agricultural development are dependent on several factors. It is essential to first identify general patterns of change in the location, importance, and management of agricultural systems, and then analyse the links between those patterns and wider cultural and ecological characteristics. This study seeks to conduct such an analysis on a Polynesian island, locations used as model systems for the study of archaeological and ecological questions (Kirch 2007a; Vitousek 2002).

Variability of Agricultural Development in Polynesia

The concept of agricultural intensification has been used to describe most documented sequences of agricultural change in Polynesia. In general, Kirch (1982, 1984, 1994) has argued that Polynesian agricultural development involves processes of adaptation, expansion, and intensification that employed a mix of arboriculture, rain-fed, irrigated, and wetland techniques. However, many researchers, Kirch included, have demonstrated that courses of agricultural development were variable (e.g., Addison 2006; Kirch 1994, 2007b; Ladefoged and Graves 2008; Leach 1979; Lepofsky 1994; Lepofsky and Kahn 2011), all including a range of cultivation strategies that are a result of different cultural and environmental characteristics (e.g., Allen 2004; Kirch et al. 2012; Ladefoged et al. 2009; Lee et al. 2006; Vitousek et al. 2004). This section briefly discusses features of cultivation techniques and agricultural development in Polynesia.

Arboriculture

Some degree of tree cropping was practiced on most Polynesian islands, and the origin of the activity dates before the human colonisation of Remote Oceania (Kirch 1989). The practice was apparently supplemental but important in most places (Lincoln and Ladefoged 2014), and arboriculture became a significant component of production systems of the Marquesas Islands (Addison 2006; Huebert 2014; Kirch 1994:304-305), the Society Islands (Lepofsky 1994), and Tikopia (Kirch and Yen 1982). The cultivation of tree crops (e.g., breadfruit (*Artocarpus altilis*) and coconut (*Cocos nucifera*)) enables an efficient use of the landscape by increasing the vertical capacity of the production system (Latinis 2000:50). For Latinis (2000:43) tree cropping is a long-term landscape investment that is a more risk averse response to environmental variability relative to practices with short-term payoffs (see also Terrell et al. 2003).

For Tikopia, Kirch (1994) argued that arboriculture was the chosen path of intensification, the development of which occurred relatively late in the prehistoric sequence (~ 15th century AD). Economic trees (e.g., breadfruit and coconut) became a sustainable resource that reduced slope erosion and helped to maintain avian biodiversity by providing increased habitat (Kirch 2007b; Kirch and Yen 1982). Kirch (1994:304) summed up the nature of intensification in Tikopia: “through a particular combination of historic contingency, human choice, and environmental constraint, the Tikopia gradually evolved a highly intensive, multistory, system of orchard gardening”. Using botanical evidence (e.g., charcoal), Huebert (2014) has documented a similar sequence of landscape domestication in the Marquesas Islands. Here, breadfruit was likely cultivated shortly after island colonization, but was spatially variable. The crop only became more important in the subsistence system after the 15th century AD, which may be tied to the ability to store the crop to mitigate the risk of production shortfalls. However, tree cropping could not be practiced everywhere. Breadfruit and coconut, the two most important tree crops in the region, grow well in the tropics but can be difficult to cultivate in the subtropics. In places such as Rapa, tree crops never became a significant part of the subsistence economy given the difficulties involved in their cultivation in such an environment (Anderson et al. 2012).

Rain-Fed Dryland Cultivation

Rain-fed cropping techniques were variable and involved the cultivation of a wide variety of crops, most notably yams (*Dioscorea* spp.), sweet potato (*Ipomoea batatas*), taro

(*Colocasia esculenta*), and banana (*Musa* spp.) (Kirch 1991b:120-121,1994). The most widely spread technique was slash-and-burn shifting cultivation. The documentation of these strategies is difficult, but they had a marked impact on the environment. Forest clearance associated with shifting cultivation caused erosion and vegetation change, and these proxies are useful for studies of agricultural change (e.g., Athens 1997; Athens and Ward 1993; Athens et al. 2002; Clark and Michlovic 1996; Kirch 1996; Kirch and Hunt 1993b; Kirch and Yen 1982; Kirch et al. 1992; Lepofsky 1994; Mann et al. 2003; Pearl 2006). Though shifting cultivation is often treated negatively in reference to environmental degradation and equated with the idea of “future eaters”, it can be sustainable and low impact in environments of low population density when used efficiently (Geertz 1963:15-28). Bayliss-Smith (1985) showed that shifting cultivation can be highly productive per unit of labour in tropical environments, and Geertz (1963:16) argued that for tropical shifting cultivation:

In ecological terms, the most distinctive positive characteristic...is that [shifting cultivation] is integrated into and, when genuinely adaptive, maintains the general structure of the pre-existing natural ecosystem into which it is projected, rather than creating and sustaining one organized along novel lines and displaying novel dynamics.

Such a situation can be accomplished through the implementation of the multi-cropping of root crops (e.g., yams and taro), herbaceous crops (e.g., banana), and tree crops (e.g., breadfruit and coconut), a practice which is known ethnohistorically from several islands (Addison 2006; Carson 2006; Kirch 1994; Kirch and Yen 1982; Lepofsky 1994; Yen 1973).

A sequence of changing depositional patterns is not a marker of the intensification process (Kirch 2006), but it does aid in the identification of the expansion of shifting cultivation systems. Thus, while land clearance and vegetation change reflecting cultivation is well-documented in the botanical record of many islands, the importance and practice of shifting cultivation through time throughout the region is poorly understood. On many islands, shifting cultivation was among the first techniques employed (e.g., Kirch 1994, 1996; Kirch and Hunt 1993b; Kirch and Yen 1982; Lepofsky 1994; McCoy 2006). Leach (1999) suggested that the technique maintained importance through the prehistoric sequence of most islands, and Yen (1973) documented the practice ethnographically on the small island of Anuta alongside more intensive techniques. It seems reasonable to suggest that this situation was not rare, and it is likely that shifting cultivation had a long history on many islands in the region along other techniques.

More intensive rain-fed dryland cultivation systems often involved the use of permanent plot markers. In Hawai'i, dryland agricultural development has been documented by the examination of the temporal patterning of stone and earthen alignments (cf. walls, embankments, rows) in expansive field systems (e.g., Allen 2004; Clark 1986; Kirch 1984; Kirch et al. 2004; Ladefoged and Graves 2000, 2008; Ladefoged et al. 2003; McCoy 2006; Rosendaul 1972). These alignments functioned in multiple ways, such as defining plot boundaries and limiting wind-caused erosion and evaporation (McCoy 2006; McCoy and Hartshorn 2007). Ladefoged and colleagues have demonstrated that the development of the leeward Kohala field system constituted by these alignments combined processes of expansion and intensification, both of which were important factors that effected the social relations of production (Ladefoged and Graves 2008; Ladefoged et al. 2009). Most developments in the system occurred in late prehistory, in the 16th century AD and later, with some use of the landscape as early as the 13th century AD (Ladefoged and Graves 2008:778-779; cf. Dye 2011). Such field systems are known from most leeward environments on the youthful islands of the archipelago, though the temporal development of each system is slightly different (Allen 2004; Clark 1986; Kirch et al. 2004; McCoy 2006).

Systems of earthen and stone alignments, or embankments, have been identified elsewhere in Polynesia as well (e.g., Barber 2004; Bell 2012; Bulmer 1989; Kirch 1994; Jennings and Holmer 1980a; Leach 1976, 1979; McFadgen 1980a; Stevenson et al. 1999; Sullivan 1985). On Alofi in West Polynesia, Kirch (1994:237-241) identified stone alignments that he interpreted as field boundaries, but did not study them in detail. In Samoa, a series of stone alignments, which appear to have been built in the 15th century AD or later (Jennings and Holmer 1980b), have been identified that may have served to demarcate garden areas, though these were closely associated with residential features as well and may not have served an agricultural function at all. In New Zealand, stone and earthen alignments are known from several contexts (Barber 2004:177-181), but the most studied are those in Palliser Bay. Here, Leach (1976, 1979, 1984) demonstrated that infrastructural developments in gardening first occurred in the 13th century AD and expanded thereafter, taking the form of terraces, stone alignments, and mounds. These areas were then abandoned by the 16th century AD or later. Similar evidence of stone alignments has been identified in the Auckland region, which Sullivan (1985) suggests saw a period of expansion in the 14th-16th centuries AD. Additionally, multiple phases of field expansion and intensification have also been documented for Pouterua by way of a relative dating method based on the spatial relationships

among alignments (Bell 2012). Leach (1999) warns, though, that equating walls found in New Zealand with those from Hawai'i is problematic, suggesting that they might represent markedly different cultivation strategies based on differences in scale.

Dryland terracing is common on Polynesian high islands (e.g., Allen 2004; Fuery 2006; Kurashima and Kirch 2011; Lepofksy 1994; Lepofsky and Kahn 2011). As Barber (2004:182) pointed out, specifically in reference to New Zealand, terracing is to be expected in environments that have limited areas of low relief. Often, these features are difficult to distinguish from irrigated systems (Kirch 2006:197) or residential features (Barber 2004:181); though, certain physical characteristics may support one function over another. For the Society Islands, Lepofsky (1994:256) posited that some dryland terraces may have served as house gardens for tuber cultivation or arboriculture, an interpretation she based on the absence of material reflecting residential use and the presence of garden soils and charcoal. Allen (2004) suggested that terracing aided to stabilise slopes and improve growing conditions in leeward Hawai'i, with their agricultural function suggested by a lack of artefacts. Rain-fed terraces are also known from colluvial slopes of windward valleys on multiple islands of the Hawaiian Archipelago, which Kurashima and Kirch (2011) documented as important components of production systems. Ethnographically documented dryland terraces on the Polynesian outlier of Anuta created permanent cultivation spaces (Yen 1973:124), which allowed more efficient management when needed.

Few of these features have been dated. In New Zealand, the technique may have been practiced as early as the 15th century AD (McFadgen 1980b:5). In the Society Islands, these features appear to have been built as early as the 13th century AD, and then expanded thereafter (Lepofsky and Kahn 2011:324). Terraces were some of the first infrastructure built in the Kona field systems on Hawai'i Island, the earliest examples dating to as early as the 15th century AD (Allen 2004:209).

The use of lithic mulches has been reported from Rapa Nui and New Zealand (e.g., Barber 2004:185-188, 2010; Bassett et al. 2004; Ladefoged et al. 2013; McFadgen 1980b; Stevenson 1997; Stevenson et al. 1999; Vitousek et al. 2014). Such additions to garden soils aid in regulating soil moisture and temperature, enhancing growing conditions for tropical plants. Other materials may have been used as mulch, such as shell (Barber 2013). On Rapa Nui, lithic gardens appear to have been developed by the 15th century AD, expanding thereafter (Stevenson et al. 1999). Ladefoged et al. (2013) have demonstrated that these

gardens are distributed in reference to soil nutrient levels, with few garden areas apparent above elevations of 350 masl because of high rainfall that increases nutrient leaching (see also Wozniac 2003). In New Zealand, soils with lithic additions have a wide distribution over both the north and south island (Barber 2004:188), and variation in particle size and density have been noted (Furey 2006:46). The chronology of these modified soils is somewhat uncertain, but most do not appear to pre-date the 15th century AD, and many more than likely date later (Furey 2006:50). Barber (2010:82-83), for instance, noted use of the technology in the South Island in the 16th century AD.

The use of drainage ditches in dryland settings is also known for New Zealand, among other places. (e.g., Barber 2004:182-183; Davidson 1974a; Furey 2006; Ishizuki 1974). These are different than raised or island bed systems found in wetland environments, and, for Spriggs (1982:10), the difference between raised beds and drainage systems is the lack of a supply canal in the latter. Dryland drainage ditches likely functioned to reduce soil erosion and protect crops from high energy precipitation run-off (Furey 2006:36-39). In several locations in the north island of New Zealand cross slope ditches that connected to drains that parallel the slope likely acted to drain water around cultivation plots (Barber 1989:30-36). In some examples, ditches converge downslope and Barber (1989:32-33) has posited that these may have been used for the reticulation of water to cultivate crops situated downslope (discussed below). The chronology of drainage ditch systems in New Zealand is poorly understood. Some may have been constructed as early as the late 13th century AD, but it is more likely they were built in the 16th-17th centuries AD (Furey 2006:38). Morphologically similar systems have been documented in Samoa dating to the last 500 years before European contact (Ishizuki 1974).

The cultivation of crops in pits or depressions has been identified in a range of environments (e.g., Stevenson et al. 1999; Yen 1973), both wet and dry, but the technique is most commonly associated with atoll environments (Chazine 2012; Kirch 1991b:121). Because of the relative lack of standing or flowing freshwater in atoll environments, pit cultivation involves the excavation of a pit to the natural freshwater lens. These pits are filled with compost or mulch to create an artificial gardening horizon to enhance growing conditions. The technique has a long antiquity in Micronesia (Weisler 1999, 1st-2nd centuries AD), where it is most common, but extant systems have also been identified in Anuta (Yen 1973), Tokelau (Quintus, unpublished data), and in the Tuamotu Archipelago (Chazine 2012).

The cultivation of crops in pits or depressions is also known from Rapa Nui (Stevenson et al. 1999), where they are technologically different than those of atolls. This technique does not seek to tap into groundwater, but rather it uses a depression to protect crops, which may be filled with lithic and organic mulch. To cultivate the planting area, smaller circular depressions are dug through the stones within the feature to the soil layers below. These planting areas presumably act to reduce variation in soil temperature and decrease wind speed to limit evapotranspiration (Morrison 2012:359-362).

Irrigation, Pondfields, and Wetland Cultivation

The cultivation of taro in irrigated and wetland environments, either natural or artificial, produces some of the highest yields of any technique in the region (Kirch 1991b:122), and can take a variety of forms (e.g., Barber 2001; Clark 1986; Kirch 1977; Kirch and Lepofsky 1993; Riley 1975). The most technologically complex form is flooded pondfield systems. These systems have been identified on various islands in a number of island groups (e.g., Addison 2006; Bartruff et al. 2012; Bollt 2012; Campbell 2001; Kirch 1994), and they are especially well-documented in Hawai'i (e.g., Allen 1991, 1992; Clark 1986; Earle 1978; Kirch and Sahlins 1992; McCoy et al. 2011; McElroy 2007; Riley 1973, 1975; Spriggs and Kirch 1992; Tuggle and Tumonari-Tuggle 1980). The construction of pondfield irrigation systems is a classic case of landesque capital intensification, in which heavy labour costs are invested in construction but the future costs of maintenance and continued production are limited. These systems are constituted by a series of terraces and canals that enable the flow and accumulation of water out of tributaries. While the construction of irrigation systems is often equated with the intensification processes, the identification of the process requires that a less intensive cultivation practice was present before the construction of the systems (such as in Yen et al. 1972). Some examples of pondfield construction represent processes of expansion (Leach 1999).

For Futuna, Kirch (1994) suggested the development and expansion of pondfield irrigation systems occurred after lowland alluvial valley infilling in the latter half of the first millennium AD, with more infrastructural investment documented in the 17th-18th century AD (Kirch and Lepofsky 1993:186). Addison (2006, 2008) argued that wetland cultivation might have been a useful technique at island colonization in the Marquesas, though the only dates available from pondfields (n = 2) demonstrate construction in 15th century AD at the earliest (Addison 2006:733). A similar chronology has been inferred from Mangaia, where

wetland cultivation was only possible after the infilling of alluvial valleys in the 14th century AD (Kirch and Lepofsky 1993:191). The construction of pondfield infrastructure in Hawai'i was underway shortly after the human colonization of the archipelago (12th century AD and later; Allen 1992), expanding thereafter (McElroy 2007). Some systems were not built until after historic contact, such as those of Anahulu Valley, as part of renewed investment motivated by chiefly territorial expansion (Kirch and Sahlins 1992).

Simpler irrigation systems, constituted by stonefaced terracing in streams without artificial canal systems, have been identified in the Society Islands (Lepofsky 1994) and in Hawai'i (Clark 1986:539-542; McCoy and Graves 2010, 2012; Riley 1973, 1975:87). These features are barrage systems that take advantage of the natural topography with a series of dams that enable cultivation. These may be referred to as integrated systems using components of rain-fed and flooded techniques (Clark 1986:539). Clark (1986) documented agricultural systems in Waimea on Hawai'i Island that were built in streams or gullies but did not include artificial channels, in addition to simple irrigation systems that channelled surface run-off to non-flooded cultivation plots. McCoy and Graves (2010) argued that this form of cultivation was an innovation in Hawai'i to take advantage of specific environments, developed in the 15th century AD or later. For the Society Islands, Lepofsky (1994:258) also documented the late prehistoric or early historic implementation of simple irrigation techniques as well, though this was based on a limited dataset. Comparable systems, though on a relatively smaller scale, may exist on Olosega Island in Samoa, in which a series of terraces were constructed in stream beds (Quintus 2011, 2012). This latter case, however, is more uncertain.

In New Zealand, some ditches transported water into low lying areas, and may better be termed as simple irrigation techniques, though soil excavated to create drains and channels may still have been used to construct cultivation beds (Barber 2004; Furey 2006). Taro cultivation in these reticulate ditch systems may have only been feasible on freely draining soils in the far north of New Zealand (Barber 2001), and other crops have been noted in and around the ditches as well (Horrocks and Barber 2005). As suggested by Barber (1984), at least some ditches may have been used to redistribute water around the garden areas. Dates from systems suggest their construction in the 16th century AD (Barber 1989:38-40).

Wetland techniques also took advantage of natural swamp or marsh lands, a technology identified as island bed or raised bed systems. The use of natural wetlands for cultivation is known from several islands (e.g., Addison and Gurr 2008; Allen 1998; Buck 1930; Kirch 1975; Kirch and Yen 1982; Lepofsky and Kahn 2011:325; Ladefoged 1993:83), but the amount of labour invested in the modification of these natural wetlands is variable. Cultivation in these environments was only possible when the marsh or swamp was freely draining, as crops can rot quickly in stagnant environments; this is the reason why drains were required. Drains were not used to completely remove water from these environments, but to enhance circulation thereby improving growing conditions for hydromorphic crops (i.e., taro) (Kirch 1991b:121).

In Tropical Polynesian and on Polynesian outliers (e.g., Kirch and Yen 1982), the technique involved, and still involves, the excavation of a series of ditches or drains, the material then piled to create “beds” on which crops could be cultivated. The temporal depth of these techniques is unknown, but it is hypothesised that wetland environments were an important cultivation zone at the time islands were colonized (Addison 2008). Some evidence of early use of wetland environments in East Polynesia has been identified on Rapa in the 11th century AD (Prebble and Anderson 2012), but the formation of other wetland marshes occurred after human colonization (e.g., Allen 1998; Clark and Michlovic 1996; Kirch and Yen 1982).

This review of agricultural techniques in Polynesia demonstrates the significant variability in practices throughout the region. This variation is remarkable because of the limited suite of crops cultivated. Populations employed a combination of techniques to meet subsistence and social needs and demands. It is within this sense that some islanders created mosaic cultivation systems and the construction of these different systems can be termed as a process of landscape domestication (Baleé and Erickson 2006; Terrell et al. 2003; Yen 1989). The development and employment of some of these techniques are not examples of intensification, and are better termed as processes of expansion or diversification (Leach 1999; Morrison 1995). Some of these techniques helped to stabilise the production system, while others were meant to increase short term production for surplus. Outcomes of processes of agricultural development were influenced by several factors.

Factors Influencing Agricultural Development in Polynesia

The explanation of courses of agricultural development in Polynesia is complex. Mirroring the rest of world, various frameworks have been proposed that have privileged the role of multiple overlapping factors, specifically population growth, spatial and temporal environmental variability, and socio-political change. No one factor accounts for any one course of agricultural development. This section briefly summarises factors and their posited influence on production in Polynesia.

High resolution demographic estimates are lacking for most islands, but degree of magnitude population growth has been linked to increased production (e.g., Kirch 1994:310-312; Lepofsky 1994). Simply put, larger populations require more food (Kirch 2006:205). Initial changes to agricultural systems, specifically increases in area under production, could be a response to simple population growth. Kirch (1984:193) went so far as to opine: “that population growth was a spur to the intensification of production in all Polynesian islands would seem hardly to require lengthy argument”. Nevertheless, Kirch (1994:312) has also stated that “recognition of the role of demographic pressure...must not lead us to the fallacy of placing the entire explanatory burden...on demographic change”. In Hawai’i for instance, empirical evidence supports the growth of population during the expansion and intensification of agricultural activities (e.g., Field et al. 2010, 2011; Kirch et al. 2012). However, the rate of increased production outpaced this demographic change (Ladefoged and Graves 2008:784; Ladefoged et al. 2008). The pressure of population growth was not the only factor involved in the process of agricultural development.

Since the pioneering work of Sahlins (1958), correlations have been drawn between the size of an island and the complexity of economic and political activities, with smaller islands being less complex. Certainly, the smaller the island the smaller the population that can be supported by the island’s “carrying capacity”. Opportunities for agricultural diversification are limited by the general homogeneity of the environment, and the evolution of landscapes can change the make-up of the ecosystem more dramatically than on larger islands (e.g., progradation changing the ratio of shallow marine to terrestrial lowland environments). Population controls may be necessary to ensure the continued resilience of the people (e.g., Firth 1936 for Tikopia). However, it is important to note that island size may not directly correlate with the amount of arable land (Kirch 2007b), and the entire land area of some small islands could be completely under production (Kirch and Yen 1982; Yen 1973).

The interaction between small island size, population growth, and the subsistence economy can lead to highly intensive cultivation systems, and the historic situation on Anuta may reflect one of the most labour intensive agrosystems in the Pacific (Yen 1973:147). In this way, island size presents opportunities and constraints to agricultural change.

Emphasis has long been placed on the opportunities and constraints presented by variability in the physical environment of individual islands or archipelagos. Of particular importance is the wet and dry distinction between windward and leeward regions of islands and archipelagos (Barrau 1965; Kirch 1984, 1994, 2007b; Riley 1973). This environmental contrast creates dual production systems, dryland techniques dominating the economy of leeward districts of islands and wetland techniques dominating the economy of windward districts. This environmental division resulted in a specialisation in each area on different crops and technologies (Kirch 1994).

Potential for agricultural production differs considerably at more localised scales, owing to rainfall patterns, slope, elevation, and soil nutrient levels (Field 2003; Kirch 2007b; Kirch et al. 2004; Ladefoged et al. 2009, 2010, 2011; Vitousek et al. 2004, 2010). Some environments were better suited for, or necessitated the use of, particular techniques (Barber 1989), and cultivation in more marginal areas presented a greater risk of yield shortfall (Allen 2004; Ladefoged and Graves 2008; Lee et al. 2006). These specific environmental situations can result in circumscribed production zones (Ladefoged et al. 2009, 2013), which were subject to cultural preferences as well (Lincoln and Ladefoged 2014). In Hawai'i, intensive dryland agricultural production was largely constrained by the relationship between substrate age and precipitation, with older substrates that receive more rainfall less likely to be able to support cultivation (Ladefoged et al. 2009). In New Zealand, wet land ditching is restricted to the North Island, where higher annual temperature and reduced fluctuation could support taro growth (Barber 2001).

The temporal changes in landscapes and climate also influenced agricultural development. General subsistence changes have been explained by coastal landscape evolution; the impact of both human-induced sedimentation and sea level fluctuation (e.g., Allen 1997, 1998; Kirch 1988; Kirch and Yen 1982). A reduction in reef area caused by progradation in Tikopia eventually closed a saltwater embayment, which decreased the abundance of marine resources and could have been one factor in an increased focus on terrestrial food production. This sequence eventually led to an intensive orchard garden

system (Kirch 2007b; Kirch and Yen 1982:330). For New Zealand, Leach and Leach (1979) argued that the interaction between declining climate and its effects on food production and marine resource exploitation resulted in the abandonment of more marginal areas in the 16th century AD.

Landscape change can improve productive capacity as well. It is now well-documented that human-induced geomorphological change created opportunities for cultivation in previously unused areas (e.g., Kirch and Yen 1982; Spriggs 1981, 1997). Erosion of slopes has often led to the infilling of ancient bays or lakes and the creation of arable wetlands (Clark and Michlovic 1996; Kirch 1996; Kirch and Yen 1982). The most pronounced effect of this was the formation of environments suitable for irrigation on some islands (Kirch 1994:242, 280). The formation of marshes conducive to the cultivation of root crops is explained in such a way as well (e.g., Allen 1998; Clark and Michlovic 1996; Dickinson 2014; Hunt and Kirch 1988).

The deposition of terrigenous sediments also expanded land suitable for dryland cultivation. In Hawai'i, Vitousek et al. (2003) have documented that the fertility of colluvial slopes can be increased by the introduction of nutrients through erosion, and the dynamics of landscape evolution can make soils on even the oldest substrate fertile. Intensive cultivation practices are documented on these slopes from multiple islands in the Hawaiian Archipelago, and the technique may have been an important component to valley production systems (Kurashima and Kirch 2011). On smaller islands, productive soils are created on coastal flats when terrigenous sediments are mixed with organic remains of past occupation and calcareous sand and coral. Such anthropogenic soils are well-documented from Tikopia (Kirch and Yen 1982) and Niuaotupapu (Kirch 1988), where they became some of the most productive soils on the islands.

Temporal variation in the physical environment was also a key factor in the development of agricultural infrastructure. Allen (2004) has argued that initial landscape capital investments in Hawai'i (e.g., terraces and stone and earthen banks) probably were geared toward stabilising year-to-year yields in the face of temporal variation in rainfall and erosion. Both Campbell (2001) and Addison (2006) argue that wetland production systems were an important risk management device at multiple points of the cultural sequence in the Marquesas and Cook Islands, due to the fact that annual yield variance in these systems is limited. Similar infrastructural developments occurred on Rapa Nui in the form of lithic

mulch gardens. These increased soil moisture levels by decreasing wind exposure and evapotranspiration (Ladefoged et al. 2013; Stevenson et al. 2002). Similar considerations may explain the proliferation of lithic mulch in New Zealand, though soil additives also increased the drainage capacity and changed the texture of the soils to suit the cultivation of sweet potato (Barber 2010:76).

The most widespread of risk management technique was storage pits, which ensured the availability of starch resources on an intra-annual and inter-annual basis (e.g., Addison 2006; Cox 1980; Kirch and Yen 1982:353; Leach 1984; Lepofsky 1994; Yen 1973). The development and expansion of breadfruit cultivation has been explained by its function in managing risk when paired with storage technology. Such storage technologies and tree crops may have been particularly important in circumscribed locations, such as islands that are small in size or have high relief landscapes (Huebert 2014). Storage was also essential in temperate locations, specifically New Zealand, where intra-annual fluctuations in sweet potato availability created a need to keep food through the winter (Davidson et al. 2007).

Socio-political relations also have influenced, and been influenced by, agricultural change. Originally recognised for Hawai'i by Wittfogel (1957), his ideas have been modified and expanded upon by several generations of researchers (e.g., Earle 1978, 1997, 2012; Field et al. 2010; Graves et al. 2011; Kirch 1984, 1994, 2010, 2012; Lepofsky 1994; Lepofsky and Kahn 2011; Spriggs and Kirch 1992). These studies highlight the role of socially prominent individuals or groups in dictating strategies of increased production for prestige and competitive purposes (Dye 2014; Kirch 1984), with less attention paid to the role of resource redistribution in times of yield shortfall (Allen 2004; Ladefoged and Graves 2000, 2008).

Acknowledged by Kirch (1984:161), “the production of food was the key to Polynesian economies, and the control and distribution of surplus food the key to larger social and political relations”. Systems of production were part of wider social and ritual practices, based on ideas of *mana* and *tapu*. Leaders in Polynesia had opportunities for the direct intervention in productive activities through the implementation of *tapu* (Firth 1936:377), and Shore (1989) notes a ubiquitous pattern of chiefly “marking” of productive land tied to ideas of *tapu*. The demonstration of *mana* through the ability of the leader to provide materially for his or her people goes hand in hand with his or her ability to maintain their social position (Shore 1989). Firth (1939) documented ethnographically the close ties between production and the ritual cycle of Tikopia, and argued that it was ritual that acted in

maintenance of the political economy. Redistribution and feasts created conditions to provide materially for households, while also demonstrating the leader's efficacy. Situations where leaders failed in their obligations to provide for their people have resulted in power shifts, such as in the Marquesas (Allen 2010; Thomas 1990, 1994). The leader was the agent of the collective, and when the leader failed to provide for the collective, he or she could be removed.

Polynesian agricultural systems include constriction points or production bottlenecks (after Earle 2011a,b) where chiefs or other prominent individuals controlled contextually important resources. Elite demands and management was likely a cause of agricultural expansion and intensification in Hawai'i that resulted in integration and coordination of dryland and wetland production systems (J. Allen 1991; M.Allen 2004:217; Ladefoged and Graves 2000, 2008; Kirch and Sahlins 1992; Spriggs and Kirch 1992). Constraints of these different environments circumscribed production systems (Ladefoged et al. 2009), resulting in constriction points that could be controlled. The agricultural infrastructure invested in these different areas created conditions amenable to management and surplus extraction (Earle 1997:83-89). The differential productive capability of dryland and wetland systems was one factor that led to the predatory expansion of leeward polities and the unification of Hawai'i Island (Graves et al. 2011; Hommon 1986, 2013; Kirch 1984, 1994, 2010), which sought to acquire productive lands to finance future political action (Kirch and Sahlins 1992). On Futuna, a similar pattern transpired where intergroup conflict often involved groups from the leeward side of the island (Kirch 1994:189-213), though on a smaller scale.

Even when there is a general lack of a dryland and wetland distinction, the unequal distribution of the most fertile land had political implications. On Rotuma, where agriculturally productive land was unevenly distributed, leaders generally originated from unproductive districts (Ladefoged 1993, 1995). Bollt (2012) has suggested the evolution of warfare on many Austral Islands was linked to unequal access to irrigated lands. The increased association between optimal areas and elites in the Society Islands indicates the elite role in intensification and desires to increase and meet social demands (Lepofsky and Kahn 2011:330). For Kirch (1991a), the control of breadfruit storage in *ma* pits became an avenue by which elites in the Marquesas could gain power through competitive feasting and community redistribution, a sentiment echoed by Law (2000) for some sweet potato storage pits in New Zealand.

Multiple factors working in tandem contribute to the temporal and spatial development of agricultural systems (e.g., Addison 2006, 2008; Allen 2004; Lepofsky and Kahn 2011; Kirch 1984, 1994, 2007b, 2010; Ladefoged and Graves 2000, 2008). Agricultural development is a historical process in which past developments influence future directions of change. Though strategies of cultivation are dependent on factors such as population growth, environmental variability, and social relations, those factors themselves, at any given time and place, are dependent on the outcomes of previous agricultural development. This textured historical process can create interpretive difficulties, and certainly no one factor can explain an entire sequence. Understanding why cultivation strategies were implemented and why they eventually changed involves documenting the use of different cultivation strategies across time and space, and comparing those strategies with relevant social and environmental factors. The study of Samoan agricultural development presents an opportunity to address these issues.

Why Study Agricultural Development in Samoa?

Explicit archaeological investigation of agricultural change has not been conducted in the Samoan Archipelago, creating a serious gap in our knowledge (Burley and Clark 2003; Kirch 1999; Kirch and Lepofsky 1993:118; Leach 1999) and leading to arguments that Samoa is evidence that intensification was not a general process in Polynesia (Leach 1999). Partially, this may be a result of ethnographic statements regarding the lack of intensive cultivation practices in the archipelago (Buck 1930; Watters 1958), as these historic era production techniques have long been assumed to extend into the prehistoric period (Green 2002:147). However, the limited archaeological examination of agricultural features across the island group does suggest that agricultural processes similar to those described above likely occurred.

Proposed drainage ditches have been identified in the Falefa Valley on 'Upolu (Davidson 1974a; Ishizuki 1974). One example identified by Ishizuki (1974:49) on slopes surrounding the valley has been classified as a system of raised beds (Kirch and Lepofsky 1993:188). While the system has not been directly dated, habitation sites in proximity are dated to the last 500 years (Ishizuki 1974:56). The other system lies near the permanent streams within the valley, in areas that Davidson (2012:2) argues were "prone to flooding", and agricultural production in the valley might have necessitated drainage ditches to mitigate the risks of flooding.

Domestic compounds, or household units and wards, have been identified elsewhere on 'Upolu in the Mt. Olo survey tract that may include cultivation plots (Holmer 1976, 1980; Kirch 2006:203). The construction of plots might signify a trend of decreased fallow periods in Samoa, as argued by Kirch (2006), but sufficient evidence has not been found to indicate that these represent anything more than house gardens. If these plots date to the same time period as the rest of the structures in the area, they were built and utilised within the 2nd millennium AD (Jennings and Holmer 1980b).

On Tutuila, a small pondfield irrigation complex, the only one that has been found in the archipelago, has been reported and mapped, though information on its chronology is lacking (Addison and Gurr 2008). Elsewhere on the island, stone alignments have been identified and interpreted to outline cultivation plots, some performing to reduce soil erosion. The preliminary analysis of these structures suggests that they were built after the middle of the 1st millennium AD, with a more intensive and expansive construction period around the 13th-14th centuries AD (Carson 2006:17-18). Furthermore, isolated features across the landscape may have had a function related to agriculture, such as terraces and stone rings (Carson 2006; Clark 1989; Clark and Herdrich 1988; Cochrane et al. 2004), and geomorphological evidence suggests increased erosion reflective of the more intensive use of upland areas around the beginning around the 13th-14th centuries AD (Pearl 2006).

On Olosega Island, labour was invested in a large ditch that ran the length of an interior uplands settlement, protecting that settlement from erosion and run-off (Quintus 2012). This ditch separates modern forest types, secondary growth forests upslope and economic forest downslope. These patterns correlate with the spatial patterning of the prehistoric settlement, as residential features are scattered within the economic forest while more limited modification to the natural slopes has been made in areas of secondary growth forest. These correlations have been used to suggest a diversified subsistence based, with arboriculture practiced within the residential area and shifting cultivation practiced upslope.

Still, the temporal development of these strategies and their relationship to cultural and environmental factors remains to be documented. Therefore, several questions endure, including:

1. What is the chronology of agricultural development?
2. What factors impacted, and caused change in, cultivation strategies?
3. How can agricultural change be characterised?

Research Design

This thesis seeks to evaluate these questions. To do so, I study agricultural development and the context within which that development occurred on Ofu Island, Manu'a Group, American Samoa. The general goal of this research is to understand the spatial and temporal variability of agricultural activities on Ofu and how these activities were associated with environmental and social factors. I assess the general processes that occurred, and identify similarities and differences between Ofu and sequences identified elsewhere in the region. The methods of this study are presented in Chapter 4, but this section discusses the general research design and describes how the above questions can be addressed using Ofu Island as a case study. This research design can be separated into three stages:

- I. Identify the location, timing, and management of agricultural systems
- II. Determine the course of agricultural change on Ofu
- III. Evaluate whether agricultural intensification occurred, determine the importance of other processes, and assess evidence of risk management

Stage I: Identify the location, timing, and management of agricultural systems

Identifying the location of agricultural activities through time is the first step in understanding agricultural development. Several lines of evidence can be, and have been, utilised to examine this question on Polynesian islands, specifically botanical remains (Huebert 2014; Lepofsky 1994), patterns of deposition (Allen 1984; Kirch et al. 1993; Kirch and Hunt 1993a; Pearl 2006), the modern distribution of vegetation (Lincoln and Ladefoged 2014; Quintus 2012), the presence of agricultural infrastructure (Ladefoged et al. 2003), and the presence of commensal species associated with gardening activities (i.e., non-marine molluscs; Kirch 1993b).

This project uses many of these same indicators. Subsurface examination on the coast is used to identify patterns of deposition that relate to erosion signalling vegetation clearance upslope. Data gathered in previous projects (i.e., Kirch and Hunt 1993a; Kirch et al. 1993) are used to supplement original research. Cultivation on the coastal flats is examined by the identification of gardening layers in subsurface deposits. Such gardening layers were recognised in the field based on organically enriched dark colour, presence of charcoal, lack of cultural material, and sediment mixing indicative of garden activity. In the interior, survey documented the surface archaeological record, and feature function analysis identified those

remains related to agricultural activities. The distribution of modern vegetation is also used as a line of evidence, as certain vegetation types have been shown to correlate with prehistoric settlements in the Manu'a group (Quintus 2012). The distribution of vegetation, based on previous vegetation surveys undertaken by the United States Forest Service (Liu and Fischer 2007), is compared to the distribution of archaeological features to assess the spatial extent of shifting cultivation and arboriculture. Finally, identified charcoal remains, from original research, and non-marine molluscs, from a past project (Kirch 1993b), are used to a very limited degree.

In Polynesia, the determination of changing agricultural management schemes has been accomplished by exploring the spatial proximity of agricultural features to other archaeological features or their distribution in space (Lepofsky and Kahn 2011), the construction of labour intensive infrastructure (Allen 2004; Kirch 1984, 1994), and evidence of plot segmentation that enables efficient management or oversight (Ladefoged and Graves 2008). In this project, changes in the management of agricultural production are documented by examining the spatial association of different agricultural strategies with socially important spaces or socially important archaeological remains (e.g., monumental architecture). This is assessed by locational spatial analysis of archaeological features in the interior uplands. Furthermore, though the construction of labour intensive agricultural infrastructure does not necessarily indicate elite control (Erickson 2006; Lansing 2007), it does imply, depending on the degree of labour invested, that community labour could be organised and that the development of *some* production strategies was communally-based. Particularly when agricultural infrastructure is technologically complex and is associated with multiple residential features, these features denote a level of community cooperation and coordination. The measurement of the size and the assessment of the internal complexity of features are based on survey data collected in this project. The temporal development of cooperative techniques and community coordination is documented by dating agricultural infrastructure.

Stage II: Determine the course of agricultural change on Ofu

In this step, the above dataset is placed within a wider context to determine the course and context of agricultural development. This is done by analysing the correlation between agricultural change and environmental, climatic, and cultural factors. On other islands in Polynesia, important factors that shape, and are shaped by, agricultural change include

environmental or landscape variability, both spatial (e.g., Kirch 1982, 2007b; Kirch et al. 2004; Lincoln and Ladefoged 2014; Vitousek et al. 2004) and temporal (e.g., Addison 2006; Allen 2004; Field 2003, 2005), socio-political change (e.g., Kirch 1984, 1994, 2010; Ladefoged and Graves 2000, 2008; Lepofsky and Kahn 2011; McCoy 2006; McCoy and Graves 2010), and population growth (e.g., Kirch 1994, 2006; Riley 1973).

Based on previous research, the coastal environment of Ofu has changed significantly over the course of human occupation (Kirch 1993d; Hunt and Kirch 1997). Such evolution of the coastline could have been an important factor in subsistence change. Excavation and extensive dating of coastal deposits undertaken in this project is geared toward examining patterns of landscape evolution on the western coast of the island, which is supplemented by previous work conducted on the south coast by Kirch and Hunt (1993b; see also Hunt and Kirch 1997). This thesis explicitly addresses the timing and spatial extent of mid to late-Holocene landscape change, and then assesses whether correlations exist between landscape evolution and subsistence change.

This study also examines the correlation between environmental/climatic hazards and cultivation strategies. The evaluation of how environmental hazards impact agricultural activities is based on historic and modern proxies, specifically addressing how documented hazards have impacted both cultivation techniques and more specific crops (e.g., Clarke 1992; Kerr 1976; Pierson et al. 1992; Solofa and Aung 2004; Watson 2007). How such environmental factors influenced agricultural development is evaluated by analysing whether cultivation strategies enhanced or counteracted the effects of these hazards through performance modelling and empirical evidence. This is similar to the framework utilised by Allen (2004) and discussed above.

The documentation of changing political relationships is based on the identification and dating of archaeological features that mark coordination and cooperation beyond the household scale. Of importance in this regard is the presence of monumental architecture on Ofu that is confirmed in this project (i.e., star mounds). Though none of these features have been dated, similar features have been dated on other islands of the archipelago (Clark 1996). These findings are supplemented by previous research on other islands of the archipelago that have explored the development of resource and labour control (e.g., Addison 2010; Holmer 1976, 1980; Johnson 2013; Martinsson-Wallin 2007; Wallin and Martinsson-Wallin 2007; Winterhoff 2007). This previous research has identified general trends in the development of

Samoan political systems, which can then be compared to the sequence of agricultural management on Ofu.

Only modest attempts are made to evaluate population growth, specifically by evaluating the expansion of archaeological features across the landscape. The spatial and temporal distribution of archaeological features on Ofu has been documented in this project and by previous research (Best 1992; Clark 2011, 2013; Clark et al. 2012; Kirch and Hunt 1993b). Additional information regarding the spatial distribution of archaeological features, specifically in unsurveyed areas, was acquired through the analysis of a Lidar dataset. This measure of population growth, at best, presents a crude indication of degree of magnitude population growth. Because of this, the correlation between agricultural development and population is only addressed in a general manner and conclusive statements are not made.

Stage III: Evaluate whether agricultural intensification occurred on Ofu, determine the importance of other processes of agricultural development, and assess evidence of risk management and changes to the social relations of production

The question of agricultural development in Samoa can be addressed after the completion of the first two steps. The empirical evidence gathered in this study is examined in reference to definitions of intensification presented at the beginning of this chapter. Specifically, intensification is assessed at multiple spatial scales. Criteria supporting intensification include the documentation of a sequence of increased labour input into agricultural activities or the construction of agricultural infrastructure *after* the utilisation of less intensive cultivation techniques at a fixed spatial scale. Similar procedures are used to evaluate agricultural expansion. Evidence supporting such a process includes the documented spatial extension of a cultivation technique at a set level of intensity into a previously unutilised area.

Important, too, is the outcomes and consequences of cultivation strategies. The management of risk of agricultural activities is an important factor influencing long-term patterns of human-environment relationships and the social relations of production (e.g., Allen 2004; Ladefoged and Graves 2008; Marston 2011; Morrison 1994). The documentation of risk management in this study is based on correlations between cultivation strategies and social and environmental factors identified in Stage II. This analysis explicitly explores how cultivation strategies impacted the variance of year-to-year production or resource availability by comparing feature performance and function to Z-score expectations of risk management

techniques. Analysis of the social relations of production is also undertaken, at least in relation to the development of a small-scale political economy. This is examined in light of changes to the degree of agricultural management. Specifically, evidence of agricultural management is studied to identify constriction points in production that may have been appropriated by leaders (after Earle 2011a).

This study documents the course of agricultural change on Ofu and addresses the underlying processes that characterise the sequence. This course of agricultural change and the general processes are then able to be compared to agricultural development elsewhere in region. This comparison highlights important general processes and unique factors that influence the development of agriculture in Polynesia.

Chapter Summary

This chapter has discussed past approaches to the study of agricultural development. Of particular interest is the concept of agricultural intensification, a process of increased labour input into agricultural activities at a set spatial and temporal scale. The concept has been influential, but critiques of it have refined our understanding of the process of agricultural development, specifically highlighting the variability of these processes and the role of multiple factors. The use of different cultivation strategies had different outcomes. Strategies that stabilised or increased production were important in the past, and the use of either was somewhat dependent on the climatic and environmental variability of the region.

The development of most agricultural systems in Polynesia has been referred to as processes of intensification. However, multiple trajectories of agricultural development have been identified, and the importance of alternative concepts, most notably expansion, has been stressed. Based on these studies numerous causal factors have been identified. Many of these factors are patterns seen throughout the region, such as population growth, but others are more contingent on local factors, such as specific temporal or spatial variation in the environment and the sequence of political development.

To add to our understanding of agricultural development, this study documents the course of agricultural development on Ofu Island. Agricultural change on Ofu is documented by examining the location, importance, and management of agriculture activities through time. The next chapter introduces the cultural and environmental context of the island before turning to a discussion of the methods and results of this study.

Chapter 3: The Samoan Socio-ecological Setting

To illustrate the context within which agricultural systems developed, this chapter describes the physical and cultural environment of Samoa, Manu'a, and Ofu Island. The first sections examine the contemporary environment, with special reference to Ofu and Manu'a, followed by a summary of cultural history. The chapter then briefly summarises ethnographic literature associated with late prehistoric and early historic political systems, and a summary of the characteristics of historic production systems is presented subsequently. This is followed by a discussion of the major crops cultivated and the environmental hazards that impact the growth of those crops. The final section reviews past archaeological investigations on Ofu.

Climate and Physical Environment

The Samoan Archipelago is located in West Polynesia situated between the Tropic of Capricorn and the equator. Today, it is separated into two political units, the Independent Nation of Samoa and the Territory of American Samoa (Fig. 3.1). The nation of Samoa, consists of 'Upolu (1,110 km²), Savai'i (1,820 km²), Manono, and Apolima (the latter two a combined 6 km²), and is the larger political unit in terms of both population (170,000) and land area (93% of all and in the archipelago).

American Samoa, made up of Tutuila (124 km²), Aunu'u (< 2km²), Ofu (7.3 km²), Olosega (5 km²), Ta'u (39 km²), and the smaller Swains Island (Olohega) and Rose Atoll, are the eastern islands of the group. Much of the population resides on Tutuila (ca. 60,000 people), the seat of the territorial government. Smaller populations reside in the Manu'a Group (Ofu, Olosega, and Ta'u), with limited habitation of Swains for copra production. Much of the archipelago is, relatively speaking, culturally homogenous, but Swains is more culturally associated with Tokelau than Samoa. The Manu'a Group forms another cultural grouping, and historically Mead (1969) indicates that the people of Manu'a considered themselves separate from the rest of Samoa.

Geology, Geomorphology, and Environment of Manu'a and Ofu

The islands of Manu'a (Fig. 3.2), the youngest of the archipelago, were formed roughly 100,000-400,000 years ago by a series of volcanic eruptions that have been followed

by progradation, subsidence, and erosion (McDougall 2010). All are relatively small, featuring significant topographic relief, with remnant sea cliffs abutting more recently formed coastal flats (Stice and McCoy 1968). Ofu and Olosega are bordered on all sides by fringing reef. The reefs are more developed on the southern and western coasts, where they can reach as much as 700 m wide. Reef on Ta'u is more limited, the widest stretch bordering the western shores.

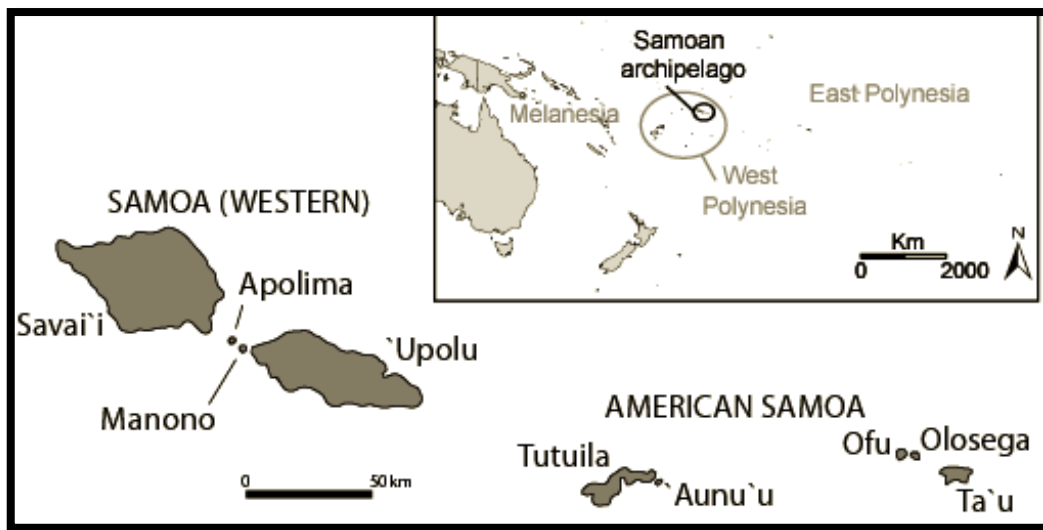


Figure 3.1 The Samoan Archipelago (Adapted from Reith and Hunt 2008:1902)

Ofu and Olosega consist of at least six volcanic cones, but are dominated by two that developed as shields and coalesced (Stice and McCoy 1968:427). The highest elevation on Ofu is Tumu (or Tumutumu) Mountain or Peak at 495 m, which is the convergence point for two dominant ridges that form the backbone of the island: Mako Ridge extending to the northwest and Leolo Ridge to the northeast (Fig. 3.3; refer also to Fig. 1.2). These ridges constitute the eroded fault scarp of the A'ofa caldera, one of the two developed shields. This configuration bounds the A'ofa volcanic caldera on all but the north side, which is marked by precipitous cliffs down to the ocean. Geological substrate age variation is limited relative to other islands in the archipelago (i.e., Tutuila, 'Upolu, and Savai'i); all areas were formed between 250-400 ka (McDougall 2010:709). Still, this variation could have substantial implications on the trajectory of agricultural development (Ladefoged et al. 2009), but precise data on the spatial variability of different substrates is unavailable at this time. Offshore volcanic activity still occurs, the most recent of which in 1866 (Craig 2009:11). Because of the youthful age, stream development is limited and only intermittent streams flow on Ofu.

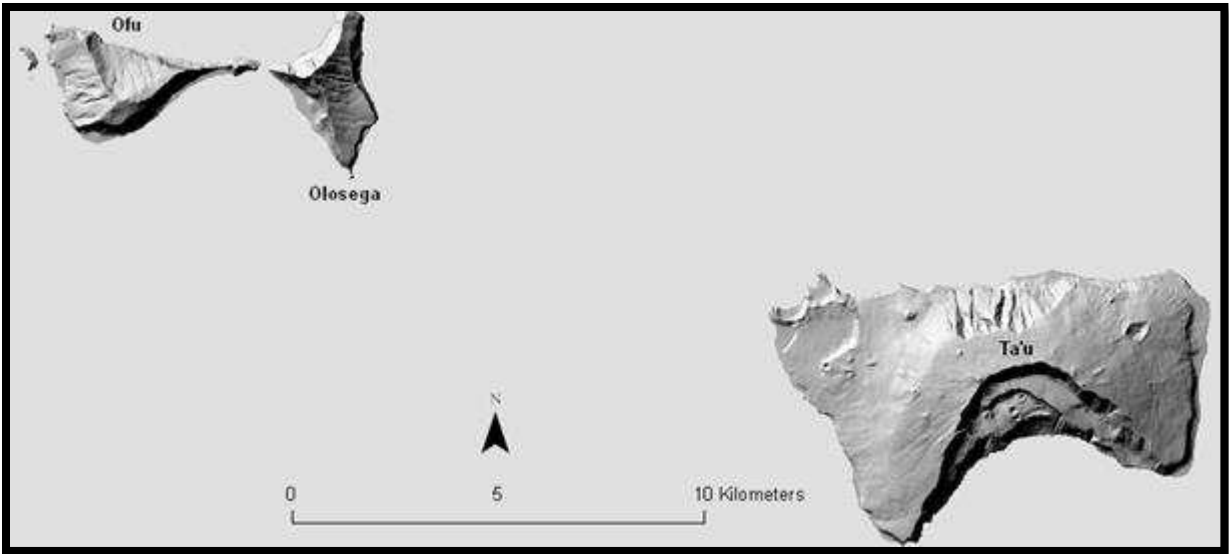


Figure 3.2 Manu'a

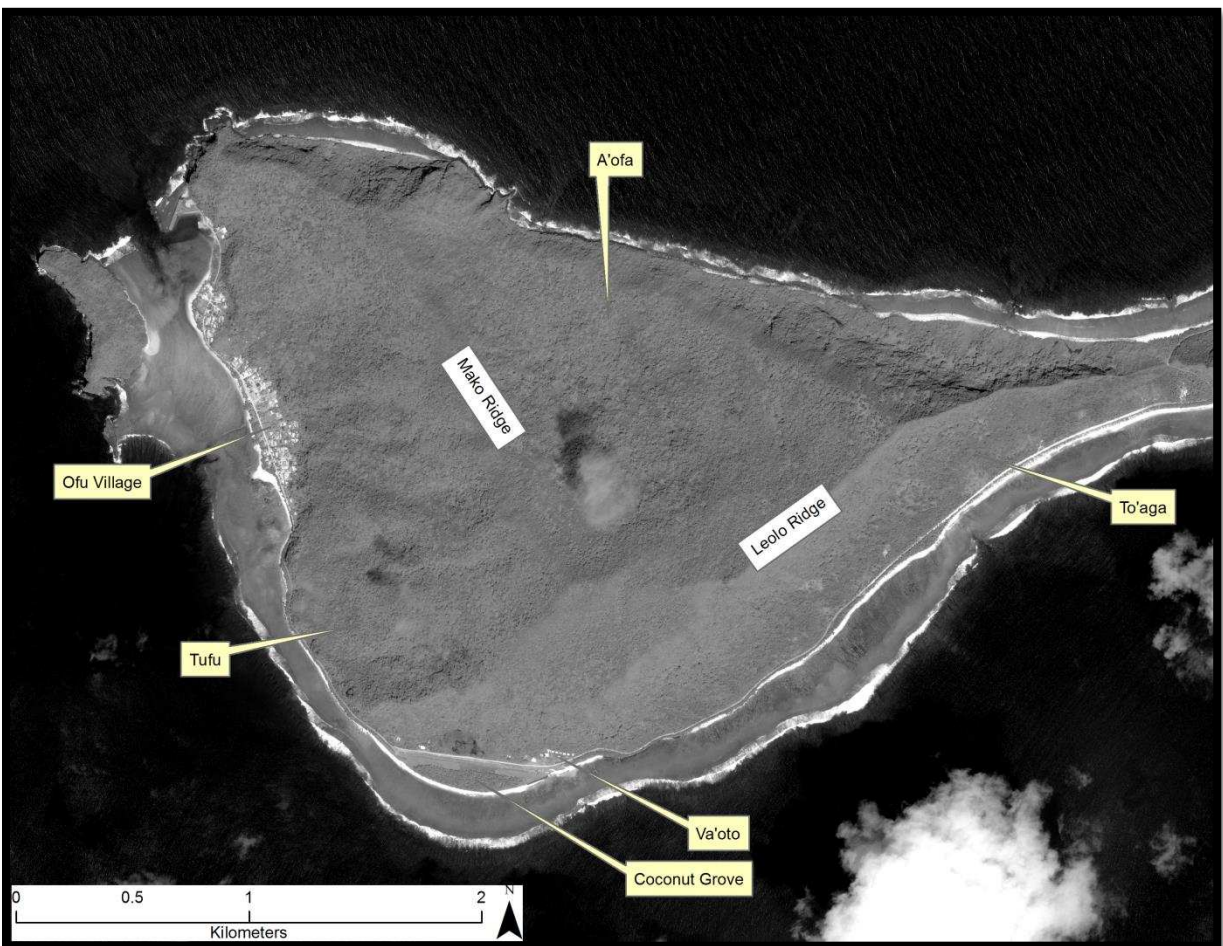


Figure 3.3 Aerial photograph of Ofu showing place names referred to in text sand the extent of the fringing reef

All soils of the interior uplands of Ofu can be classified as Ofu silty clays that have good drainage capability but are highly erodible (Nakamura 1984). Though it is likely that the nutrient capacity of these soils is variable, no data is available to evaluate such variability. Soils of the coast are calcareous beach sands, consisting of broken down reef mixed with eroded terrigenous sediments. The more inland soils on the coast possess significantly more terrigenous sediments than seaward soils, caused by the erosion of the inland slopes that has occurred within the last 1,000 years (Kirch and Hunt 1993a).

The entire island of Ofu is covered by forest, except for a few areas around the coast (refer to Fig. 3.3). These forests are variable and reflective of ~2,700 years of human land use (Quintus 2011, 2012). Much can be classified as economic (human cultivated plants) or secondary vegetation (vegetation that developed and spread as a result of forest clearance by natural or human processes), while pristine rain and cloud forest is still situated in the higher elevations (Liu and Fischer 2007). Roughly 775 species of native plants have been documented in Samoa, the second most in tropical Polynesia behind Hawai'i (Whistler 2001:8). Many more plants have been introduced by generations of human inhabitants.

The modern village of Ofu is situated on the western coastal flat (Fig. 3.4), bordered by the widest stretch of fringing reef (refer to Fig. 3.3). The village is split into two named sectors, Alaufau to the north and Ofu to the south. For ease of discussion, Ofu Village will be used to describe the whole area in this study. Wide coastal flats are also present on the south side of the island. Today, these coastal areas are characterised by multiple zones, as exemplified by To'aga (Fig. 3.5). The intertidal zones exhibit calcareous sediments created by the weathering of the fringing reef. The presence of beach rock along the shoreline above the high tide mark, formed under intertidal conditions, suggests that the coast is currently undergoing a process of erosion (Kirch 1993d). The next zone inland is the beach ridge, followed by the thickly vegetated back crest that drops slightly then levels before beginning to rise nearer the talus slopes that border the inland cliffs. The cultivation of both tree and root crops occurs in the back beach areas today, where calcareous sediments have mixed with terrigenous sediments and organic remains from past land use. As one moves inland, the soil matrices include large basalt boulders that have been displaced from the interior through mass wasting processes. Freshwater marshes have formed on the coast of all three islands of the Manu'a Group, and are valuable for the exploitation of wild resources, particularly birds, and cultivated resources. On Ofu, the marsh is located on the south coast inland of the modern runway and the Coconut Grove archaeological site.

It is understood that geomorphological change has had a significant effect on the cultural landscape throughout the archipelago (Clark and Michlovic 1996; Dickinson and Green 1998; Pearl 2006), and nowhere is it more apparent than on Ofu. Though specifics are still debated, relative sea level appears to have fluctuated over the last 5,000 years (Dickinson 2003, 2009). Following the Pleistocene, sea level rose to the Holocene highstand that reached between one and two meters above modern levels (Dickinson 2001, 2003, 2009). Sea level then dropped, stabilising at the present level sometime in the 1st millennium or early 2nd millennium AD (Dickinson 2003; Kirch 1993d:34).

As modelled by Kirch (1993d) for Ofu, sea level change and island subsidence, combined with increased sedimentation from both terrigenous erosion and increased biogenic input (Fig. 3.6), caused drastic reshaping of the Ofu coastline. Marine regression and progradation occurred in the 1st millennium AD, as sea level fall and eventual stabilisation resulted in the extensive erosion of coral reef that formed under highstand conditions. After progradation, the deposition of terrigenous sediments from the interior, coupled with occasional high energy storm surges contributed to a process of coastal aggradation. As sea level approached modern levels, and as subsidence continued, coastal erosion began and continues to the present day (Kirch 1993d:38-39).

Predictions and expectations regarding archaeological site locations on Ofu can be, and have been (Kirch and Hunt 1993b; Rieth et al. 2008), proposed based on this model. Older archaeological deposits should be situated near the inland talus slopes. These deposits are likely to be located on calcareous sands buried under colluvium, sometimes as much as two or three metres of colluvium. The matrices of these deposits should mark a changing sediment source, from marine-derived sediments to terrigenously-derived sediments, as the shoreline prograded towards its current configuration. Therefore, more youthful archaeological deposits should be found as one moves seaward.



Figure 3.4 Ofu Village

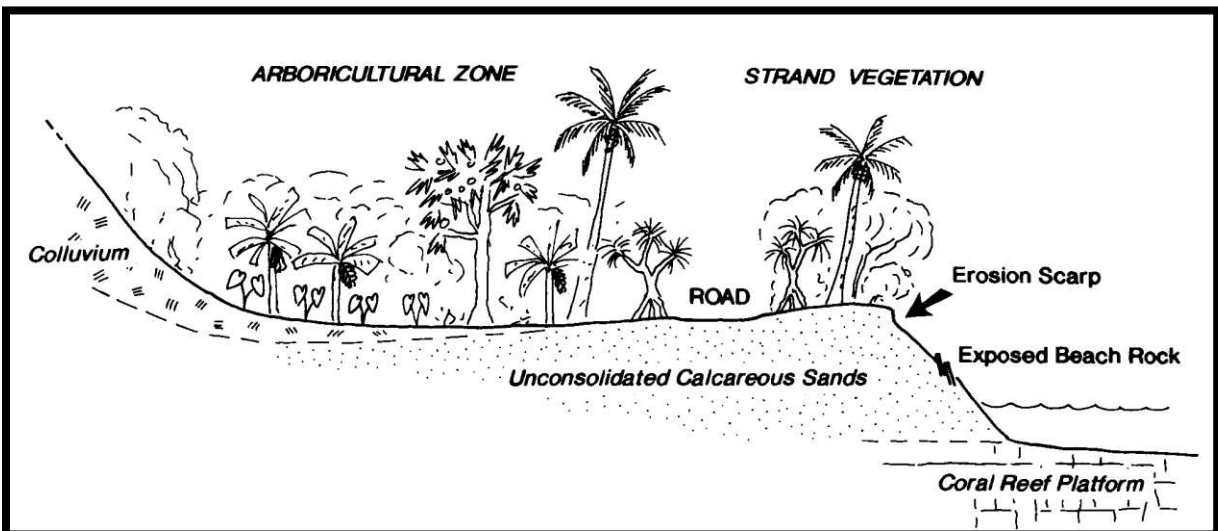


Figure 3.5 Model of a vegetation and soil transect across To'aga (From Kirch 1993d:33)

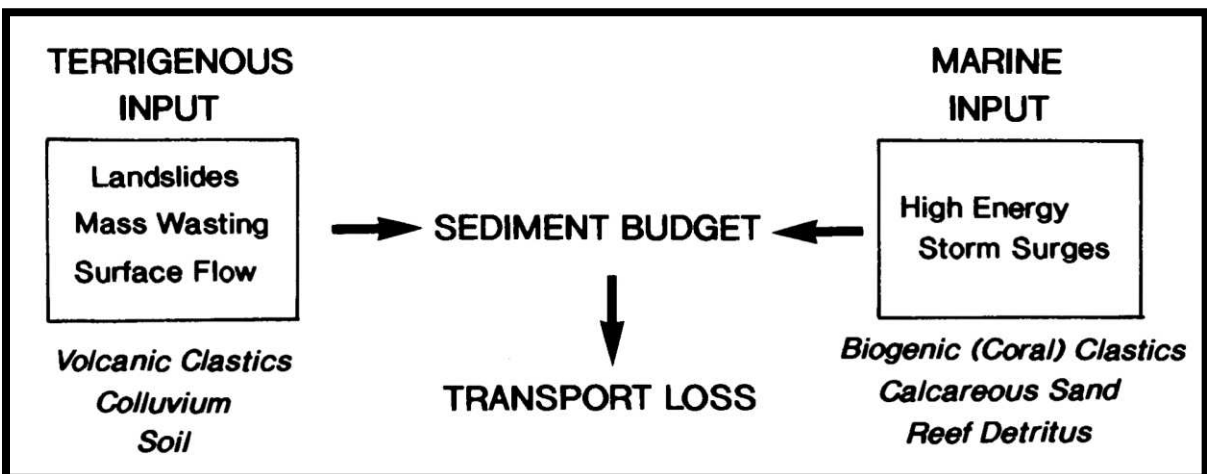


Figure 3.6 Modelled inputs to the sediment budget on Ofu (From Kirch 1993d:35)

Climate

Daily temperatures in Samoa reach about 30°C and relative humidity is high, with a daily average of 72-77 percent. Some intra-annual variability exists in temperature, but that variability, between the warmer month of January and the colder month of July, is around 1°C. Annual rainfall for Tutuila, similar to Ofu, ranges from 3,175 to 6,350 mm per year, differing as a result of topography and wind patterns (Clark and Michlovic 1996:153). The highest rainfall occurs in high elevation areas. For instance on Ta'u, the highest elevations can receive as much as 7,000 mm of rain per year (Craig 2009). Seventy-five percent of yearly precipitation falls between November and April, with average monthly rainfall of around 350 mm during this time. Though a dryer season, from April to November, is recognised, it is more accurately described as less wet with those “dry” months still averaging close to 150 mm of precipitation. These seasonal changes correlate with the position of the South Pacific Convergence Zone (SPCZ) (ABM and CSIRO 2011:188). More variability is introduced on an inter-annual scale by ENSO (El Niño-Southern Oscillation).

ENSO is one of the world's largest sources of climatic variation, and conditions of El Niño and La Niña years in Samoa are tied to changes in sea surface temperature and air pressure between the western and eastern tropical Pacific (Fig. 3.7). Normally, the eastern Pacific is characterised by cold waters while the western Pacific by warm waters; a pattern with a similar atmospheric pressure gradient. However, the periodic breakdown of the Walker circulation system occurs every 2.5-7 years (Tudhope et al. 2001:1511), changing system dynamics and allowing the extension of the warm waters to move eastward along the equator during El Niño years. This is accompanied by humid and warm weather that shifts tropical rainfall eastward.

In terms of the effects of ENSO phases, Samoa lies in an area characterised by variability (Dai and Wigley 2000:1285). Generally, the pattern follows that of Tonga and Fiji in the sense that during El Niño precipitation declines, air temperature rises, and tropical storm frequency and intensity increase (ABM and CSIRO 2011; Alory and Delcroix 1999; Chand and Walsh 2009). Increased storminess in the late 1980s and early 1990s, in which cyclones had a devastating impact on a number of social and economic sectors, illustrate these effects (ABM and CSIRO 2011:191). One of the early 1990s cyclones, Val, caused more than 368 million USD in damage in the archipelago (Crawley 1992). Additionally, recent evidence suggests that Samoa experiences sea level fall of as much as 20-30 cm during

some strong El Niño events (Widlansky et al. 2014). Declines in sea level are known to be of such significance as to cause the exposure and destruction of the tops of coral heads, a process in Samoa referred to as *taimasa* (foul smelling tide) (Widlansky et al. 2014:1071). La Niña years are created by the opposite process and manifest in the opposite way. The normal range of warm water moves westward, resulting in increased precipitation and decreased storminess in the Fiji-Tonga-Samoa region.

Samoa is unusual in the sense that El Niño years are not always characterised by decreases in *average* precipitation (Fig. 3.8). On Tutuila, for instance, increased precipitation has been documented for the last two El Niño years, whereas a feature of La Niña years has been decreased precipitation (online NOAA weather data). Most precipitation during El Niño falls over short time spans during tropical cyclones (Solofa and Aung 2004:49). Increased precipitation can cause floods and landslides that can destroy crops and residential infrastructure. Tropical cyclones can severely decimate food supplies as well as infrastructure.

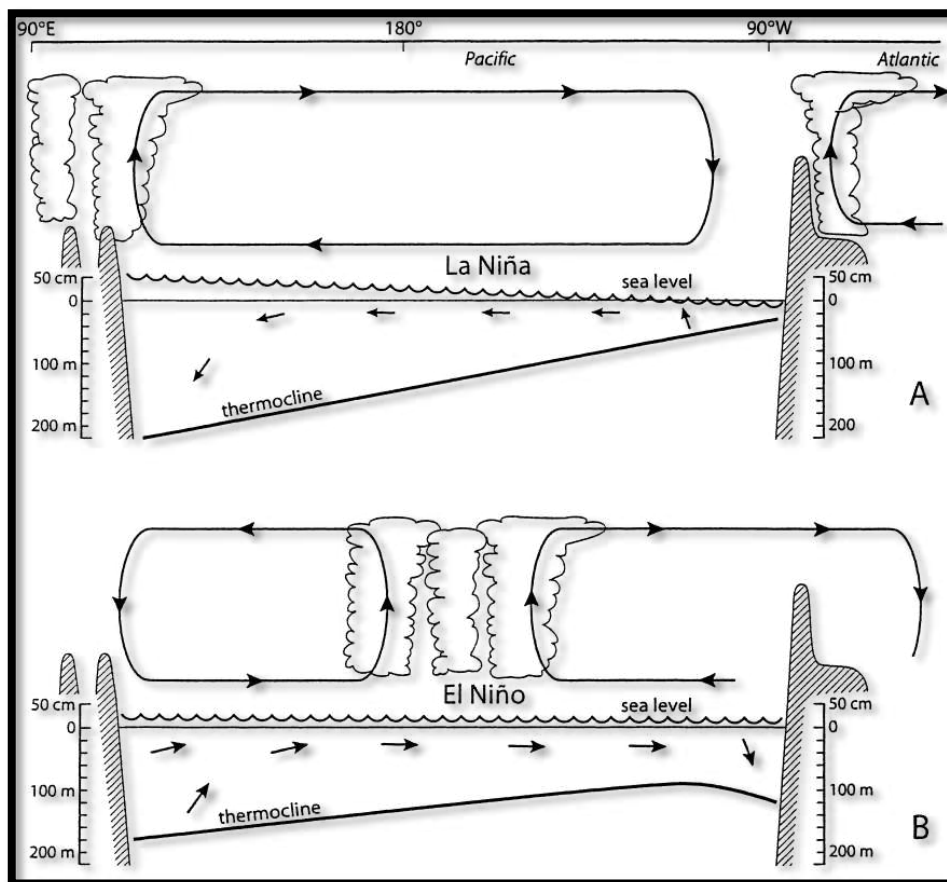


Figure 3.7 Modelled influence of El Niño and La Niña events (From Chu 2004:301)

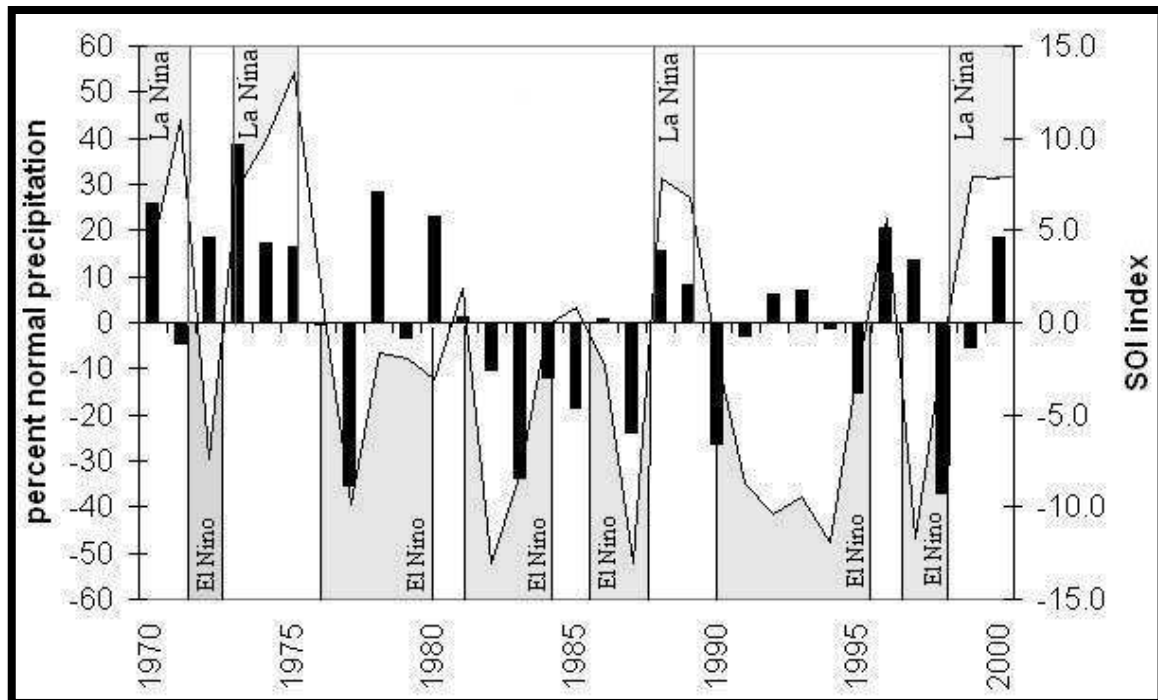


Figure 3.8 Historic rainfall patterns in relation to ENSO phases in Samoa (from Solofa and Aung 2004:48, Fig.1)

Further variability in the SPCZ region, which can modulate the strength and frequency of El Niño and La Niña events, is introduced by the Interdecadal Pacific Oscillation (IPO) (Folland et al. 2002). IPO cycles between two phases over 15-30 years periods, the negative and the positive, that manifest in similar ways to La Niña and El Niño events respectively (Folland et al. 2002; Linsley et al. 2004, 2008; Salinger et al. 2001). During negative phases, the SPCZ shifts south toward Fiji resulting in increased precipitation in the Fiji-Tonga-Samoa region, while during positive phases the convergence zone shifts north toward or past Samoa decreasing rainfall (ABM and CSIRO 2011:189; Linsley et al. 2008). Therefore, if ENSO warm events occur during an IPO positive phase, it may increase the frequency and intensity of ENSO warm phases (Salinger et al. 2001:1710). The temporal depth of this cycle is not known, but Linsley et al. (2006, 2008) have demonstrated that it extends at least into the 17th century AD.

Climatic Variability in the Past: A Synthesis

A small series of long-term climatic models have been developed in the tropics, but there remains a great deal of uncertainty. This may be due in part to the complexities and diversity of ENSO cycles, specifically relating to the variability of the location of sea surface temperature anomalies (U.S. CLIVER Project Office 2013). Documented ENSO teleconnections, which are climatic relations between two distinct geographical areas that can

be thousands of km apart, indicate that during some events modern changes in ENSO activity in one region reflect changes in another region. However, these teleconnections may be temporally and spatially variable (Graham 2004, Graham et al. 2007). Additionally, the regional variation identified in climatic models illustrate differences in the local manifestations of climatic periods or episodes, which precludes the use of climatic records from outside of region to examine Pacific background climate (Allen 2006). However, climatic data from outside the Pacific may be helpful if compared to and used in conjunction with data gathered in the Pacific. The following discussion is a summary of the most relevant data on past climate after which a climatic sequence can be proposed for Samoa.

Most models only span the last few centuries, though one important exception is work conducted by Cobb et al. (2003, 2013). According to this model, climate has remained relatively stable in the last 1,100 years, including only minor temperature fluctuations, with the exception of a cold/dry period around the 10th century AD and warming in the last 100 years (Cobb et al. 2003:274). More specifically, as summarised by Allen (2006:525), the MCA (Medieval Climatic Anomaly) from the 10th-13th centuries AD may have been cooler and drier in some regions of the Pacific, while the LIA (Little Ice Age) from 15th-20th centuries AD may have been somewhat warmer and wetter. However, some coral proxies provide more ambiguity about the situation in the 16th and 17th centuries AD (Emile-Geay et al. 2013), which implies that the mean climate of the Pacific during the LIA was regionally variable.

ENSO frequency and strength also fluctuated in the mid to late-Holocene. In the Galapagos, increased ENSO activity is posited between the 1st and 6th centuries AD, the authors arguing that “the period between 2000 and 1000 calBP was a period of extremely high, if not the highest, ENSO event frequency during the Holocene” (Conroy et al. 2008:1175). Based on an Ecuadorian sediment core, ENSO activity may have begun to increase roughly 7000 BP, and steadily rose until the 9th century AD (Moy et al. 2002:164). After that time, the authors suggest that activity declined, though peaks in the number of El Niño events per 100 years occurred in the 8th century AD and the 12th century AD (Moy et al. 2002:183, Fig.1a; Fig. 3.9). Because the latter records originate from outside the Pacific, it is unclear how the sequence relates to the tropical Pacific. These records are mentioned here because they increase the time depth of the ENSO cycle (cf. Cobb et al. 2003; Emile-Geay et al. 2013), and correlations between these records and those from Palmyra have been quantitatively assessed; though, the degree of correlation fluctuates though time (Graham

2004). Specifically, increases in ENSO activity during the late 12th or early 13th century are supported by the Palmyra coral record (Cobb 2003), and increased El Niño strength and frequency is recorded in a number of other proxies for the 17th century (Cobb et al. 2003:273; Cobb et al. 2013:68; D’Arrigo et al. 2005; Graham 2004:439-440). The frequency and strength of ENSO warm periods in the 17th century might have been impacted by fluctuations of the IPO (Linsley et al. 2008).

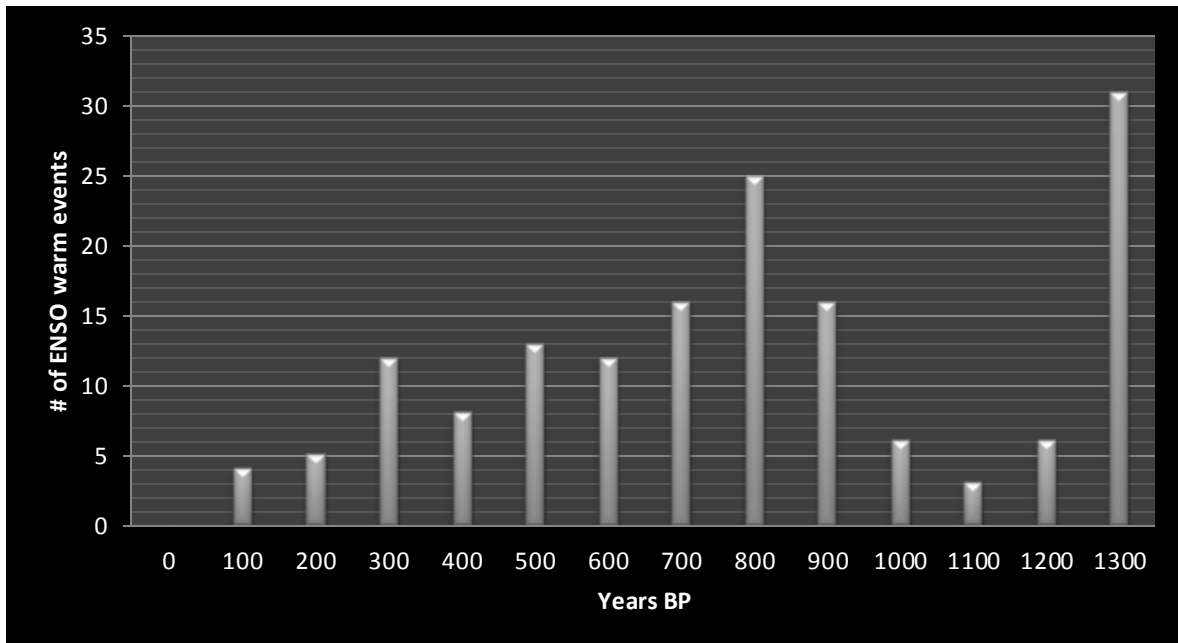


Figure 3.9 Number of ENSO warm events (El Niño) per 100 years. (From Moy et al. 2002 data)

Sequence and Manifestation of Climatic Fluctuations in Prehistoric Samoa

Regional climatic variability has only recently been recognised by archaeologists in the Pacific (Allen 2006). Samoa, as described above, is particularly intriguing, as the archipelago is on the edge of an area that separates extreme long-term climatic variability from stability (Dai and Wigley 2000; Salinger et al. 1995). This has been echoed by archaeologists Field and Lape (2010:117) who state that “the most extreme deficits in rainfall during ENSO events of the last century occurred in regions of Samoa, Tonga, Fiji, New Caledonia, Vanuatu, Indonesia, and the Southern Philippines” while also stating that “a narrow band that includes...Samoa...would have remained relatively stable, with few detectable anomalies in temperatures or precipitation” (Field and Lape 2010:118). This apparent contradiction may stem from the movement of the SPCZ, which may either increase or decrease climatic variability on an inter-annual or inter-decadal scale. But, generally, El

Niño years would result in rainfall deficits and more tropical cyclones. Precipitation would normalise or, perhaps, increase during La Niña years and the frequency of tropical cyclones would decrease.

The past climate of Samoa, and the rest of the Pacific, remains poorly known and controversial (e.g., Allen 2006; Cobb et al. 2013), but below is a summary of the chronology and possible manifestation of climatic changes in Samoa:

1. Increased frequency and amplitude of ENSO events may have occurred in the 1st millennium AD (following Conroy et al. 2008). More specifically, strong ENSO signatures have been reported in Ecuador in the 5th and 8th centuries AD (Moy et al. 2002), though it remains unclear whether this translates to the Pacific since comparable records are unavailable from the region. If it did, Samoa would have experienced decreased precipitation and increased frequency of tropical storms.
2. The MCA (AD 900-1200) may have been a time of cooler weather (Cobb et al. 2003; Emile-Geay et al. 2013). It appears that it was drier in the Eastern Central Pacific, but it is unknown whether this would have been true of Samoa as well. If it was similar to a La Niña background climate, as Cobb et al. (2003) argue, Samoa may have experienced higher than average precipitation.
3. In the 12th and 13th centuries AD, ENSO activity may have increased (Cobb et al. 2003; Moy et al. 2002), and El Niño-like mean climatic conditions might have emerged (Cobb et al. 2003; cf. Emile-Geay et al. 2013). On average, given a background El Niño-like state, Samoa would have been drier than normal with more frequent cyclones.
4. Change occurred in the 17th century AD. In many records, this period featured some of the strongest ENSO activity (Cobb et al. 2003). Such a situation, combined with a possible mean climatic El Niño-like state, suggests that Samoa may have been drier with a higher frequency of tropical cyclones.

Summary

The environment of Ofu is temporally and spatially variable. Substantial landscape evolution in the late Holocene has modified the coastal and marine environments, changing the ratio of shallow marine to terrestrial lowlands environments. Further temporal variability

is introduced by extra-annual climatic patterns, specifically ENSO cycles, which impact precipitation, but more importantly the periodicity of tropical storms. The nature of climate change through the course of human habitation on the island is unclear, but research in the region does suggest that conditions varied in the mid-late Holocene. A summary of Samoan cultural history is presented next to further explore the context within which agricultural change occurred on Ofu.

Samoan Cultural History

The human colonisation of Samoa was part of the Lapita expansion, a group or groups of people who colonised Remote Oceania and carried a distinctive pottery type (Green 1979; Kirch 1997; Specht et al. 2014). The earliest dates in the archipelago indicate colonisation by at least the 8th-9th centuries BC (Petchey 2001; Rieth 2007). However, the Lapita signature in the archipelago is weak, represented by one site, Mulifanua, implying 1) this phase of colonisation was limited, and/or 2) that geomorphological processes have destroyed or deeply buried early sites (Clark 1996; Clark and Michlovic 1996; Dickinson and Green 1998; Green 2002; Kirch 1993d; Rieth et al. 2008). Given that only one site has been found, very little can be inferred about the people. Artefacts found at Mulifanua are consistent with Lapita assemblages elsewhere, and the pottery assemblage is similar to the Late Eastern variety (Petchey 1995). One adze found on 'Upolu with Lapita pottery may be of exotic origin (Leach and Green 1989).

Shortly after Lapita settlement of 'Upolu, or even contemporaneously with it (Clark and Michlovic 1996; Kirch 1993c), populations using plainware (non-decorated) pottery spread; such pottery is found on all inhabited islands of the archipelago. The earliest of these sites are found on coastal flats near productive reefs. Artefact assemblages consist of ceramics, basalt and volcanic glass flakes and tools, worked shell, and worked bone (Clark 2011, 2013; Clark and Michlovic 1996; Green 1974; Janetski 1980; Kirch 1993a). On Ofu, colonists evidently relied primarily on marine resources (Clark 2011; Nagaoka 1993), but terrestrial resources, such as birds and domesticated plants and animals, were also exploited (Kirch and Hunt 1993b; Steadman 1993).

Conventionally, early settlements are argued to have been sedentary households scattered along the coast (Addison and Matisoo-Smith 2010). Recently, this view has been challenged as few structural remains (i.e., post molds) have been discovered indicative of such long-term and permanent habitation. Given this absence, Clark (2011, 2013) has argued

for a residential pattern based on semi-nomadism, in which resources were exploited from a patch before the population moved to another in a circuit-like pattern. Additionally, inter-archipelago movement and inter-group interactions appear to be less frequent than originally thought, as evidence of such practices is limited in Samoa (e.g., Burley et al. 2011; Cochrane et al. 2013).

Sustained interior settlement or expansion away from the coast occurred at the beginning of the 1st millennium AD or earlier on the larger islands of the archipelago (‘Upolu, Savai’i, and Tutuila), typified by multiple sites in Falefa Valley on ‘Upolu (Davidson 1974a), by the Pulemelei site on Savai’i (Wallin et al. 2007) and by the Vaipito and Vainu’u sites on Tutuila (Addison and Asaua 2010; Eckert and Welsch 2009). Green (2002:138) has argued that this period saw the development of what he terms the “House Society” of Samoa (see also Kirch and Green 2001). Nevertheless, limited evidence has been found of such household components in this period outside of ‘Upolu and Savai’i (Davidson 1974c:232).

The following period beginning in the middle of the 1st millennium AD is referred to as the “Dark Ages” (Davidson 1979:94-95; Rieth 2007). This characterisation is not necessarily based on any major cultural change, but, rather, the paucity of archaeological materials dating to the period. One reason is the lack of diagnostic artefacts and the apparent abandonment of pottery by this time (Green 2002:140; but see Clark and Michlovic 1996). However, more recent research is beginning to inform on this period. Following patterns originating in earlier times, populations likely expanded into more inland locations and around the coast (Green 2002:140). Landscape modifications, in the form of terraces, mounds, and walls are known from this period on ‘Upolu and Savai’i (e.g., Holmer 1976, 1980; Jennings and Holmer 1980b:6-10; Wallin and Martinsson-Wallin 2007), but are less represented in American Samoa (but see Carson 2006). Stone tools were increasingly manufactured (Addison and Asaua 2006; Addison et al. 2008:101-104), but with less intensive production relative to later periods. The increased usage of terrestrial landscapes is apparent, and increased deposition of volcanic sediments with a high density of charcoal suggests increased vegetation burning on the inland slopes (Clark and Michlovic 1996; Kirch and Hunt 1993a; Pearl 2006).

Many researchers argue for population continuity through Samoan prehistory, that is no intrusion of additional groups (Davidson 2012). On the contrary, Addison and Matisoo-

Smith (2010) have suggested that a population intrusion occurred in the 5th-7th centuries AD coming from the atolls of Micronesia. Based on genetic evidence of dog, chicken, and rat dispersal, these researchers suggest that at least two biological introductions of each species took place. They also argue that such intrusion caused cultural change. Given present evidence, however, it is difficult to assess whether these patterns indicate intrusion or simply cultural contact but relative continuity (Davidson 2012), the latter argued by others based on material culture similarities (e.g., Anderson 2000).

The last 1,000 years of Samoan prehistory saw the development of more complex socio-political systems and changes in resource use (Green 2002; Quintus 2011; Winterhoff 2007). Large mounds, walls, and paths dominate the landscape of Samoa along with large pits, or *umu ti* (ovens used to cook underground stems of *Cordyline fruticosa*) (Carson 2002; Davidson 1974a,b,c; Holmer 1976, 1980; Sand et al. 2012; Wallin and Martinsson-Wallin 2007). These landscape modifications are generally highly patterned, many in what has been termed wards and household units (Holmer 1980) (Fig. 3.10). Such constructions are indicators of a developing political system that became increasingly hierarchical. Similar patterns are found on the islands of American Samoa, but large mounds are absent and remains are limited to features such as terraces and smaller platforms. Still, these features are highly patterned, indicative of structured communities and hierarchical political systems (Quintus and Clark 2012). Late prehistoric archaeological features are restricted to the interior upland regions on the smaller islands of Ofu and Olosega (Quintus 2011, 2012; Quintus and Clark 2012). Late prehistoric coastal settlement is limited, with only isolated archaeological features (i.e., *in situ umu* ovens) and few cultural deposits dated to this period (ASPA site files).

Defensive sites were built during the last 1,000 years on the western islands of the archipelago, including on Tutuila (Best 1993; Clark 1996; Clark and Herdrich 1993). Most fortifications are bank and ditch structures cut across the ridgeline in the mountainous interiors (Best 1993; Scott and Green 1969); some are quite large while others are simple. At least on Tutuila, many of these defensive sites are associated with basalt quarries. These quarries are expansive in some instances, especially Tatagamatau (Best et al. 1989; Best et al. 1992) (Fig. 3.11). Tools and raw material from some of these quarries have been found throughout the archipelago as well as throughout the central Pacific (Best et al. 1992), and the control of these resources might have been an important source of power in the Samoan political economy (Winterhoff 2007).

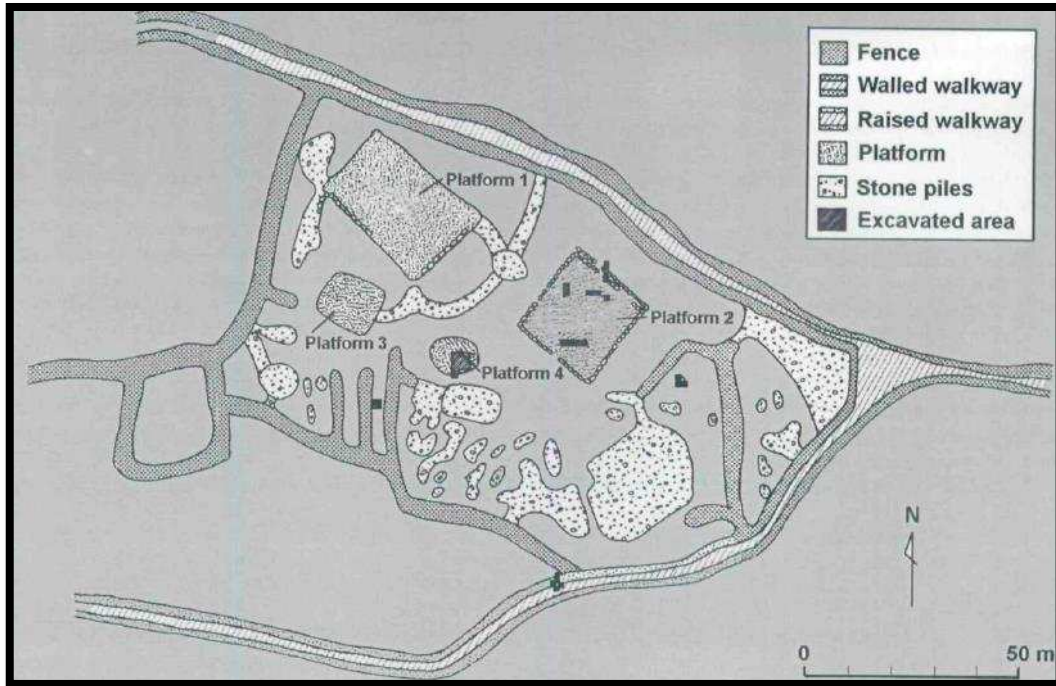


Figure 3.10 Typical bounded household on the larger islands of the archipelago (From Martinsson-Wallin 2007:17)

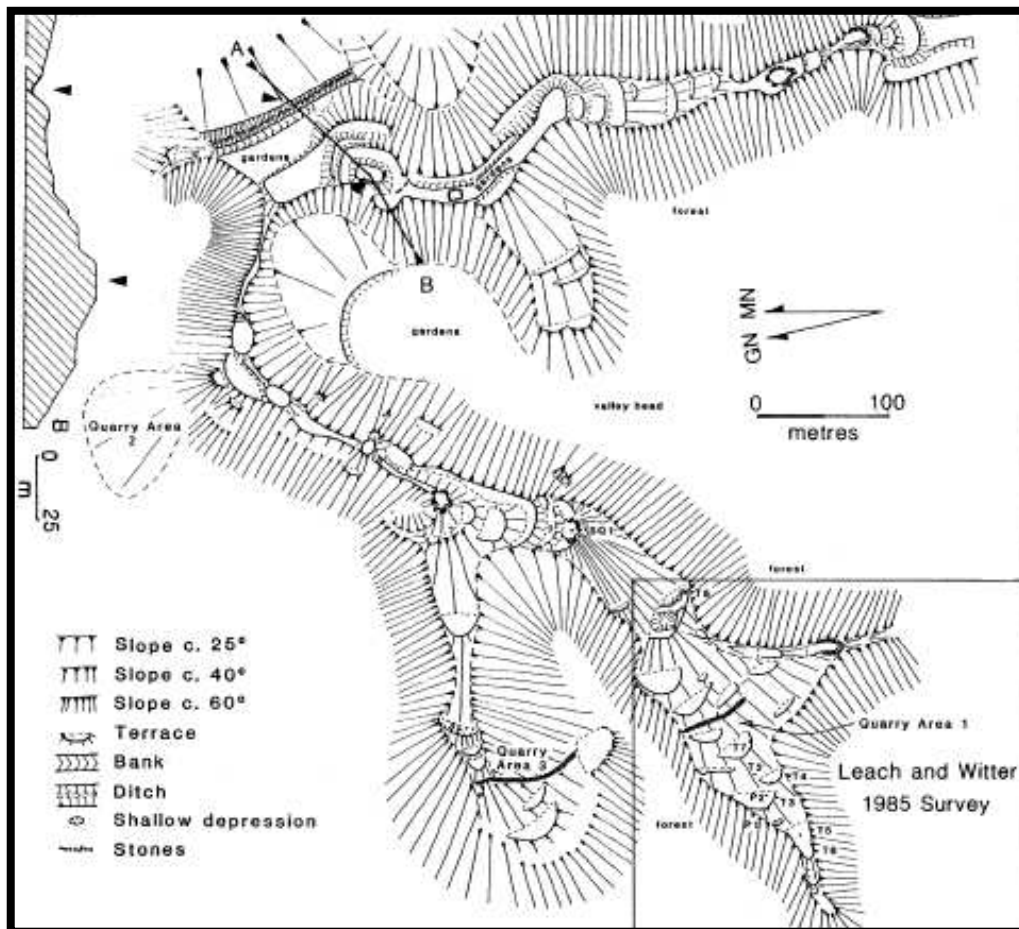


Figure 3.11 Complex of ditches and terraces at Tatagamatau, Tutuila (From Best 1993:420)

A unique feature type in Samoa is the star mound (Fig. 3.12), examples of which are dated to the 15th century AD and later. These features have been identified on ridgetops on almost all islands as well as on the broad plains of ‘Upolu and Tutuila (Clark and Herdrich 1993; Davidson 1974b; Herdrich 1991; Hewitt 1980; Holmer 1976, 1980:101; Quintus and Clark 2012; Sand et al. 2012). Their function remains a matter of discussion, but researchers argue that they were used, at least in part, as platforms for the sport of pigeon catching (Herdrich 1991). Pigeon catching was not a subsistence activity. Rather, Krämer (1902, II:388) noted “the *lupe* (pigeon) was not hunted to be eaten, for it was considered sacred”, later noting that “being the favourites of the chief’s they were worshipped by the people almost like idols”. Herdrich (1991) has argued that the game was highly competitive and monopolised by those of high rank. Herdrich and Clark (1993) have suggested that this competition may have been an avenue for *mana* demonstration by individuals seeking to usurp leaders, and the sport might have had a profound influence on the growing political system. Pigeon catching involved individual competitors directly, competing for individual status and prestige, perhaps acting as a symbolic representation of warfare (Herdrich 1991:394, 418). These features are examples of monumental architecture indicative of changes in socio-political structure and increased status competition.

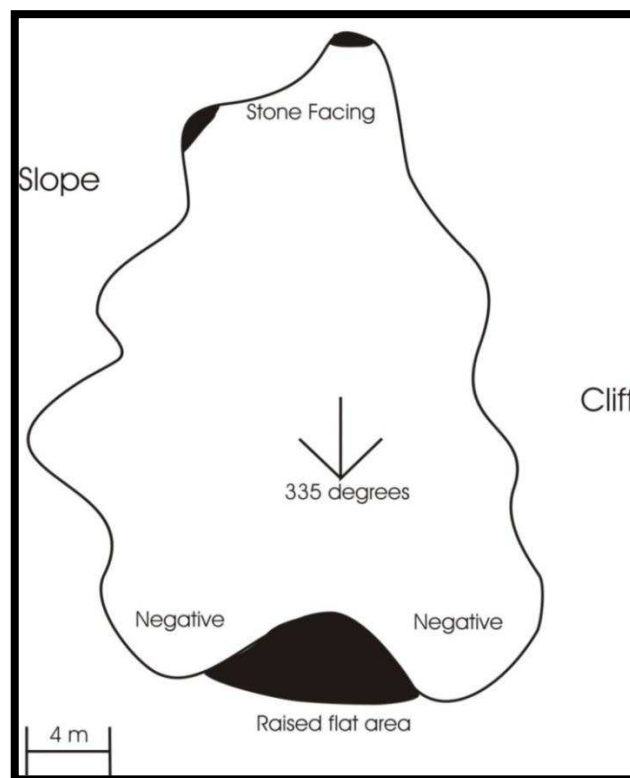


Figure 3.12 Typical star mound from Olosega (From Quintus 2011)

Historic contact began in 1722 with the sighting of Manu'a by Roggeveen, and continued with Bougainville, resulting in the naming of the archipelago the Navigator Islands in 1768. Sustained European presence did not occur until the missionary John Williams began work in 1830 (Moyle 1984). Settlement became more nucleated around the coast as a response to missionary activity and availability of European goods (Davidson 1969). Subsistence changed as European animals and plants were introduced and population declined due to disease. Old world religion altered the daily lives of the population and restricted the traditional ways of recreation and worship. To the modern period, changes are common as the islands continue to become more globalised.

Characteristics of Proto-Historic Samoan Political Systems

The nature and the courses of political evolution have been thought to be particularly relevant for examinations of agricultural development (e.g., Earle 1978, 1997; Kirch 1984, 1991a, 1994, 2006). This section briefly reviews characteristics of the late prehistoric and early historic Samoan political systems, and traces their possible development based on the modest archaeological data available. An understanding of the timing and process of socio-political development is essential as cultivation strategies can change, sometimes significantly, in response to changes in the social relations of production and the creation of production bottlenecks.

The 19th and 20th century AD Samoan political system was a variant of the well-studied Polynesian chiefdom (Goldman 1970; Sahlins 1958). The basic division was between those with titles and those without, the former referred to as *matai*. Each *matai* was chosen by the family ('*aiga*) to hold its title, and all *matai* in each political unit formed a council called the *fono*. *Matai* were differentiated by their respective duties, divided between high chiefs (*ali'i*) and orators (*tulāfale*). Because the ancestors who founded the political system were *ali'i*, these chiefs were given special privileges that were not extended to orators (Techerkezoff 2000:152). All titled men, however, were allotted some special privileges, which included *tabu*, chiefly languages, and differential access to resources (Sahlins 1958:31-37). Made up of these individual parts, each *fono*, at the village, district, or island level, had influence in decision-making within their boundaries. Nevertheless, authority often rested in the village or '*aiga*, as larger scale *fono* were often ineffective (Sahlins 1958:34).

The 19th and 20th century *matai*-based political system has been thought by some to stem from the prehistoric period (Goldman 1970; Sahlins 1958). Others, however, argue that

aspects of the *matai* system developed after sustained European contact, and the prehistoric situation may have resembled those of other Polynesian high islands and neighbouring Tonga (e.g., Meleiseā 1995; Schoeffel 1978, 1987, 1995). Based largely on examinations of oral history and linguistic evidence of the western islands of the group, as opposed to the traditions of Manu'a, these researchers argue that power in precontact Samoa was concentrated above the household and family level. Power did often reside in the chiefly titles (Mageo 2002; Mead 1969; Shore 1982:69), like it does in modern Samoa, but in some instances power also resided in the individual and lineage (Meleiseā 1995:21, footnote 2). This power was held by high chiefs (*ali'i*), whose influence often stretched across districts or even island wide. *Ali'i* were of the highest rank and held sacred power, but secular power was exercised by lesser chiefs (*tulāfale*) (Shoeffel 1987:185). All rank and titles depended on their presumed genealogical connection through maternal lineages (Shoeffel 1978, 1987), the highest chiefs descended from Tagaloaalagi (the creator) (Meleiseā 1995:21). The highest ranked *ali'i* were *ali'i pa'ia* (sacred chiefs), who were “as living gods among humanity, imbued with supernatural powers by famous ancestors by whose names they were titled” (Meleiseā 1995:21; see also Schoeffel 1978). The complexity of the relationship between different types of chiefs can be summarised in the following passage of Meleiseā (1987:15):

The power of high-ranking *ali'i* was legitimized by the *mana* of his/her aristocratic antecedents and ultimate descent from a god. On the other hand, *tulāfale* derived their authority (*pule*) to act from the *ali'i*, and acted always in the name of an *ali'i* or his/her *nu'u*. But the system, at least from approximately the 16th century, gave great power to the *tulāfale*, for although they could exercise authority only in the name of an *ali'i*, it was the *tulāfale*, acting in groups, who collectively bestowed the highest of *ali'i* titles.

Prior to the late 19th century AD, *matai* were heads of family groups, but did not necessarily possess any power outside of the *nu'u* (roughly, villages). It was not until the late 19th century and early 20th century that, as a result of a centralised colonial government, “the difference between local *matai* and supra-local *ali'i* and *tulāfale* became less and less perceptible” (Techerkezoff 2000:172).

Like elsewhere in Polynesia, the political system of Samoa was intimately tied to cosmology and the concept of *mana*. *Mana*, which has been variously defined because its contextual dependency (Firth 1940; Keesing 1984), is often thought of as a divine source of power that is channelled principally by those of chiefly status (see Shore 1989:138). As *mana* was mobile, dynamic, and fickle, it was the job of those in political power to continually

demonstrate their *mana* to the surrounding populace to legitimise their ability to lead. Shore (1994:166) suggested that status anxiety relating the demonstration of *mana* in Samoa “was and is as much a part of chiefly ideology as any expressions of sanctity attaching to chiefly power”. Agricultural production, a measure of the individual leader’s productive capabilities, was an avenue of demonstration. For Mageo (2002:507) *mana* in Samoa “is a hypercharged life force manifest in an abundance of food”. Based on Samoan myth, a chief that failed to demonstrate his *mana* faced the “removal of his descent line and the transfer of his authority to another chief” (Shore 1989:139). Chiefly taxation, in the form of food offerings, was not as well developed in Samoa as elsewhere, but Mead (1969:70) has remarked that, in the early 20th century, each family had at least some obligations to fulfil, especially at times of visitations of high status guests from outside the village and during community wide building projects. Moreover, Sahlins (1958:31) has argued that, even in post-contact times, “local councils supervised the production of the individual households and controlled the pig breeding and land cultivation”.

Unfortunately, the prehistoric development of Samoan political systems is not well understood. Oral tradition suggests that the archipelago was a fairly centralised political entity at one time, probably before the 16th century AD, with separate districts on each island (Meleiseā 1995). During this time, the seat of power was placed in the Manu’a Group, the highest titled individual being the Tu’i Manu’a. At some point, possibly in the 13th-17th century AD as speculated by Goldman (1970), the Tu’i Manu’a lost authority over the western islands of the group, and an alternative focus of rank was created in the west (Schoeffel 1989:185). These islands then became separate political entities with their own line of high titled individuals and families. Interestingly, Goldman (1970:260) illustrated the structural differences in late precontact political systems between Manu’a and the rest of the islands by opining that “Manu’a may be said to have been the center of intricate patterns of personal and collective power; Western Samoa, of direct and crude distinctions between strong and weak”.

Archaeologically, large settlement pattern surveys, such as ones conducted by Green and Davidson (1969, 1974), Jennings and colleagues (Jennings and Holmer 1980a; Jennings et al. 1976, 1982), Clark and Herdrich (1986, 1993; Clark 1989), Pearl (2004, 2006), and others (Quintus 2011; Quintus and Clark 2012), have led to the collection of data that support the idea of a growing chiefly authority over the past 1,000 years. For instance, household variability indicative of social inequality, in terms of size, height, and construction material,

is documented from throughout the archipelago (Holmer 1980; Quintus and Clark 2012). At a similar time, the political dynamics of basalt tool manufacturing began to change. Winterhoff (2007:212, 216) argues, using the premise that large-scale craft specialisation can be equated with management, that the last 800 years of Samoan prehistory saw increased control of resources by the elite class on Tutuila. Large quarries that provided basalt to far reaching island groups are some of the most defended positions in the archipelago, certainly on Tutuila where most of them have been found (Winterhoff 2007:205-206, 212-213). In Winterhoff's model, this greater defense can be correlated with the needs of groups to protect their sources of powers, in this case basalt. The construction of star mounds is consistent with this sequence of political development, all dated examples being constructed in the 15th century AD or later (Clark 1996; Herdrich 1991; Martinsson-Wallin and Wehlin 2010; Wallin et al. 2007). Star mounds are ubiquitous throughout the archipelago, but are found at their highest density on the island of Olosega (Quintus and Clark 2012).

Agricultural Strategies, Crops, and Hazards in Historic Samoa

The cultivation of taro and *tamu* (*Alocasia macrorrhiza*) in dryland multi-cropped gardens was at contact, and still is, the dominant form of food production in Samoa (Carson 2006; Misa and Vargo 1993; Fig. 3.13). At contact, dryland fields were located inland of settlements, and crops were grown in plots demarcated on the household scale (Buck 1930; Kramer 1902-03; Watters 1958). More specifically, as documented by Fox and Cumberland in the 1950s and 1960s (1962:203-204), arable land in Samoa was divided into three zones, the coconut zone, the mixed crop zone, and the taro zone. The coconut zone was situated just behind the village, extending until the slope increased, at which point one encountered the mixed cropping zone. This zone was planted with banana and other smaller crops, often mixed with taro. Extensive shifting cultivation plots primarily of taro, but other crops as well, were grown on the slopes overlooking the village and further inland. To these three zones, I would also note, as have others (Krämer 1902-03, Vol II:154), the cultivation of tree crops in villages amongst residential features (see similar situation in Kirch 1994 for Futuna), the primary zone of breadfruit cultivation. This is the ideal historic pattern, but many variations existed and continue to exist as a result of the physical environment and changing land use patterns.

Today throughout the archipelago, dryland systems are extensive and new gardens are created in gently sloping or flat areas where there is enough space and water for growth.

Water requirements are not normally a consideration as most land receives ample rainfall. The cultivation of root crops on the coast of Ofu is restricted to areas wherein volcanic sediments have been deposited, specifically the coastal marsh or near talus slopes where terrigenous sediments have been mixed within calcareous sediments and organic material. Gardens are also restricted by slope. Taro can grow on even some of the steepest slopes (up to 45 degrees in Samoa), but there is a point of diminishing returns in which crop production returns are outweighed by the labour needed to create and maintain the garden space. Slope is much more of a limitation on the smaller islands of American Samoa where the topography is characterised by cliffs and mountains.

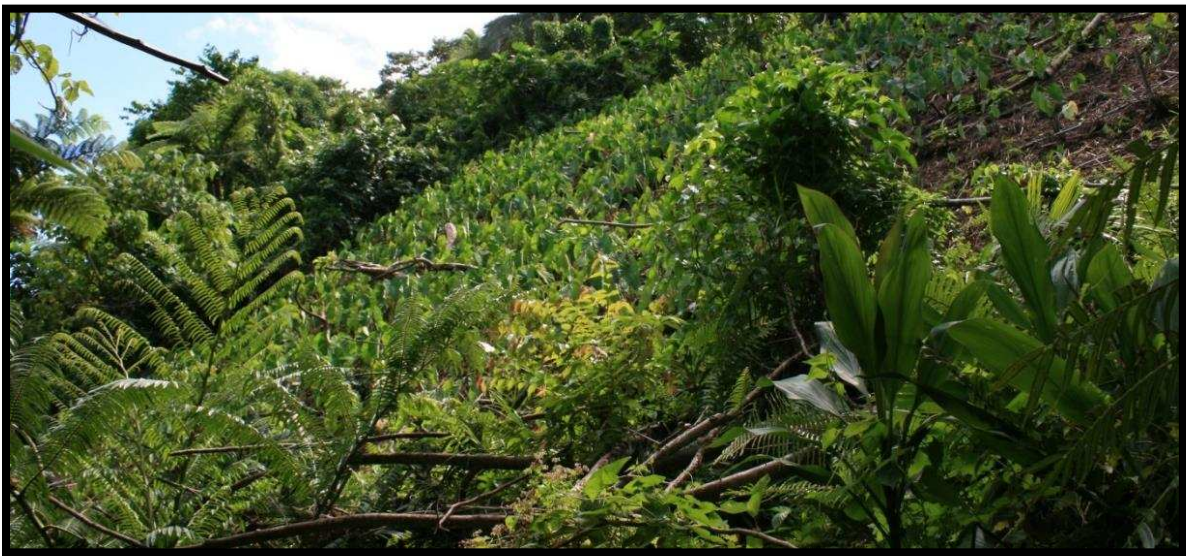


Figure 3.13 Taro garden on the slopes of Tufu Stream

Through the 20th century and into modern times, fields are slashed and, sometimes, burned; plots are used until yields start to decline, perhaps for two to four years (Coulter 1941:26; Fox and Cumberland 1962:220). At the point of diminishing returns, another plot is cleared and the process repeated. Fallow period is dependent on the amount of land available and population size, but ranged in the 1950s and 60s from less than two years to as many as ten or more (Fox and Cumberland 1962:220-221). Often, instead of burning, logs and cuttings are left to rot as a kind of natural fertilizer.

Most crops could be planted year-round, but cropping followed a specific regime that included yams, a relatively unimportant crop in modern Samoa (Fox and Cumberland 1962:216), being planted prior to taro (Watters 1958:341). The importance of taro in the diet

relative to yams may have been related to the seasonality of the latter, with previous authors noting that informants suggested the cultivation of yams may result in famines at certain times of year (Whistler 2001:20). Sweet potatoes may have been introduced before European contact, though this is unclear, and the crop appears to never have been important in the subsistence economy (Whistler 2001:21-22). Potentially, this may relate to the excess amount of precipitation in the archipelago and the drainage requirements of the crop. Multi-cropping continues to be practiced in many areas (Carson 2006; Misa and Vargo 1993; Tuitele-Lewis 2005:50), mimicking the natural forest and protecting against crop specific diseases, pests, and erosion, though the temporal depth of the pattern is unclear.

Historically and in modern times, the tools used for cultivation are the *oso* (digging stick) and the *oso to* (planting stick), aided by the introduced bush knife. After crops are planted, farmers occasionally visit the gardens to weed and maintain growth, some more than others depending on the area under cultivation. Fox and Cumberland (1962:217) have argued that less than 10 percent of arable taro land was under cultivation at any one time in the middle of the 20th century, though Watters (1958:340-341) has asserted that village areas had substantial field systems in the past, some up to a mile long.

Some natural marshes, those close to villages, are used, and were used historically, to cultivate taro (Addison and Gurr 2008; Buck 1930; Carson 2006; Fig. 3.14). Buck (1930:547) states that no irrigation was practiced in Samoa in the 19th and 20th century AD, implying that cultivation in these marshes or other wetland environments was more comparable to shifting cultivation than to irrigation in other areas of Polynesia. In fact, the marsh areas are conducive for cultivation only because of their increased soil moisture, as natural drainage out of these environments creates an arable zone by producing a flow of fresh water. If drainage is restricted, water becomes stagnant and the area cannot be cultivated. Some modification of these marshes does occur. Paths through the marshes are created using large stones and stick fences running along the sides of ditches, effectively dividing the land into plots. Each plot is largely planted with taro and is mulched with coconut leaves, which reduces weed growth and maintains soil moisture. In the late 19th century and early 20th century, crops were planted in or near streams to utilise the natural flow of water (Buck 1930), and, on 'Upolu, estuaries of the larger streams were put under cultivation (Krämer 1902-03).

Other strategies or cultivation techniques are used to manage or mitigate the chance of resource shortfall. Not a prized food resource, but *tamu* has been documented as a famine food eaten at times of drought or after large tropic storm activity (Coulter 1941:21; Fox and Cumberland 1962:219). Farmers may choose to plant later to avoid cyclone damage (Watters 1958:342), while crop diversification and multi-cropping help avoid crop-specific fluctuations (Quintus 2012; Watters 1958:342). Tree crops can be used to provide wind breaks and to stabilise slopes (Tuitele-Lewis 2005:50). Mulching is practiced (Watters 1958:342), but to differing intensities depending on techniques. So is burning, which increases soil nutrition and reduced weed growth. Storage is limited in modern times, though *masi* pits, for the fermentation of starches, developed in prehistory and became invaluable (Watters 1958:349). These are recorded archaeologically on Ofu (Clark et al. 2012).



Figure 3.14 Taro growing in the Ofu Marsh. Note the mulch of coconut fronds

The cultivation of a few species of plants forms the bulk of the subsistence economy. The following describes the economic use of the most heavily exploited crops: taro, coconut, breadfruit, and banana. This section draws heavily on the work of Whistler (2001).

Taro

Undeniably the most important plant in the 19th and 20th century AD Samoan subsistence economy was taro; the crop had such ceremonial importance that Buck (1930:129) asserts it was the “correct vegetable to serve to high chiefs.” Originally

domesticated in Near Oceania and Asia, the plant has a wide distribution (Lebot 1999). Taro is a member of the Araceae family which includes a number of species, the most commonly grown of which are in the genus *Colocasia*. Two botanical varieties of the species *Colocasia esculenta* are recognised by some in Samoa, var. *esculenta* and var. *antiquorum*, the former the one most commonly grown to eat (Brooks and Utufiti 2001; Purseglove 1972:62). However, twenty-six named varieties are known to have been cultivated in Samoa in the past (Whistler 2001:15; cf. Christopherson 1935), differentiated based on social role or location (Buck 1930:546).

The plant is a root crop, like a potato or yam, with a long stem and heart-shaped leaves, which can be grown in both dry and wetland settings. In dry settings, taro still requires annual precipitation between 1,500 and 2,000 mm for growth (Onwueme 1999), below which irrigation is necessary. Somewhat contrary to this, Copley suggests that the crop is best cultivated in areas which receive an annual precipitation exceeding 2,500 mm (Copley 1976:125). This discrepancy may relate to variable soil conditions, with high precipitation needed for cultivation in well-drained settings. The starchy bottom stem, the nutrient storage organ of the plant referred to as the corm, matures between 6-9 months, and thereafter the leaves and corms are harvested. Unlike giant taro (*Alocasia macrorrhiza*), the corms of which can be left in the ground as a form of storage, the corms of taro cannot be left in the ground after they mature as they will rot. However, crops in sloping, well-drained lands may not rot as quickly as those in low lying, moist soils (Coulter 1941:26). After harvest, part of the plant, a portion that includes the top crown of the corm and part of the stalk that attaches to the corm, is either dried or immediately replanted. Fields continue to be replanted until the occurrence of disease, pests, hazards, or declining yields. Whistler (2001:17) stated that cultivation in streams can be continuous, without fallow, as the stream flow replenishes lost nutrients.

Taro can be directly impacted by tropical cyclones, with documented official losses following these events reaching between 30 to 50 percent (Paulson 1993:46), but cyclone damage is minimal compared to that caused by landslides, floods, and debris flows, as well as, to a lesser extent, drought. Since taro is more often than not grown in a dryland setting in Samoa, rainfall fluctuation can cause decreased yield or decreased corm size, whereas landslides, floods, or debris flows may destroy the entire crop. Some gardens are now protected from landslides and floods by linear earthen mounds, either around the gardens themselves or on the banks of stream from which sediment can discharge or overflow.

Alternatively, farmers have begun bordering gardens with rows of thick grass (Fig. 3.15), which act to reduce the energy of runoff, diminish the impact of loose debris, and decrease soil erosion.



Figure 3.15 Long grass guarding downslope taro plots from debris transported from upslope

Breadfruit

Breadfruit is the second most important subsistence crop in Samoa (Buck 1930:131), and Wilkes (1854:181) opined in the 1840s that breadfruit “is the most abundant of all trees” in Samoa. The tree is native to Near Oceania (Lebot 1999; Zerega et al. 2004), and has since been distributed throughout Remote Oceania, with 37 named varieties grown in Samoa (Whistler 2001:28). The trees are easily recognised by both the shape of the fruit and that of the leaves, specifically in regards to the degree of incisions (Fig. 3.19). They are best grown in deep volcanic soils, where they reach up to 30 m in height, but can survive in inferior soils as well (Whistler 2001:28). Breadfruit is seasonal and fruit is available half the year (Whistler 2001:29), with a peak around December and January, being unavailable in February, March, October, and November. The tree rose to prominence in many parts of the Pacific because of its ability to be preserved (Addison 2006; Cox 1980; Whistler 2001). To store, the mature plant is harvested and placed in a large, sealed silage pit where it ferments and can be kept for a period of time, recorded to have been preserved up to several decades in the Marquesas (Robarts 1974) and 3 to 5 months in Samoa (Pritchard 1898:127). This fermented breadfruit,

called *masi* in Samoa, was eaten at times of famine (Whistler 2001:30). The importance of breadfruit in the subsistence economy may fluctuate over an annual cycle given availability, but the wood is available throughout the year and is culturally important as a desired construction material associated with chieftainship (Buck 1930:19). Buck (1930:19) further states that “breadfruit is the only timber for a proper guest house”, guest houses being signs of prestige situated along the *malae*, or communal central open area, of the village.

Breadfruit vulnerability is similar to that of coconut, but it has the added advantage of being storable. Like other leafy trees, cyclones can cause the complete removal of foliage and fruits. In 1990, 50-90 percent of mature trees were blown completely over (Clarke 1992:71). While some fruits can be picked from the ground and salvaged, it takes a significant amount of time to regrow trees that have been uprooted or defoliated, and it is several years before the trees bear fruit again (Paulson 1993:46). In recent years, after severe cyclones in 1987 and 2005, village members on Ofu Island have commented on the complete loss of breadfruit crops and the time it takes to recover from such an event. To combat loss, increased food shipments from Tutuila were necessary in these years, which may not have been possible in prehistory. The counteraction of loss in the past may have been possible with food storage, and the myth of the first *lua'i masi* (storage pit) connects such food storage with high winds. In this tradition, breadfruit storage is equated with westerlies, which almost only occur during El Niño years in the Samoan Archipelago. As Buck (1930:132-133) relays:

Owing to her parents not being able to get the breadfruit down from the trees, Sina brought them the *tuaoloa* (east) and *to'elau* (N.E. trade) winds to bring down the fruit for them. The two winds failed to bring down sufficient fruit, much to the crippled couple's disgust. In answer to their complaints, Sina sent the boisterous *la'i* (west) wind which effectively brought down the fruit. The old couple, at last satisfied, gathered the fruit and stored the excess quantity in the hole alluded to, where it became converted into *masi*.

Coconut

Originating in the Old World, multiple varieties of coconut have spread throughout the Pacific, one of which is native to Samoa. The native variety features large husks and smaller nuts, while the Polynesian introduction is more readily utilised for food and drink (Whistler 2001:24). Coconuts are self-propagating and require very little labour before harvest. In the historic period, the economic benefits of coconut, with its low labour intensity and increased demand, led to the development of a copra industry throughout the Pacific, of which Samoa was a part. Besides copra, coconut is used for cooking, eating, drinking, and

pig fodder (Whistler 2001:26). Additionally, various parts of the coconut are used as raw material, especially the fibres which can be fashioned into a sennit and used to build houses and canoes, while the fronds are useful for thatch and decorative plaiting.

Coconuts are known for their resilient nature, being able to live and reproduce in some of the most inhospitable island environments, including the shallow sandy soils of the coast on Ofu. While taro can be devastated by landslides and drought, the coconut often perseveres through these hazards. However, the coconut crop can be negatively impacted, especially by tropical cyclones. High winds of cyclones are known to remove foliage and fruit or even uproot the trees completely. The cyclones of the early 1990s (1990, 1991) devastated the coconut crop in Samoa, which still had not recovered by 1995 (Paulson and Rogers 1997:176). The situation was similar in 1915 with officials reporting that not one coconut tree on Ofu could be saved, and estimating that it would be at least seven years before a tree was ready to bear fruit once again (Health Officer of American Samoa 1915:1).

Banana (Plantains)

Bananas, a group that includes plantains (Whistler 2001:31), constitute a sizable portion of the modern Samoan diet (Clarke 1992:69). Origins of the banana are complex, genetically exhibiting evidence of significant hybridisation, but again they appear to have originated in Near Oceania/Southeast Asia (Perrier et al. 2011). Part of the *Musaceae* family, bananas are grown in a variety of habitats, from the coast to the high mountains. They possess an appearance similar to trees, and are often classified as such (see Clarke 1992), but they are actually large herbaceous plants that can reach 6 m in height (Whistler 2009:158; Fig. 3.16). A native species of banana that produces seeded fruits has been reported in Samoa ('Upolu and Savai'i only), though its large seeds preclude its use as a subsistence crop (Whistler 2001:31, 2009:155). The exact number of subsistence banana varieties is uncertain, but a range from 25-37 is accepted (Whistler 2001:32, 2009:155). These are seedless and produce only one crop of fruit during their lifetime, but are easily regrown as suckers develop on the bottom of the plant and quickly take root (Whistler 2001:31-32). Bananas can be harvested throughout the year and most bananas or plantains are eaten as starches, being harvested when they are green. Further, like breadfruit, banana can be preserved and stored (Buck 1930:134; Cox 1980; Fig. 3.17).

Of the crops discussed, bananas are the most susceptible to damage from hazards, though they can recover quickly. Given their weak stalks, bananas can be destroyed during

cyclones or even high winds, with up to 100 percent of crops destroyed during severe cyclones (Watson 2007:25-26). Damaged trees can be cut by farmers to induce another growth cycle that begins a short time after (Clarke 1992:69). However, Paulson (1993:46), describing the process of vegetation growth after the cyclones of the early 1990s, states that in some areas banana was not available for six months after storms. Unlike breadfruit, bananas are not seasonal, aiding in recovery from storms (Whistler 2009:156). The plant can be drought tolerant, but the annual minimum required rainfall is in excess of 2,000 mm (Nelson et al. 2006:5). During landslides, bananas can either be buried or destroyed by rapidly moving sediments.

Historic Hazards and Agriculture

As demonstrated, all of the crops discussed above are susceptible to damage from commonly occurring hazards. This section explores these hazards and discusses their historic and contemporary impact on cultivation in the Samoan Archipelago.

Tropical Cyclones. Cyclone events are highly variable; the number and frequency fluctuating as a result of climatic cycling. Between 1840 and 1966, Samoa experienced six severe cyclones and 42 lesser tropical storms, while three severe cyclones were documented between 1988 and 1992 alone (Pierson et al. 1992:2). An average of ten per decade have some impact on the archipelago, but in some years, particularly El Niño years (Hilton 1998:63), as many as five may be recorded (ABM CSIRO 2011:190). In fact, two of the most severe storms in recent memory, Cyclone Ofa (1990) and Val (1991), occurred within 22 months of each other. Pierson et al. (1992:2) state that “such storms are visibly, if patchily, devastating to natural communities as well as human infrastructure”. Further, these researchers (1992:2) state that “cyclone damage and recovery has an irregular, multi-year periodicity”. The following is the description of damage following a severe cyclone in 1915:

On landing at this village on [sic] was struck by the intense havoc wrought by the wind. The storm evidently was here most violent, and came from the southeast. Of the 74 native homes not one remained standing. The church, built of cement with substantial walls and corrugated iron roof, was razed to the ground, the whole structure being but a pile of broken concrete; not one wall remained standing. The six other houses of European design and substantial cement construction were but a tumbled down heap of ruin. The whole village site was a mass of broken timber, fallen native houses and general debris. (Letter to the Governor from the Health Officer of American Samoa 1915:1, Fig. 3.18)

Early historic reports suggest that such storms also had a significant effect on staple crops and infrastructure (e.g., Lundie 1846:179-182), especially the 1889 cyclone on ‘Upolu, and more recent reports provide quantitative assessments. In 1959, a cyclone destroyed houses in the main villages of the Manu’a group and caused damage to all crops, particularly banana. The cyclone of 1966 resulted in the complete devastation of the banana and breadfruit crop in, then, Western Samoa, and it was estimated that breadfruit production would reach below 50 percent of the pre-storm totals for five years following the storm (Kerr 1976). A reduction in copra production of as much as 50 percent was documented in the same storm (Kerr 1976). Shortly after, in 1968, a storm destroyed 70 percent of mature or crop bearing banana stems (Kerr 1976). Cyclone Ofa in 1990 destroyed between 50 and 90 percent of mature trees at different locations on ‘Upolu (Clarke 1992:71), while the storm led to a ban on taro exportation. Seiden et al. (2012:290) note that within the period that these cyclones occurred, specifically between 1989 and 1995, “the dietary availability of starchy root crops decreased 78%”. The cyclone impacted Western Samoa more than Tutuila (Clarke 1992), and some areas on Tutuila were damaged more than others. The patchiness of destruction was apparently managed as less impacted areas were able to provide supplies. The variability of damage on ‘Upolu, an island of over 1000 km² in area, meant that taro production in less impacted areas could counteract the loss of productivity in heavily impacted areas (Clarke 1992:67-68). The size of Ofu (7 km²) precludes this possibility as, usually, the damage caused by cyclones impacts the entire Manu’a Group.



Figure 3.16 Bananas in a fallowed garden plot



Figure 3.17 The preparation of *masi* pit storage (From Cox 1980:183)

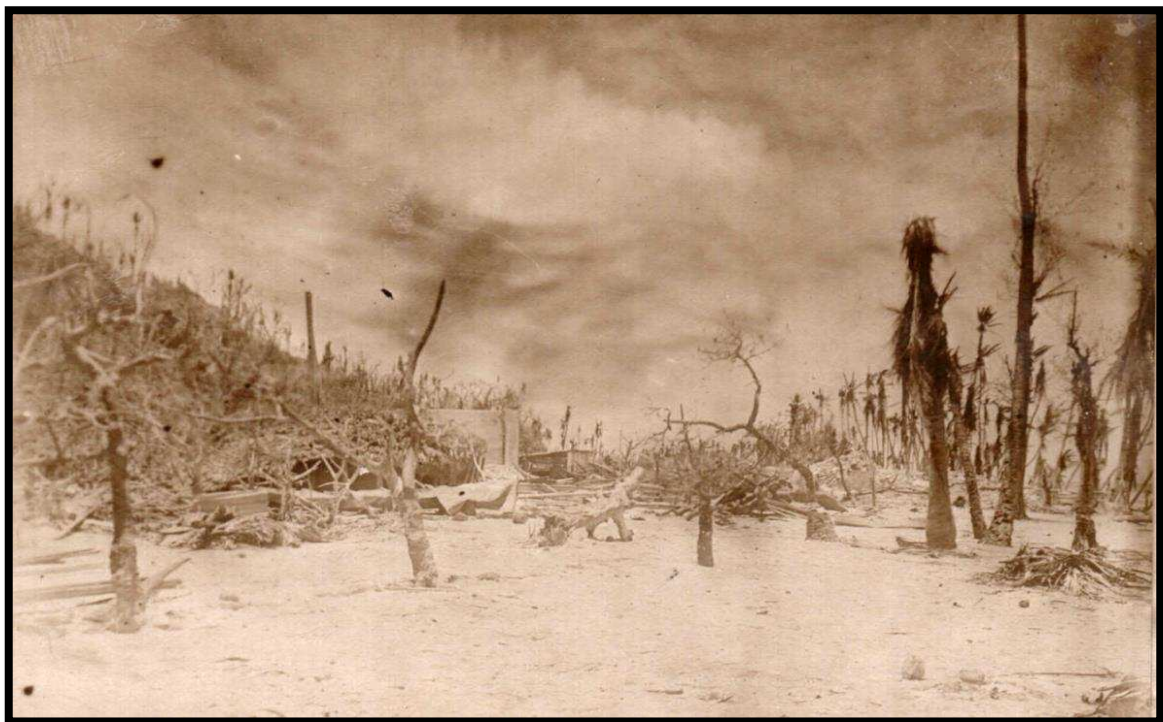


Figure 3.18 Damage from the 1915 cyclone in Ofu Village (Courtesy of David Herdrich of the American Samoa Historic Preservation Office)

Landslides, Debris Flows, and Flooding. High intensity rainfall periods can cause surface flooding, landslides, or debris flows, defined as the movement of water with soil and large clastics, that deleteriously impact crops. Precipitation during a single event has been documented as high as 200 mm in two hours on Tutuila (Tuitele-Lewis 2005:7; NOAA Weather Data), and surface flooding occurs when the amount of precipitation exceeds the infiltration levels of the soils. Though empirical data regarding their frequency are not available, these hazards are often thought of as attributes of cyclones and lesser tropical storms, and, thus, the periodicity of their occurrence is likely similar to that described for cyclones above. Most of the soils of Ofu are classified as highly erodible, which, in conjunction with slope, make the island particularly vulnerable.

The high energy movement of water and sediment has the ability to destroy infrastructure in modern Samoa, as well as agricultural produce. Landslides and debris flows, though the extent of damage is spatially limited, are capable of destroying houses, roads, and vegetation (Pacific Disaster Center 2003:3; Fig. 3.22, 3.23). Since the risk of rain-triggered erosion increases as vegetation is cleared from steep slopes, areas which are cultivated, the event of a landslide might result in garden destruction by the stripping or burying of crops. Landslides, debris flows, and flooding are often localised events that impact small areas. This effect can be counteracted by the spatial diversification of garden space, unlike the effects of droughts or cyclones which disturb the entire island.

Droughts. Moisture deficiency is usually not a problem associated with the Samoan Archipelago, as rainfall often occurs daily. Nevertheless, precipitation in some areas can fall beneath the needs for the growth of some crops, namely taro, and is commonly listed in modern reports as a hazard (ABM CSIRO 2011:191). Because the study area is a volcanic high island, rainfall patterns can be affected by orographic lifting. Though this factor can create a marked windward/leeward dichotomy on some islands, as on 'Upolu and Savai'i, it does not on Ofu. Still, the higher elevations of the island receive more precipitation than the coast, and, therefore, crops growing at higher elevations are less susceptible to drought than crops grown on the coast.

During the extreme ENSO years of 1997-98, precipitation decreased throughout the archipelago resulting in decreased crop production and water shortages. On Tutuila, roughly 1,700 mm of rain fell, less than half of normal range. At a monthly scale, the normally less wet months saw little to no rainfall while the normally wet months saw between 50 mm and

254 mm. However, data addressing the impact of ENSO-related drought events are limited, and the data that are available show limited to no correlation between decreases in production and drought (Solofa and Aung 2004). For example, Solofa and Aung (2004:49) argue that “the reflection of severe events such as the 1997-1998 drought does not show in the agricultural sector performance”, which they attribute to “recent sector development”. Giambelluca et al. (1988) identified areas prone to drought on the high islands of ‘Upolu and Savai’i, but their analyses were meant to be predictive with little discussion of the impact of actual drought on cultivation. Additionally, on Ofu, it is likely that, even with a reduction in rainfall of over 50 percent, much of the interior could still support cultivation of key crops as annual precipitation often exceeds 4,000 mm of rain. The coast, except for the small wetland area, would be more vulnerable during drier periods of the year (April to November).

Summary

Since European contact, dryland shifting cultivation in extensive gardens has been the dominant form of food production in Samoa. Produce from these gardens is supplemented by arboriculture and limited wet land cultivation. Based on these techniques, a small set of plants satisfy the subsistence needs of the populations, notably taro, coconut, breadfruit, and banana. All of these crops can be grown effectively in the Samoan Archipelago, but they are susceptible to a range of environmental hazards. Cyclones, especially, have the ability to decimate yields of breadfruit, coconut, and banana. Additionally, both localised events, such as landslides, surface flooding, and debris flows, and, to a lesser extent, droughts can impact herbaceous plants.

Questions remain as to the temporal depth of this cultivation system, and the process by which it developed, especially in the context of the cultural, environmental, and climatic sequences. The study of the archaeological and geomorphological record of Ofu Island in this thesis, paired with results of previous research, address these questions.

Past Archaeological Investigation on Ofu

The limited field research that has been conducted on Ofu has proven to be productive and enlightening for Samoan archaeology and the wider Pacific. Much of the data available comes from two academic projects (e.g., Clark 2011, 2013; Clark et al. 2012; Kirch and Hunt 1993b; Hunt and Kirch 1988, 1997), but smaller projects have also contributed significant information (e.g., ASPA site files; Best 1992; Kennedy 1995; Moore and Kennedy 1996). A

prehistoric sequence of the southern coast is in place, but, prior to this thesis, the rest of the island remained relatively unexplored. This section provides a brief history of archaeology on Ofu and a discussion of known archaeological complexes relevant to this study (Fig. 3.3 above; Table 3.1).

A History of Archaeology on Ofu Island

Archaeological field work on Ofu began with Kikuchi (1963), who collected stories and did spot checking. More sustained field research on Ofu began with the work of Clark in 1980. While limited in time and scope, Clark formally recorded sites for the American Samoa Historic Preservation Office (ASHPO) throughout the territory, and offered preliminary significance determinations. Most sites recorded by Clark were located on the coast, but he did report interior sites on Olosega.

Further research was not conducted until the late 1980s, when Kirch and Hunt (1993b; Hunt and Kirch 1988) conducted limited surveys of Manu'a. Their intensive survey and subsequent excavation was restricted to To'aga on the southern coast. At To'aga, Kirch and Hunt recorded a deeply-stratified, ceramic-bearing deposit dated to the beginning of the 1st millennium BC. However, the dating of the area recently has been contested based on material culture disconformities, specifically the absence of dentate stamped pottery, and the lack of dated short-lived wood taxa (Rieth and Hunt 2008).

Following the work of Kirch and Hunt, Kennedy and Moore conducted limited work on the northeastern coast of Ofu, identifying a small assemblage of indigenous artefacts (Kennedy 1995; Moore and Kennedy 1996). Best (1992) conducted a small survey in conjunction with proposed road construction, largely around the coastline, although a very small portion of the interior on the slopes directly inland of the village was investigated. Best identified a high density of remains along the coast, and documented the first archaeological remains in the interior of the island, immediately inland of Ofu Village. Of particular importance, Best briefly investigated another deeply-stratified, ceramic-bearing deposit on the south coast, this one close to the Va'oto Lodge situated west of To'aga (AS-13-13; Va'oto Site).

Given the potential of the Va'oto site, Clark began a long-term investigation of the area in the late 1990s and into the 2000s. This project led to the identification and excavation of multiple ceramic sites, including another south of the modern runway in a coconut grove

(AS-13-37; Coconut Grove Site). Additionally, small scale reconnaissance surveys were undertaken to explore the interior of the island (Clark et al. 2012). Below is a description and discussion of the previously recorded sites important to this thesis. To'aga is not included here as it was discussed at length in previous sections of this chapter.

Table 3.1 Major recorded archaeological complexes on Ofu

Complex	Site Number	Location	Period	Reference
To'aga	AS-13-1	Coastal	Colonisation-Historic Period	Best 1992; Kirch and Hunt 1993b
Va'oto	AS-13-13	Coastal	Colonisation- 2000 BP	Best 1992; Clark 2011, 2013
Coconut Grove	AS-13-37	Coastal	Colonisation- 2000 BP	Clark 2013
A'ofa	AS-13-39	Interior	1000 BP?-Historic Period	Clark et al. 2012

Va'oto

First discovered by Best (1992), the Va'oto site (AS-13-13) was examined more recently by Clark (Clark 2011, 2013). Similar to To'aga, the deposit was found to be deeply stratified and produced dates from the early portion of the Samoan cultural sequence. The stratigraphy changes considerably across the site, but up to six cultural layers can be distinguished, with multiple subdivisions within the larger strata. The upper portion of the deposit has been disturbed by bulldozer activity related to the construction (and re-construction) of the Va'oto Lodge, but the layers representing at least the 1st millennium BC are intact. The earliest layers, Layers V and IV, have yielded some of the earliest dates in the archipelago (Beta-249327, 2520±40, 2σ 798-521 BC; Beta-249326, 2430±40, 2σ 753-404 BC; Beta-128706, 2460±40, 2σ 761-415 BC; Beta-297824, 2520±30, 2σ 795-542 BC), while Layers II and III extend to the beginning of the 1st millennium AD (Clark, unpublished data).

As with To'aga, sherds of plainware pottery are common in the earliest layers, and no decorated sherds have been found. Volcanic glass and basalt make up the bulk of the stone artefact assemblage; an exotic adze of unknown origin was found in the lowest stratum suggesting possible contacts beyond Samoa. Most Samoan sites have yielded relatively little in the way of fishing gear, but Va'oto is similar to To'aga in producing a relatively large assemblage of fishhooks (n = 28 from To'aga, n = 26 from Va'oto). Shell scrapers, bracelets, and beads, along with other bone and coral artefacts have been recovered, as well. Shell,

urchin spines, and bone (mostly fish) are abundant at the site (Aakre 2013). Like To'aga, an increasing terrigenous component to the sediment budget is observable through the sequence.

Coconut Grove

The Coconut Grove site (AS-13-37) is located a short distance west of Va'oto, the southernmost extension of the island. Field research has been conducted at the site since 2011 directed by Clark (Clark 2013). Excavation in a modern ditch revealed a small number of artefacts, specifically volcanic glass flakes, along with a cultural deposit overlying sterile sand. Bioturbation and disturbances resulting from cultivation are clear in Layer I, but Layer II appears not to have been disturbed by gardening activities (Fig. 3.24).

Two radiocarbon determinations from the site indicate that it dates from the earliest period of human habitation on Ofu (~6th-7th centuries BC) (Clark per comm. 2014). The first determination was taken from the interface between the basal cultural layer and the sterile sand beneath, the date being contemporaneous with the earliest from Va'oto (Beta-307473, 2470±30, 2σ 768-431 BC) (Clark, unpublished data). The second, from the top of Layer II, dated somewhat later as expected (Beta-308978, 2370±30, 2σ 540-388 BC) (Clark, unpublished data).



Figure 3.19 The shallow stratigraphy of Coconut Grove (AS-13-37) (author's photo)

The Coconut Grove landscape rises gently from the marsh to the coast, with two postulated beach ridges that are slightly more pronounced rises apparent before the final rise

at the modern beach ridge. The most intensive habitation, dating to the 1st millennium BC, occurred back of the most inland beach ridge, an area that includes the modern trench within which the deposit was first identified. The site is situated directly seaward of the modern freshwater marsh. The limited archaeological investigation of the area between the marsh and the coconut grove location suggests that the area could have been the land surface of a water body at some point based on the presence of marine sand and a possible remnant reef below a layer of colluvium (Addison per comm. 2014). The patterning of these beach ridges and the location of archaeological remains broadly support previous models of coastline progradation (Kirch 1993d). However, local variability may also be present in that the area between the inland cliffs and the coconut grove site could have been a water body that was infilled during the course of human occupation.

A'ofa

A'ofa is located on the tablelands of the remnant A'ofa crater. Archaeological survey has identified a large number of landscape modifications (Clark et al. 2012), the most common of which are terraces. Some larger ones possess evidence of past residential activity, while others on the slopes were much narrower and shorter. Additionally, depressions and extensive ditching was identified in the area. While not necessarily part of A'ofa, archaeological remains have been found on ridges overlooking the complex. A single star mound was documented by Herdrich and Clark, but could not be relocated in subsequent years due to the density of vegetation. Just downslope of the reported star mound location, several large depressions have been found (Clark et al. 2012). Further survey has documented multiple star mounds in other areas of the same ridge; though, the density of these features is much lower than on Olosega and the exact number is unknown.

Chapter Summary

Ofu, part of the Manu'a group of the Samoan Archipelago, is a dynamic landscape. Late Holocene coastal reconfigurations were considerable, likely impacting the location of archaeological sites. The climate of the region is characterised by variability, impacted by both inter-annual (ENSO) and inter-decadal (IPO) cycles. Most importantly to the discussion of agriculture, this variability influences the frequency and intensity of tropical storms. Long-term changes in the climate of the region have also been identified, though these are poorly understood for Samoa given the lack of a local paleoclimatic record.

The archipelago was colonised by humans ~2700 BP. Populations likely expanded across the archipelago, eventually inhabiting the interiors of the larger, western islands, though coastal settlement in Manu'a persists until the beginning of the 2nd millennium AD. Eventually, groups across the archipelago began constructing earthen and stone residential features, and spatial patterns apparent in the distribution of these features have been utilised to infer the development of a hierarchical political system. Associated with this apparent increase in political complexity was the construction of fortifications, for defensive purposes, and special purpose monumental architecture (e.g., star mounds), reflecting changes in the nature of socio-political relations across the archipelago.

The 19th and 20th century Samoan political system has been classified by ethnographers as a chiefdom (e.g., Marcus 1989). Since at least the late 19th century AD, power has been concentrated at the household level, held by titled individuals referred to as *matai*. However, some have argued that the political system was more centralised during the prehistoric period. In these potentially late prehistoric political systems, some individuals held both sacred and secular power that spanned entire districts and, in some circumstances, entire islands or groups of islands (Meleiseā 1995). The demonstration of *mana* was important to maintain and negotiate individual and group power. One way of demonstrating *mana* was through agricultural productivity.

The production system as documented in the 19th and 20th century provides a view of the endpoint of these changes. The historic and modern terrestrial food production systems were based on the cultivation of taro in dryland systems. Some wetland cultivation was practiced, but this was done opportunistically in naturally occurring wet land environments such as marshes or estuaries. The subsistence economy relied on the exploitation of a few key crops, specifically taro, breadfruit, coconut, and banana. These crops are impacted by hazards such as cyclones, landslides, floods, and drought.

Questions remain as to the prehistoric sequence that led to this endpoint, specifically regarding how the human population responded to a variable environment and changing patterns of socio-political relations. Was the agricultural system always defined by techniques considered non-intensive? How did the food production system act to mitigate the probability of food shortfalls? How did the food production system respond to documented landscape evolution? The methods for addressing these questions are presented in the next chapter.

Chapter 4: Methods of Analysis

Multidisciplinary landscape approaches that use geomorphological, ecological, and archaeological techniques have successfully been employed to examine agricultural systems in Polynesia (e.g., Allen 2004; Field 2005; Kirch 1994; Ladefoged et al. 2009, 2011; Vitousek et al. 2004, 2010). This project used multidisciplinary techniques to document landscape evolution and agricultural activities on Ofu Island, and this chapter summarises these methods. Field work was undertaken in two phases: subsurface investigation both on the coast and in the interior and surface survey in the interior. These methods were directed towards documenting the location, timing, and management of agricultural activities as well as the environmental and cultural context within which cultivation strategies developed.

Subsurface Examinations

Subsurface investigation was conducted to document the chronology of cultural and geomorphological features within and across given areas. Three types of investigations were undertaken on the western coast in modern day Ofu Village: coring, trench excavation, and controlled test excavation. Only trench excavation was conducted in the interior uplands of the island. Given different goals of excavation in coastal and interior zones, slightly different methods were employed.

Coring was used as a way to identify promising deposits on the coast along two transects running perpendicular to the shoreline. A small diameter C-section probe with extensions that reached 1.4 metres below surface (mbs) was used. Soil stratigraphy was interpreted from the probe, and drawn and described. These descriptions included soil texture (e.g., clay, silt, sand), colour, and inclusions (e.g., shell, charcoal, coral, and rock). Special attention was paid to indications of increased burning activity and changes in texture and colour of sediments indicative of erosion from the interior, as these can be used to document the location of agricultural activities. The location of each core was point-plotted with a Trimble GeoXT series GPS unit georeferenced using UTM coordinate system WGS 1984 Zone 2s, and an overview photograph was taken of each transect. When promising deposits were identified, controlled excavation units or back-hoe trenches were dug to expose larger sections of stratigraphy. The location of each area that was excavated was point-plotted with a GPS and photographed before and after excavation.

In three back-hoe trenches, soil stratigraphy was drawn and photographed for at least one wall. Each individual stratum was described for soil texture, dry colour (using a Munsell colour chart), structure, inclusions, and strata boundaries and transitions (USDA 1993). If charcoal was identified, it was sampled for radiocarbon dating with special attention given to the dating of basal layers and terrigenous deposits. These were of specific interest because they could mark changes in geomorphology or human land use on the coast or on interior slopes. Before backfilling, soils were sampled from each stratum.

Four units were test excavated using controlled methods. These were dug with trowels in 10 cm arbitrary “levels” within strata referred to here as “layers”. All material was screened through 1/4 inch (6.35 mm) mesh while samples were taken for 1/8 inch (3.175 mm) screening. All features encountered were given unique numbers, and bulk soil samples were taken out of each to be water-screened in 1/16 inch (1.58 mm) mesh for small artefacts, faunal remains, and charcoal. All were systematically described in terms of size, shape, and inclusions. Charcoal sampled for radiocarbon dating was always recovered *in situ*. When artefacts were encountered *in situ* they were given unique specimen numbers, collected, and transported back to the laboratory. When found in the screen, they were collected and placed in a bag for that level and layer, and then transported back to the laboratory where they were given unique specimen numbers within that layer and level. All faunal material whether found *in situ* or in the screen was collected and bagged by layer and level. Soil samples were taken from each layer using a similar methodology as discussed above for trench excavations. At the completion of each level or layer, whichever came first, photographs were taken and maps drawn of the excavation floor. At the end of each unit, all walls were photographed and one representative wall was drawn. *In situ* stratigraphy was described according to USDA standards (USDA 1993), with particular attention given to strata boundaries and transitions.

Given differences in soil matrices and the specific goals of the study, test excavation in the interior uplands used a different methodology. The goal of excavation here was to identify the base of surface features, ascertain whether multiple phases of construction were present, and collect charcoal for dating. Given these aims, methods of excavation were similar to those employed by McElroy (2007, 2012) to excavate agricultural features in Hawai'i. Before trenching, the excavation unit was point-plotted with a GPS and photographs were taken. Trenches were dug perpendicular to features with shovel and pick axe. Excavation continued until charcoal was no longer identifiable in the matrix or until a stratigraphic change was encountered that represented the lower boundary of fill used to

construct the earthen modification. When artefacts were identified, they were noted, photographed, and collected. Charcoal for radiocarbon dating was sampled from the interface between stratigraphic layers, if any existed. When a clear stratigraphic division was present and the lower layer did not appear to represent filling associated with feature construction, charcoal close to that transition was taken for dating. Sampling from this location provides an opportunity to obtain a maximum age of the feature. When no stratigraphic or charcoal density changes could be identified, charcoal samples were taken from the base of excavation. When faunal material was encountered, a sample was taken for analysis. After completion of the trench, the walls were photographed but were only drawn when stratigraphic differences were apparent in profile.

Laboratory Analysis of Sampled Sediments

Particle size analysis, the measurement of the size distribution of the individual particles that make up a sediment or soil, was used in the interpretation of depositional environments and sequences of geomorphological change. Size ranges and degree of sorting of a sediment can reflect the energy level of the environment (Kirch et al. 1993), which may be impacted by human or natural agents (e.g., M. Allen 1998), thereby informing on the nature of geomorphological changes in a given area. Also relevant to this study, J. Allen (1984) has demonstrated that cultivation and forest clearance can be inferred using particle size analysis of deposits downslope of activity, a technique that aids in the documentation of agricultural activity even if field features are not present.

Analysis of sediments was conducted on samples taken from controlled excavation and trench layers on the coast (n = 34; all layers of T1, T3, XU-3, and XU-4, and the bottom three layers of XU-2). In each case, sediments representative of each layer were sampled, usually a roughly 10x15x10 cm block cut from a clean profile wall. These samples were placed in heavy Ziploc bags and transported to the University of Auckland for analysis. Analysis was completed at the University of Auckland Particle Analysis and Sedimentology Lab utilising a Malvern Mastersizer 2000 Laser Diffraction particle analyser. This technique employs a laser beam that transmits through a solution. The diffraction of the beam off the particles is then measured based on soil type (e.g., beach carbonate, estuarine sediment, etc.). Each particle of different size transmits a different signature, which enables the machine to accurately measure the proportion of different particles in each sample.

All samples were mechanically sieved through 1/4 inch mesh to remove clastics with a size of over -1Φ . As most of these had been noted and removed in the field to reduce shipping weights, analysis is restricted to course sand sized particles and smaller. In the case of clay or silt, samples were mixed with a 4 percent Calgon solution and left over a 24 hour period to ensure that individual particles dispersed. Sand was dispersed using a built-in water mechanism in the particle analyser. The analysis of representative subsamples was ensured by mixing sediments, either by vortex in the case of clays or simple mechanical shaking in the case of sands. To reduce residuals and improve accuracy, clay and silt samples were coded as “estuarine sediments”, while sand samples were coded as “beach carbonate”. Nevertheless, because some of the samples were a mix of different sediment sources, residual readings were higher than normal. The results were classified using the Udden-Wentworth scale based on descriptive terms that correspond to individual phi size classes (e.g., clays, silts, fine sands, medium sands, course sands, etc.; Table 4.1). Results of the grain size analysis are presented in Chapter 5 in frequency distribution graphs as the percentage of the total weight of each class.

These analyses do not directly document the source of sediments, whether they derive from a marine or terrestrial environment, but results of particle size analysis supplemented by field observations were used to infer sediment source. Specifically, in this study clay and silt particles are correlated with terrigenous sediments.

Table 4.1 Udden-Wentworth Scale

Descriptive Term	Phi Size
Very course sand	-1.0 to 0.0
Coarse sand	0.0 to 1.0
Medium sand	1.0 to 2.0
Fine sand	2.0 to 3.0
Very fine sand	3.0 to 4.0
Coarse silt	4.0 to 5.0
Medium silt	5.0 to 6.0
Fine silt	6.0 to 7.0
Very fine silt	7.0 to 8.0
Clay	8.0 phi and smaller

Survey

Feature Identification and Mapping

Pedestrian survey was conducted in two interior upland areas, Tufu and A'ofa (Fig. 4.1). This was done to document the distribution of surface features across these landscapes. Though archaeological remains exist in other areas of the island, as identified using a Lidar dataset (see below), other areas were not surveyed given time constraints and the perceived degree to which historic land use had resulted in the alteration of the prehistoric features in areas other than A'ofa and Tufu.

In order to record the full range of activities present, a sample area of Tufu and A'ofa was recorded in detail, referred to in this study as the detailed survey area. Pedestrian survey in detailed survey areas was undertaken in parallel transects. Though areas of dense vegetation sometimes prevented passage by way of transects, all land was visually inspected by at least one individual. When transecting was possible, crew members, ranging from 2-4 in each crew, walked spaced 5-10 m apart. When archaeological features were encountered, each was plotted utilising a Trimble GeoXT series GPS rover unit georeferenced using UTM coordinate system WGS 1984 Zone 2s. At the end of each day, GPS points, areas, and lines were differentially corrected using a base station located on Tutuila (ASPA).

Archaeological remains identified during survey were both discrete (constructed of a single morphological element) and aggregate features (constructed of multiple morphological elements) (Table 4.2). Feature types encountered on Ofu included terraces, depressions, ditch-and-parcel complexes, ditched terraces, and central open spaces. The description of these feature types is expanded upon in Chapter 6. Each feature was described and photographed in the field. All information was transcribed in both a notebook and into a data dictionary on the GPS units. For each feature type, a set of physical characteristics were recorded with the aim of analysing morphological variability and, subsequently, feature function. For terraces, this included size, shape, and the presence and type of paving. For depressions, characteristics recorded included the presence of a stone (coral or basalt) boulder edge around the feature, diameter and depth, and the presence of associated features. In Tufu, the full distribution of depressions was not able to be documented due to time constraints of field work. However, a sample was recorded for comparison to A'ofa. Terraces and depressions were measured for maximum and minimum dimensions using a 50 m tape in the field.

Some feature types were more difficult to document given their spatial extent, most notably the aggregate feature types of ditch-and-parcel complexes and ditched terraces. When identified, their spatial extent was GPS-plotted with a series of points or a line. Each ditch element was measured for depth and width, noting the presence of bunds (earthen banks of ditches). Finally, the area encompassed by the ditch was examined, noting the presence of modification, which is the distinguishing trait between the two aggregate feature types that include ditch elements. When the area encompassed by the ditch was artificially flattened, the area was recorded as if it was a regular terracing noting size and paving type. Even when a portion of the land encompassed by the ditch was terraced, it was only labelled as a ditched terrace, as opposed to a ditch-and-parcel complex, when a higher proportion of land was terraced instead of sloping (Chapter 6). The length of ditches was measured on GPS after they were outlined, with their width and depth measured in the field using an 8 m tape.

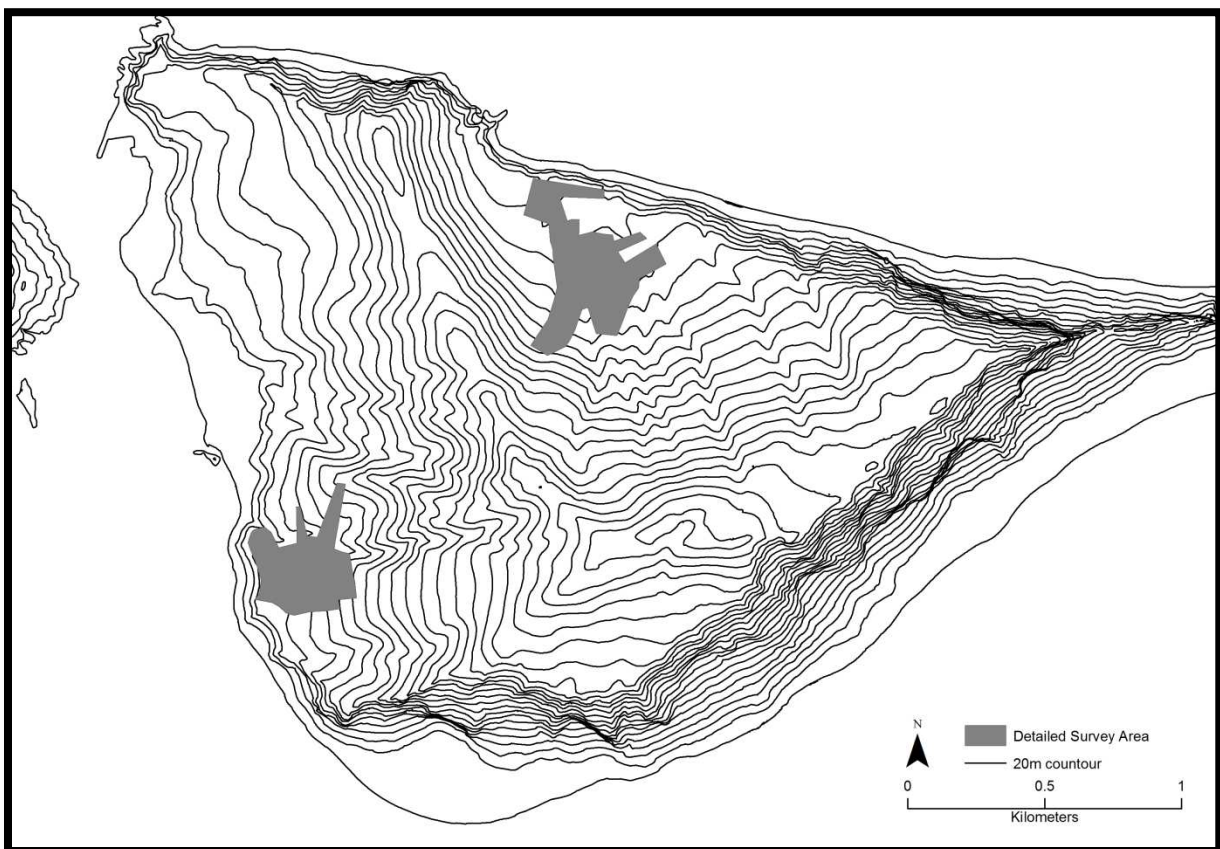


Figure 4.1 Location of the two interior areas surveyed on Ofu. More details are provided in Chapter 6

Table 4.2 Feature morphology and definitions

Morphological Elements/Discrete Features	Definition
1. Ditch	artificially constructed channel situated below the level of the ground surface that is longer than it is wide
2. Parcel	<i>sloping</i> land that is bounded on three sides by ditching
3. Terrace	<i>artificially flattened</i> earthen structure with three free-standing sides or less
4. Depression	circular sunken area that is the result of cultural activity, cf. pit
5. Edging	stone (coral or basalt) surrounding depressions
6. Paving	rounded to sub-rounded coral and rounded to sub-angular basalt that has been scattered on a flat surface
Aggregate Feature Types	
1. Ditched Terrace	a <i>terrace</i> that has been ringed by a ditch with coral gravel and/or plate coral paving
2. Ditch-and-Parcel Complex	feature with at least one ditch branch that surround an area of <i>sloping</i> land
2.1 Ditch-and-parcel network	multiple connected ditch branches or segments that usually define multiple parcels
2.2 Ditch-and-parcel single branch feature	single ditch branch that surrounds a parcel in a U-shaped pattern
3. Central Space	absence of structures in inhabitable environments on land larger than needed for a single domestic unit. The area must be located in a central position or seaward of a central position and bordered by parallel terracing, which should be the largest terraces in the zone

Methods of Spatial Analysis

All survey-collected feature information was integrated into a Geographic Information System (GIS). GIS is a software package that's "main purpose is to store, manipulate, analyse and present information about geographic space" (Wheatley and Gillings 2002:9). Many researchers tend to use the software as a means to create maps, which can be accomplished quickly. However, the software's capability of aiding in analysis and interpretation of spatial patterns has been readily recognised in the last decade, and developments in software capabilities have resulted in the availability of a wide range of computer aided models and simulations. Nevertheless, given the ease of viewing spatial data, one of the most commonly employed techniques is exploratory spatial data and statistical analysis without the aid of simulations and models (Connelly and Lake 2006:112-148; McCoy and Ladefoged 2009:265). This project used both statistical locational analysis and more specific modelling tools in GIS.

GPS data collected in the field was downloaded into PathFinder software and post-processed utilising the American Samoa base station on Tutuila. The post-processed data was converted into shape files (.shp) and uploaded to a working GIS environment in ArcGIS 10.1. As dense vegetation cover at times precluded the effective outlining of some terraces in the field, or made some appear distorted, area features were edited in GIS to make them more representative of the actual on the ground features. A database was created to store feature attribute information (e.g., size, type, paving), which could then be queried. When all databases were completed and all information confirmed as accurate, analysis was undertaken using locational data analysis through statistics and specific tools in the ArcGIS software package.

Lidar Analysis. GIS modelling and map creation used Light Detection and Ranging (Lidar) imagery. Lidar is an airborne laser measurement system that employs time-of-flight laser pulses. The signatures of different measured pulses, some of which can penetrate vegetation, are classified to create point clouds of various returns (e.g., bare-earth, structures, vegetation, etc.). These point cloud returns are then interpolated to create surfaces, often digital elevation models, from which derivative products (e.g., hillshades, slope maps, etc.) can be created.

Lidar data used in this project was flown by Photo Science, Inc. in 2012, during the first field season, at the request of the National Oceanic and Atmospheric Administration (NOAA). Data was collected across American Samoa by a small aircraft flying low altitude

overlapping swaths over the islands in 108 flight lines and 7 lifts (Raber 2012). Data collection was accomplished on a relatively cloud free day, and was post-processed by Photo Science, Inc. to create classified LAS files in TerraScan and TerraModeler. Data from most of the island was procured, but bare-earth returns are unavailable for some small areas, most notably a portion of A'ofa. This is most likely due to cloud cover on the day of flight. All point data were calibrated by Photo Science, Inc. using a series of control points on each island. All bare-earth returns were processed and converted from LAS datasets into DEM files, which were subsequently merged together. The resultant product delivered by Photo Science, Inc. features a horizontal accuracy of 1 m and a vertical accuracy of ~15 cm. Elevation data included in these files is measured from the mean low tide line on the day of data acquisition.

I acquired these data prior to the 2013 field season. Digital elevation models were used to create a number of surface layers, specifically slope, hillshade, and relief maps using the ArcGIS surface analysis toolset. The acquisition of the Lidar dataset, paired with the results of pedestrian survey, enabled a digital island-wide interior survey to be undertaken via a simple GIS procedure to identify zones of high archaeological feature density. The methods employed in this analysis built on the work of McCoy et al. (2011). Specifically, a slope-contrast map was generated and areas of flat land in otherwise sloping landscape were isolated to identify terracing, though the specifics were altered with additional steps. These methods are as follows.

The comparison of survey results and a Lidar-derived slope map indicated that human constructed features, specifically terraces, could be easily identified in unsurveyed zones using the Lidar dataset. This comparison indicated that when a slope map was classified, areas of 0-10 degree slope corresponded to areas of field observed terraces (Fig. 4.2). An iterative GIS procedure building on this correlation was created to understand the patterning of archaeological features at an island-wide scale by measuring the density of terraces across the landscape.

To do so, a high resolution slope map was generated in ArcGIS from the Lidar dataset. This map was then reclassified, with classes of 0-10 degrees and 10.1+ degrees, to highlight flat surfaces in otherwise steep slopes (Fig. 4.3). To measure the density of features in the interior, the raster slope file was converted to vector polygons that outlined the 0-10 degree slope areas (Fig. 4.4). Much of what was outlined as 0-10 degree slope are human

constructed features, but the Lidar dataset also included noise (e.g., understory vegetation). To exclude noise from further analysis as much as possible, all polygons with an area of less than 20 m² were removed. This figure was based on the minimum terrace area measured during detailed survey (Chapter 6). This created a map of the approximate distribution of terraces across the island.

In order to quantify the density of features in different areas, polygons of 0-10 degree slope were converted to points, with a point generated for each vertex of each polygon (Fig. 4.5). To further ensure that the majority of points represented archaeological features, those associated with historic and modern trails and roads were deleted. Boundaries of high feature density zones were calculated using the point density tool in ArcGIS. The vertex points were used as input and their density was calculated using a rectangular neighbourhood with a 30 x 30 m search area. The output generated was a point density raster with a 5 m cell resolution, which was reclassified to include the majority of terraces identified during pedestrian survey. In other words, areas of high feature density were outlined based on threshold manipulation to include known terraces through trial and error. These boundaries provide important reference points for locational analysis of features identified through pedestrian survey. These quantitatively-derived boundaries were used to calculate a mean centre for the Tufu and A'ofa high feature density zones using the mean centre tool in ArcGIS. These mean centres are used as reference points for statistical analysis (discussed below).

Determining the spatial extent of cultivation techniques. Archaeologists and ecologists have found that the distribution of modern vegetation types aid in establishing the spatial extent of cultivation practices (e.g., Lincoln and Ladefoged 2014; Quintus 2012). In this project, United States Forest Service (USFS) vegetation maps were utilised to outline the spatial extent of past land use activities (Liu and Fischer 2007). These maps were previously drawn by the USFS employing high resolution satellite imagery. Georeferenced .shp file copies of these maps, with the associated database of plant classifications and area measurements, were integrated into a GIS. Of relevance to this project, these maps distinguish modified forest from “pristine forest”, and further divide modified forests into economic (e.g., breadfruit, coconut) and secondary forest zones (e.g., *Hibiscus tiliaceus*; terminology of the original vegetation maps). These vegetation patterns were quantitatively compared to the results of pedestrian and Lidar-based survey to estimate the spatial extent of some cultivation techniques (i.e., shifting cultivation and arboriculture). The results and discussion of this procedure is presented in Chapter 6.

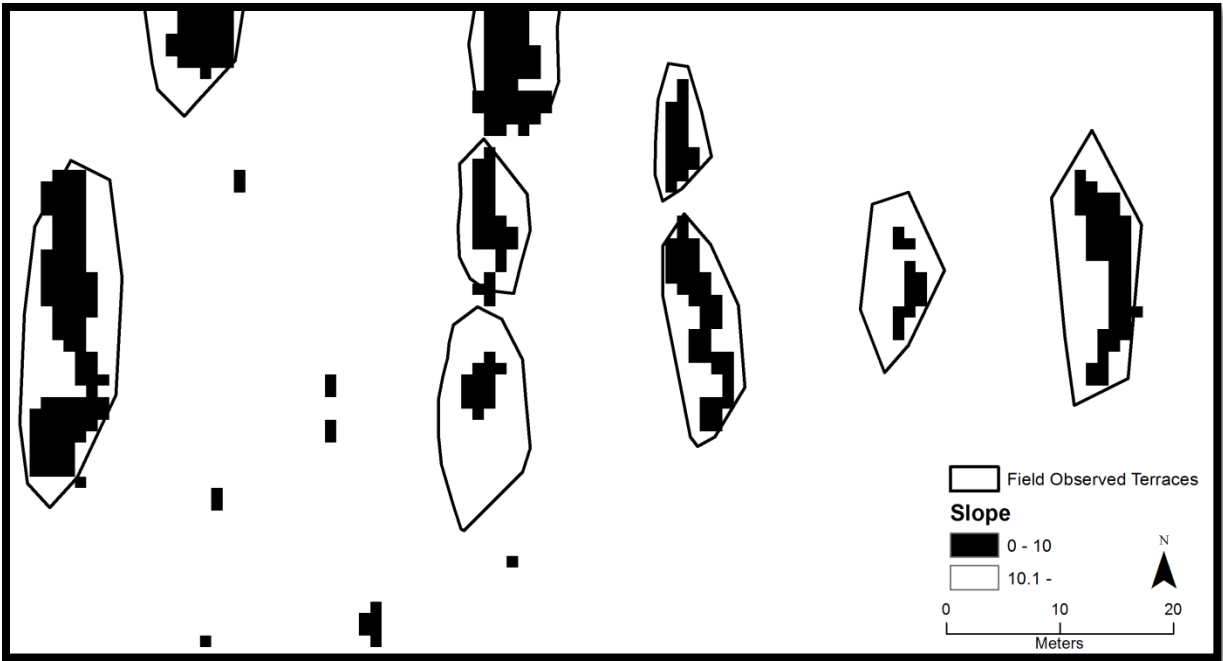


Figure 4.2 The correlation between field observed terraces and 0-10 degree slope

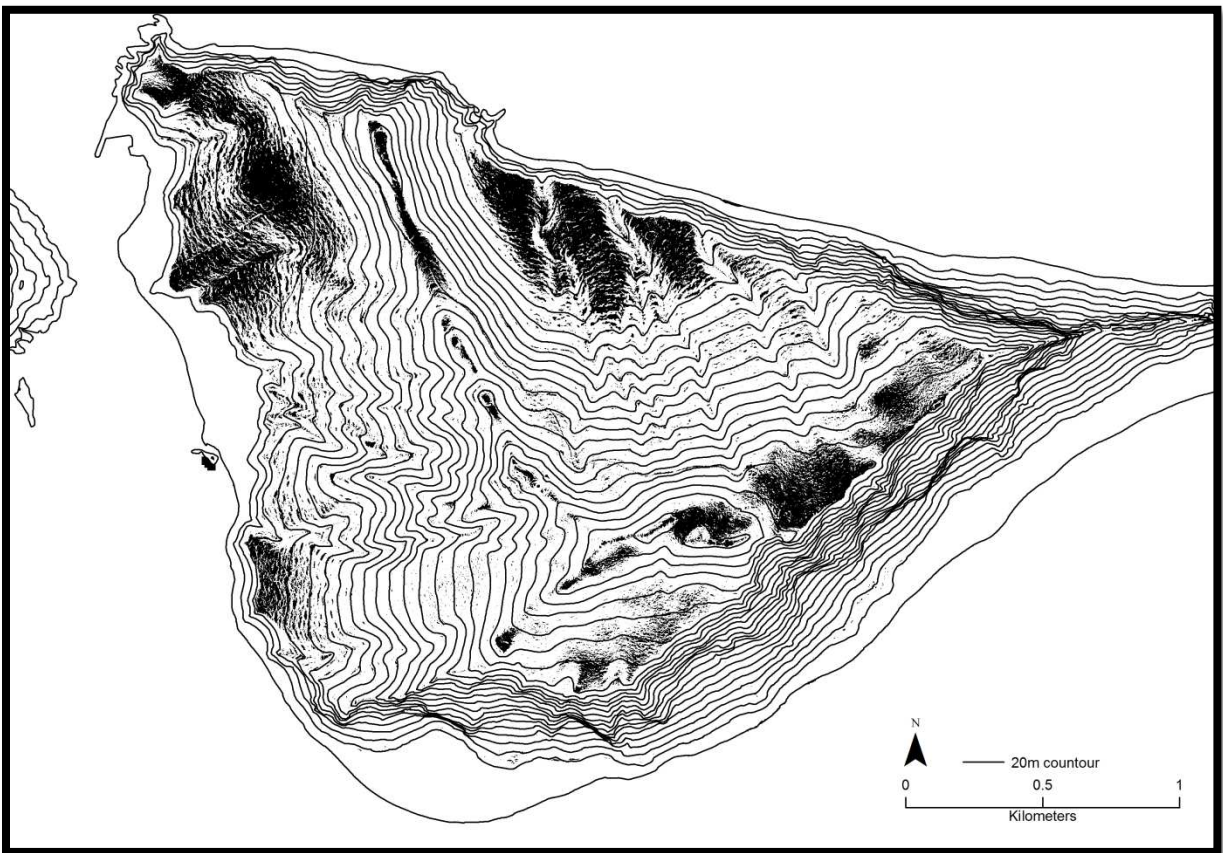


Figure 4.3 Slope contrast map of Ofu

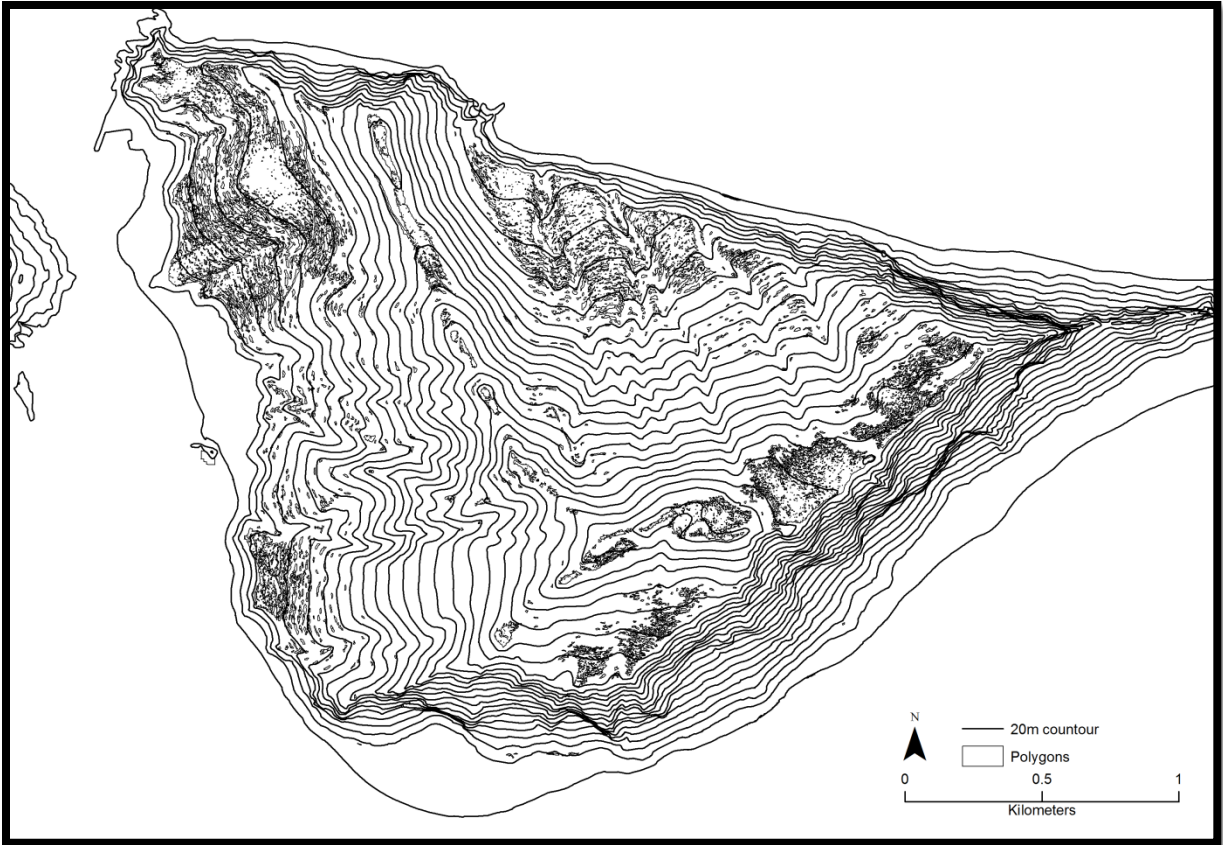


Figure 4.4 Slope map converted to Polygons. Polygons with areas less than 20 m square removed

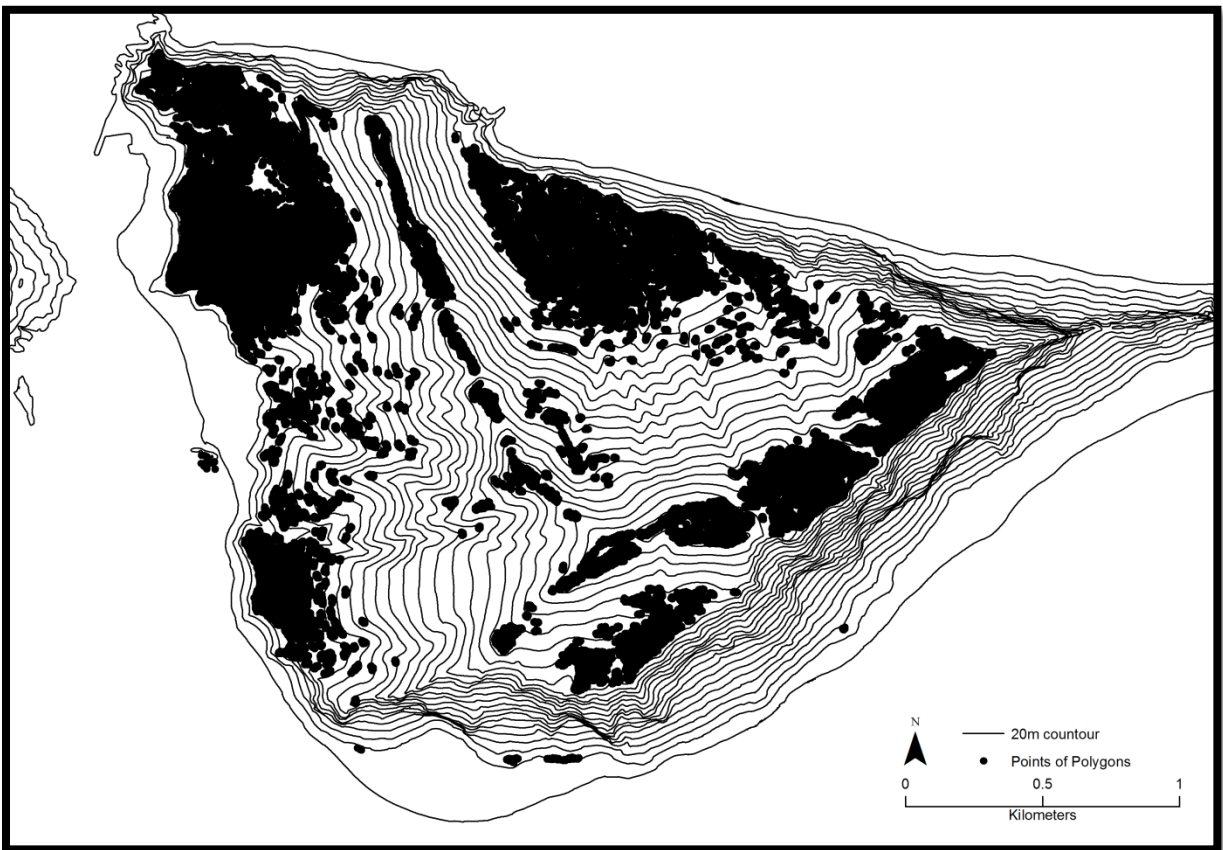


Figure 4.5 Polygons converted to points with points of historic trails removed

Feature data analysis. After pedestrian survey of A'ofa and Tufu was completed, all feature information was compiled and input into Excel spreadsheets. Summary statistics (e.g., mean, range, and standard deviation) were calculated for all feature classes, as defined above, in each survey zone. Feature variability was assessed by creating size classes of equal intervals and comparing those ranges with other feature attributes (e.g., paving, edging). Size breaks were consistent between the Tufu and A'ofa survey areas, ensuring comparability. Based on the co-variance of multiple attributes (e.g., size, location, paving, edging), features were grouped into classification schemes. Terraces were classified based on size and the presence/absence of coral; depressions by diameter and the presence/absence of a stone edge; and ditch-and-parcel complexes by the number of connecting branches (one or more than one).

After all calculations were completed, the data was displayed in geographical space. All features were visually examined to assess their association with other features (ditch-and-parcel complexes with terraces) and environmental attributes (e.g., ditch-and-parcel complexes with streams). This was aided by the creation of buffers surrounding streams or feature types. More spatial patterns were discerned using locational statistics, specifically by exploring the relationships between feature size, elevation, and centrality. For correlation analysis, the Lidar dataset was the source of elevation data and centre points were calculated in ArcGIS based on the boundaries of the high feature density zones. These relationships, between elevation and terrace size and ditch-and-parcel size and distance from the mean centre of the high feature density zones, were plotted in Excel and trend lines added to highlight patterns. The strength of relationships was assessed using a coefficient of determination (R^2) calculated during regression analysis in Excel. The correlation of two variables was quantified using Pearson's Product-Moment Correlation Coefficient (R), and a critical values table was used to determine p-values for the correlations. Pearson's chi-square tests were used to examine significance of correlation in categorical datasets, accomplished in Excel.

Terrestrial laser scanning and hydrology. Some areas in each high feature density zone were mapped in greater detail using terrestrial laser scanning under the direction of Dr. Stephanie Day (NDSU Geoscience faculty). Terrestrial Laser Scanning (TLS) is a measuring system based on time-of-flight laser pulses. Similar to Lidar, this technique, because it is tripod based, has the capabilities to scan and measure vertical or near vertical features with more accuracy. This project utilised a Faro Focus 3D 120, owned and operated by North

Dakota State University geoscience faculty, which can produce outputs with centimetre scale resolution (usually under 10 cm). The Faro is a phase shift scanner with the ability to measure up to 976,000 points per second, and has a collection range between 0.6 and 120 m. Laser scanning was utilised to create 3D visualisations of individual features or a series of features. The aim was to better document the morphology of individual features, but specifically to assess the hydrological functioning of ditch-and-parcel complexes. As vegetation can impede the modelling of the landscape, multiple scans from different angles were taken of individual features to create a composite image, with vegetation removed during data processing in Faro SCENE software. The alignment of multiple scans was automated, accomplished by the software package by detecting white spheres that were placed in the landscape and scanned along with the archaeological features.

Hydrological discharge was calculated in ArcGIS for one ditch-and-parcel complex. A 25 cm DEM, where resolution was reduced to decrease the time necessary to post-process the data, was created by laser scanning a ditch-and-parcel complex using a total of 15 scans over an area of 1900 m². From this DEM, hydrology was modelled by identifying channel thalweg, the lowest elevation in a water course, utilising the flow accumulation tool in ArcGIS, from which a flow line was created from cells of greatest accumulation. Discharge was estimated using the Manning Equation (Manning 1891):

$$Q = \frac{k}{n} AR^{2/3} \sqrt{S}$$

In this equation, k is a conversion factor of 1 m^{1/3}/s for SI units, A is cross-sectional area, R is hydraulic radius, S is slope, and n is the unitless Manning's roughness coefficient. A larger n value assumes greater roughness and a lower n value assumes less roughness in the channel. For this calculation, n is assumed to be 0.024, which is a value appropriate for a straight clean weathered channel with some gravel or short grasses (Stephanie Day, project geologist, per comm. 2013). Area and hydraulic radius, a characterisation of the cross-sectional shape of the ditch calculated by dividing A by P (perimeter of feature that is wet), were found by subtracting the ditch DEM from a plane estimating the water surface in the full ditch. For simplicity sake, a steady uniform flow in a full ditch was assumed, and the water surface followed the slope of the ditch. The complete ditch volume was calculated and divided by the length of the ditch to find the average cross-sectional area. Because the size of the ditch was consistent throughout, the average area provides a good representation of the ditch capacity. The average hydraulic radius was calculated under similar assumptions.

Charcoal Sample Selection and Preparation

Radiocarbon dating has been a contentious issue in Polynesian prehistory. Of importance is the identification, selection, and interpretation of individual samples (Allen and Huebert 2014; Allen and Wallace 2008). Many researchers have proposed specific criteria to evaluate the validity and accuracy of radiocarbon dates (e.g., Mulrooney et al. 2011; Rieth and Hunt 2008; Rieth et al. 2011; Spriggs and Anderson 1993; Wilmhurst et al. 2011), highlighting the importance of short-lived materials taken from clear cultural contexts. Other researchers have used probability statistics and computer programming to reduce the range of radiocarbon dates, and to provide a more accurate measure of the dating of target events (e.g., Athens et al. 2014; Cochrane et al. 2013; Dye 2011). Radiocarbon dating in this project attempts to account for critiques made by these individuals.

As noted above in reference to field methods, charcoal was sampled from *in situ* locations. Samples were dried in the field using a commercial oven at temperatures recommended by Beta Analytic Inc. (~60°C). After drying, samples were sieved through fine mesh to isolate charcoal and remove sediment and organic material. All charcoal samples were transported to the University of Auckland for identification and storage. Samples were identified by Jennifer Huebert using the University of Auckland wood charcoal reference collection. When possible, short-lived samples, as defined as lifespans of a decade or less (Allen and Huebert 2014:261), were selected to limit the problem of in-built age. However, in some circumstances charcoal of long-lived economic trees was dated when short-lived samples were not available. In these situations, the uncertainty of the dates is made explicit and a justification of their use is provided. In general, these were dated because they provide information regarding land use. All samples were analysed at the commercial laboratory Beta Analytic Inc. (Miami, FL, USA) utilising accelerated mass spectrometry (AMS). Determinations were calibrated in OxCal version 4.2 utilising the northern hemisphere IntCal 13 calibration curve (Bronk Ramsey 2009; Reimer et al. 2013).

Chapter Summary

Subsurface investigation was conducted on the west coast of the island, in modern day Ofu Village, as well as in the interior of the island. Particular attention was given to areas where deposits were identified that could inform on the chronology of coastal settlement, the patterns of land use of the slopes surrounding the coastline, and the changing configuration of

the coastline. Particle size analysis of sampled sediments was undertaken to examine the nature of changing depositional environments, supplementing visual examination accomplished in the field. Excavation was conducted in the interior to create a chronology of land use and surface feature construction. Surface survey was undertaken in two areas, which exhibited similar surface archaeological features. These features were all systematically described, and the geospatial and morphological data associated with each were uploaded into a GIS environment. GIS was utilised to explore spatial patterns in the data, by way of locational data analysis. Additionally, this project made use of aerial Lidar and terrestrial laser scanner datasets.

Chapter 5: The Archaeology of Ofu Village

Archaeological investigations on the coast were undertaken over an area of 9 ha on the western coastal flat of Ofu(AS-13-41) (Fig. 5.1; Table 5.1). This coastal flat is the widest on island, with the interior slopes located ~200 m from the beach at its maximum dimension. The lone village is situated on this coast, and structures, such as houses, house platforms, churches, stores, etc., are spread throughout. Most of these are located inland of the modern road, itself between 20 m and 60 m from the present shoreline. The village is split into two named sectors (Ofu and Alaufau). Excavation and coring was conducting in each, but it was more intensive in the named sector of Ofu. In the following discussion, Ofu Village refers to the collective whole.

The subsurface investigations of site formation processes in Ofu Village addressed three goals. First, they were used to assess the nature of prehistoric land use over time. Second, they enabled an examination of shifting cultivation systems on the coast and on the slopes inland. Third, they were utilised to test the model of landscape evolution presented by Kirch (1993d). To address these goals, coring, controlled excavation, and trench excavation techniques were employed to examine an area of ~16 m². The following is a description and discussion of the results of this subsurface examination.

Table 5.1 Summary of subsurface excavations conducted in Ofu Village (see below for more details)

Subsurface Unit	Terminal Depth	Time Period	Material Culture
XU-1	220 cmbd	Late Prehistoric	Lithic and shell artefacts
XU-2	*210 cmbd	Unknown	None identified
XU-3	203 cmbd	Late Prehistoric	Lithic artefacts
XU-4	318 cmbd	Early Prehistoric	Ceramic, lithic, and shell artefacts
Trench 1	165 cmbs	Unknown	None identified
Trench 2	143 cmbs	Unknown	None identified
Trench 3	*152 cmbs	Late Prehistoric	None identified

***denotes termination prior to positive identification of a sterile layer**

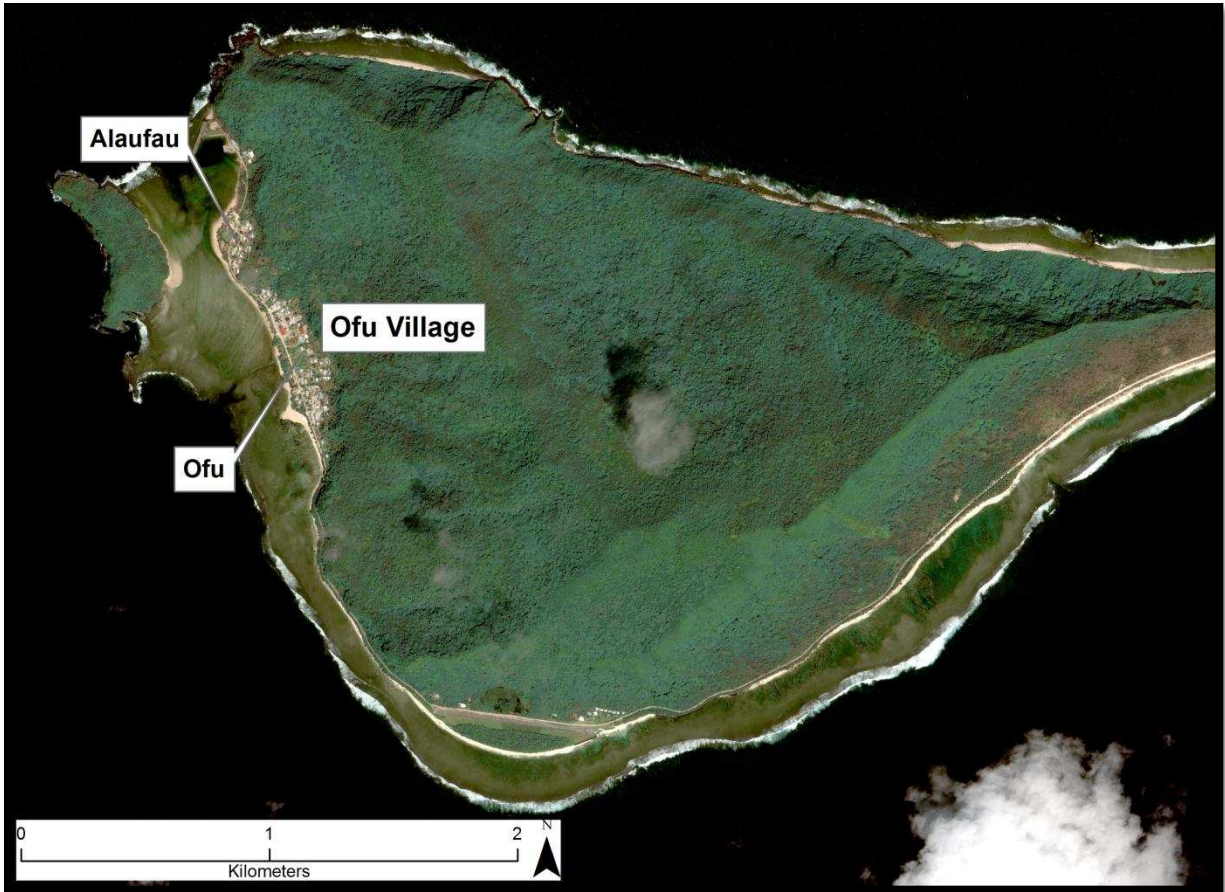


Figure 5.1 Overview of Ofu Village

Coring

Coring was conducted to identify promising deposits that could address the timing and sequence of geomorphological change and land use practices. Areas both inland and seaward of the present road were cored. Locations, near the centre of the village in the named sector of Ofu (Transect 1) and near the northern edge of the village in named sector of Alaufau (Transect 2), were chosen based on environmental attributes that signify that these might be places in which deposits of significant temporal depth could be found (Lepofsky 1988) (e.g., access to the reef and reef breaks for canoe passage).

Cores in Transect 1 were arranged perpendicular to the shoreline (Fig. 5.2, 5.3), beginning on the inland side of the modern road. The first layer of all cores consisted of a dark brown sandy loam soil. Calcareous sediments dominated the matrices in the two seaward most cores through to termination. However, in each, a dark layer of soil was identified at ~40 cmbs, with increased organic content and some particulate charcoal. In the

other three cores, terrigenous sediments were noted. As one moves inland, one is likely to encounter these sediments higher in the soil stratigraphy, at ~50 cmbs in Core 3 and at ~40 cmbs in Core 4 and 5. Cultural activity is evidenced in all three by increased charcoal frequency and the presence of faunal material. These materials were densest, based on visual approximation, at depths of 40-50 cmbs in Core 3, 43-60 cmbs in Core 4, and 40-50 cmbs in Core 5.

Coring was undertaken both seaward and inland of the modern road in Transect 2 (Fig. 5.4). Core 1, seaward of the road, could not be probed deeper than 90 cmbs due to the presence of large inclusions. No possible cultural material was noted and the soil was homogenous white beach sand. In contrast, two cores inland of the road provide evidence of human occupation and geomorphological change. The matrix of Core 2 consisted primarily of calcareous sand, multiple strata identifiable by colour, with possible cultural deposits separated by sterile white sand layers. A thick layer of terrigenous clay was discovered in Core 4, originating at a depth of 124 cmbs and extending past the length of the coring device (140 cm). Similar stratigraphy as that identified in Core 2 was found above this layer. Material indicative of cultural activity, specifically particulate charcoal and shell, was plentiful in both cores, especially near their termination points.



Figure 5.2 Location of the cores in Transect 1

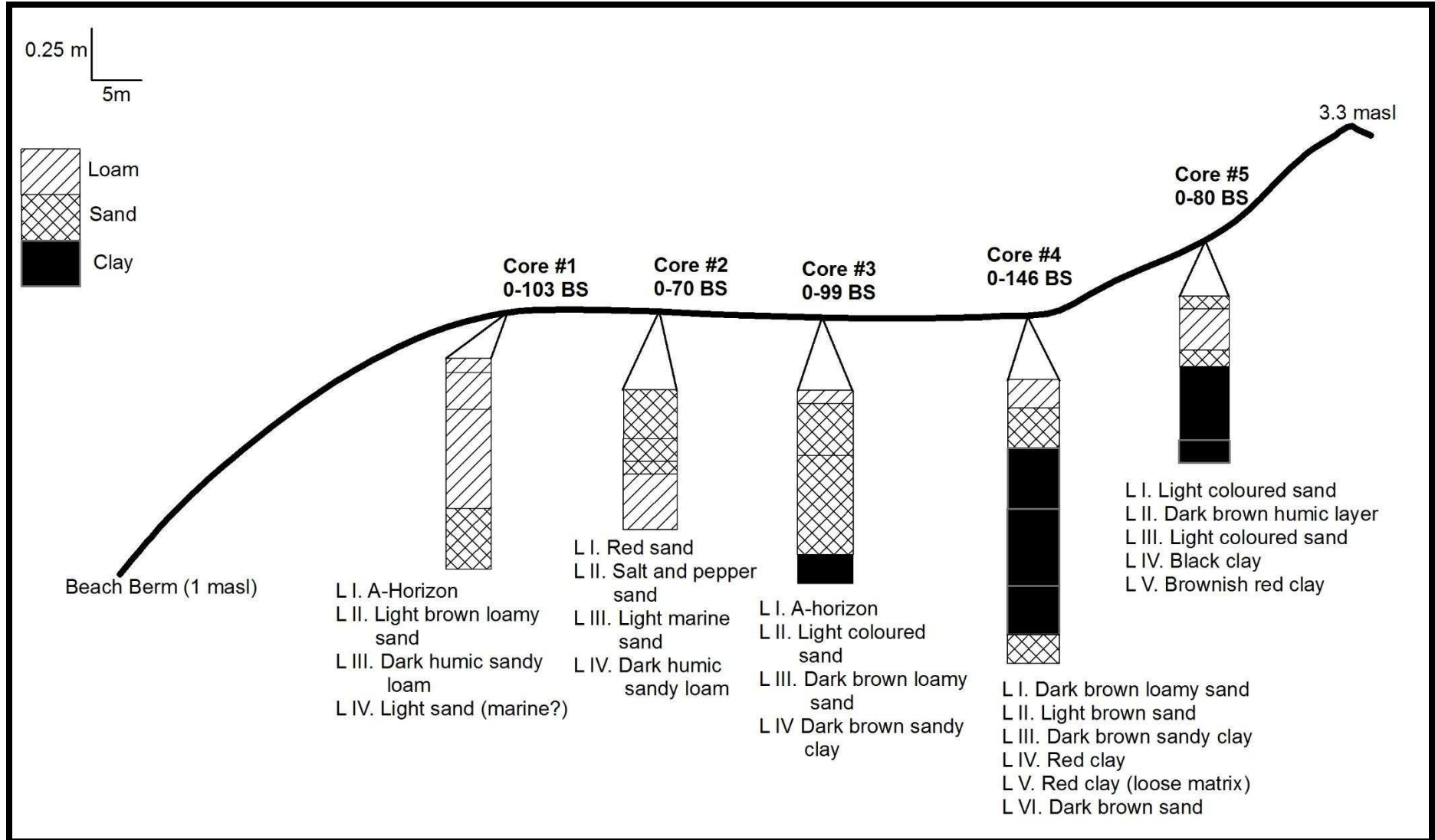


Figure 5.3 Diagrammatic section representation of Transect 1



Figure 5.4 Location of cores in Transect 2. Core 1 is not shown, but was situated immediately seaward of the present road in line with others

In summary, promising deposits were documented in both locations cored, specifically near Core 2 of Transect 2 and near Cores 4 and 5 in Transect 1. Coring in Transect 1 documented a changing stratigraphic sequence along a line that ran from the coast to the inland slopes. Evidence of terrigenous sedimentation was found near the slopes, while evidence of cultural activity, in the form of shell and charcoal, was identified in multiple cores. In Transect 2, evidence of terrigenous deposition was identified inland of the road. These deposits exhibited a high density of charcoal inclusions and shell, potentially indicative of both agricultural activity on the slopes and cultural activity on the coast. Increased precipitation could also have been a factor in increased terrigenous deposition, but forest clearance would still be necessary to induce erosion, and the charcoal in the deposits attests to vegetation clearance. The interpretation that charcoal stems from human-induced vegetation burning is supported by the rarity of natural fires in the humid tropics (Kirch and Hunt 1993b:235). Natural fires can occur, but when they do they are spatially restricted and do not spread. The density of charcoal at different depths of these deposits is evidence that natural forest burning is not the lone cause. Controlled excavation and trenching was conducted in these same locations to gather more detailed data regarding the depositional history of each.

Controlled Excavation Units

Following coring, four units were dug in areas in which evidence of geomorphological and cultural activities had been identified. Locations of excavation were sought that would inform on the changing depositional sequences along the coastal-inland and north-south spatial extent of the village. However, the presence of modern structures and difficulties acquiring permission to dig on certain land precluded this to some degree (Fig. 5.5). Therefore, XU-1 represents an attempt to examine the depositional history of Alaufau near coring Transect 2, while XU-2, XU-3, and XU-4 were situated near coring Transect 1. This section describes the results of each of the four controlled excavation units. Following layer descriptions, a brief interpretation of the stratigraphy is presented. References are made to faunal material found in each layer, but these analyses are still underway and all references here are qualitative and ordinal. Unless otherwise stated, all faunal material, including shell, is interpreted to be culturally deposited.

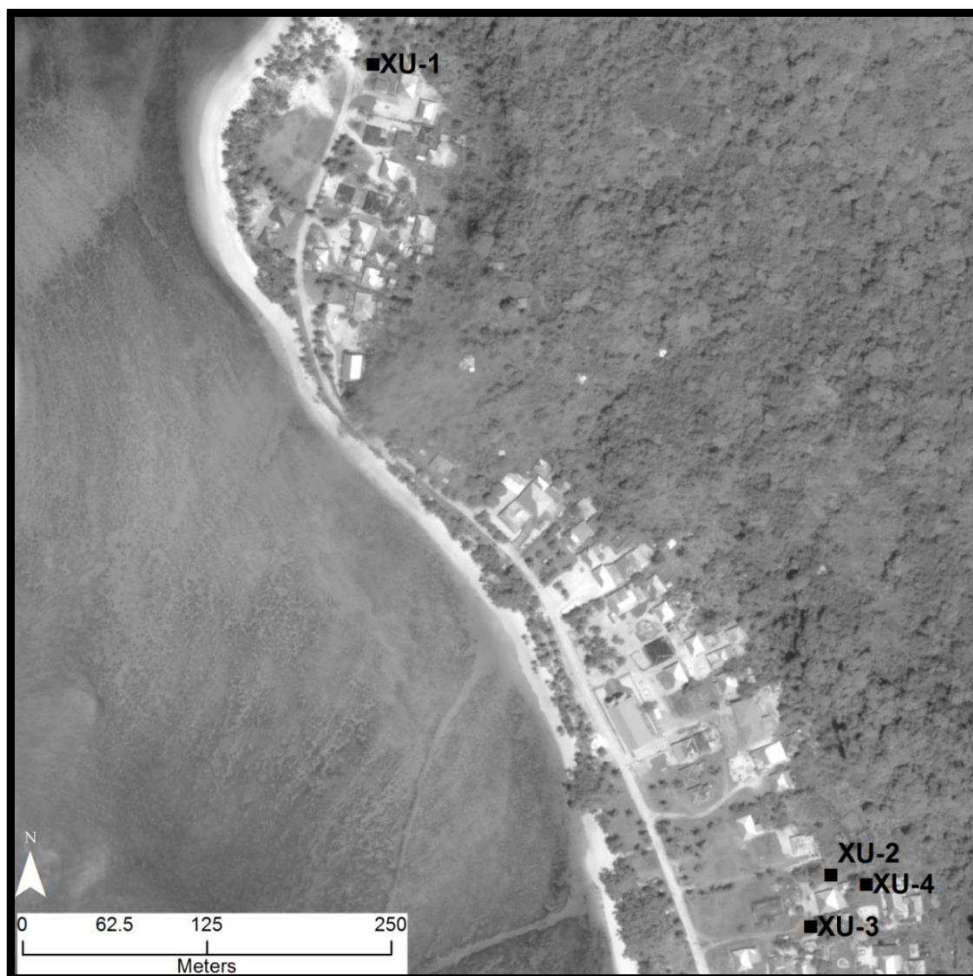


Figure 5.5 Location of controlled excavation units in Ofu Village

XU-1

XU-1 is a 2x1 m unit laid out immediately inland of Core 2 of Transect 2. Eight layers were recorded, one of which had recognised sublayers. Four intact prehistoric combustion features and a very small assemblage of cultural material (e.g., shell, fishbone, lithics) were noted. The excavation was terminated within a sterile sand layer at a depth of 220 cmbd (Fig. 5.6).

Layer I was a 35-40 cm thick 10 YR 4/3 (Brown), but heterogeneous, loamy medium grained sand with a granular structure. Inclusions were rarer than in deeper layers, though historic artefacts (e.g., metal and glass), shell, and some coral gravel (less than 5 percent of the matrix) were noted. Some bone was found, most of which appears to be pig (*Sus scrofa*). The transition to Layer Ib was gradual. **Layer Ib** was a loamy clay of terrigenous origin exhibiting an extensive, but shallow, combustion feature in the northwest corner. Historic artefacts were recovered along with a mammalian rib and fish bone. Thin cemented calcareous sand covered the underlying clay/charcoal mix at the interface between Layer I and Ib. The boundary with Layer II was abrupt with a smooth topography.

Layer II was a 20-35 cm thick loamy medium grained sand with a 10 YR 3/2 (Very dark grayish brown) hue and granular structure. Some small clay pockets were encountered in the matrix as well. Historic artefacts (e.g., glass) were identified along with small amounts of coral and shell (less than 5 percent of the matrix). Particulate charcoal was encountered with increased depth. The boundary with Layer III was diffuse, exhibiting a significant amount of mixture at the interface, and the topography was wavy.

Layer III was a 0-25 cm thick 10 YR 5/4 (Yellowish brown) coloured medium to coarse grained sand with a granular structure. The size of sand grains, mixed with some basalt and coral gravel (~5-10 percent of the matrix), made this layer very loose. The layer was thickest on the seaward side of the unit and was completely absent in the east (inland) wall. Some charcoal was identified, confined to the top of the layer, while shell, which appeared naturally weathered, increased in quantity with depth. A single fire altered basalt cobble and some fish bones were noted at the bottom, but it is unlikely that these were in primary cultural context given the sterility of the rest of the layer. When the layer was present, the transition to Layer IV was abrupt with a somewhat wavy topography.

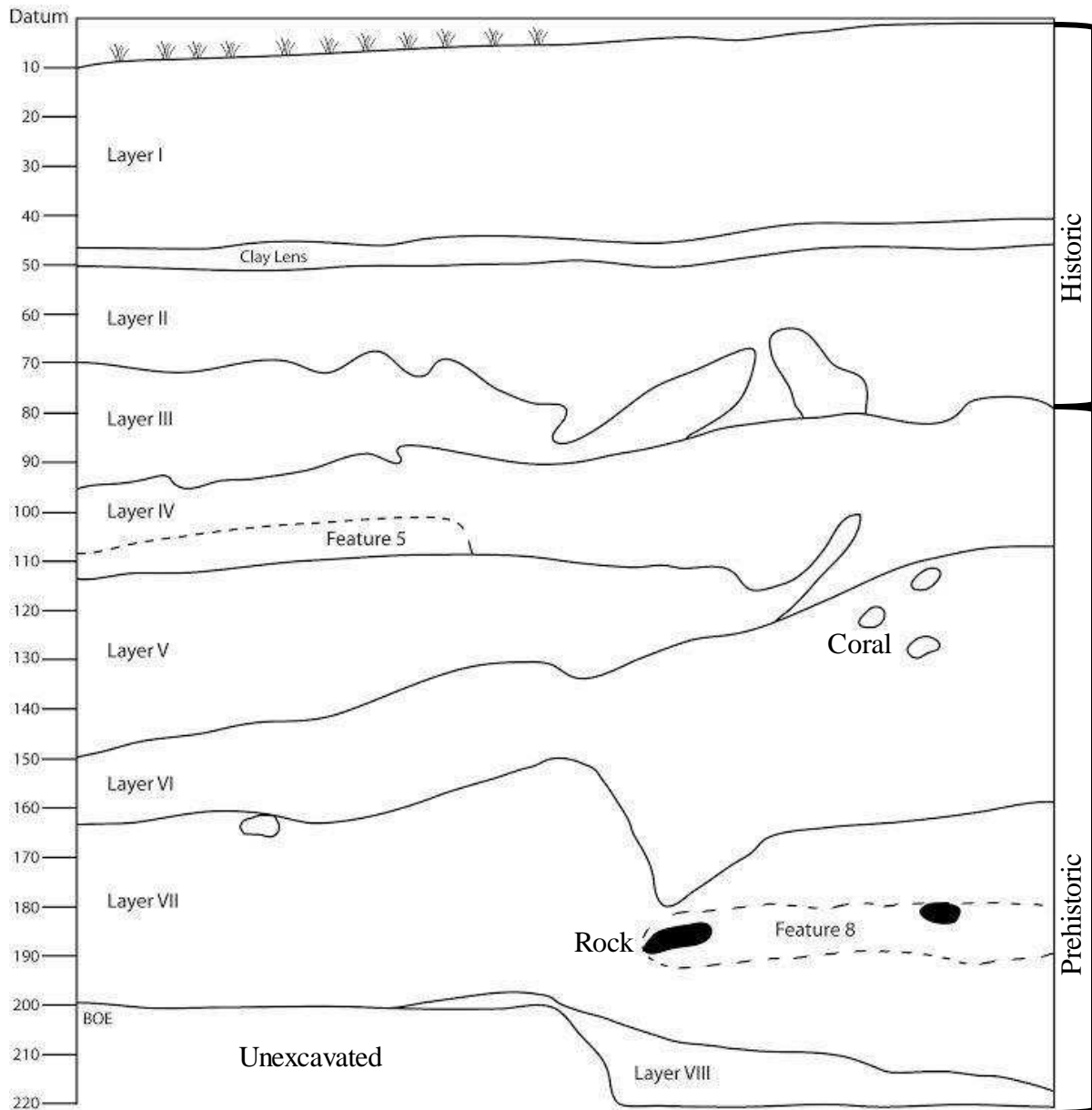


Figure 5.6 Profile of the northern wall of XU-1. Note thinning of Layers III, V, and VI

Layer IV was a 15-35 cm thick 10 YR 4/2 (Dark grayish brown) granular medium to coarse grained loamy sand. Shell, angular basalt, and sub-rounded coral were noted in higher concentrations relative to the previous three layers (~10-15 percent of the matrix). Most of the coral and basalt was fire altered and located in the western half of the unit near Feature 5. This was a large, but shallow (110x85x10 cm), combustion feature located near the bottom of the layer. Prehistoric basalt artefacts were identified outside of the feature (n = 2). Fish bone was identified, but still was not common. The boundary with Layer V was gradual with an irregular topography.

Layer V was a 0-40 cm thick 10 YR 6/3 (Pale brown) granular medium grained sand with a few large angular coral inclusions. These inclusions, though, constituted a small proportion of the total matrix (less than 5 percent). The sand was very clean, similar in colour and texture to dune and beach sand on the present coastline. Some small charcoal fragments were found, though no features were recorded and no artefacts were identified. Darker splotches of soil were present toward the eastern end of the unit and near the boundary between Layer V and VI. Like Layer III, this layer is absent in the eastern wall and thickest in the seaward, western wall. The boundary with Layer VI was abrupt with a wavy topography.

Layer VI was a 15-55 cm thick 5 YR 3/2 (Dark reddish brown) sandy clay with a sub-angular blocky structure. Rounded to sub-rounded coral and basalt gravel was dense (~15-20 percent of the matrix). Shell density increased, but remained sparse compared to other archaeological sites on the island (e.g., Nagaoka 1993). All shell was fragmented and degraded, likely a result of a post-depositional environment with high terrigenous clay content. Artefacts remained rare, represented by ten basalt flakes and a fishhook blank. The frequency of particulate charcoal was higher than in previous layers, and some larger pieces (2-5 cm) were also recovered. Two small combustion-like features were uncovered near the middle of the layer (Features 6 and 7). Neither feature exhibited characteristics markedly different than the surrounding matrix other than a darker colour and charcoal. They were both small, 20-30 cm in diameter, and shallow, 10-15 cm deep, with no noticeable increase in shell or fishbone density relative to the surrounding matrix. The top of a larger feature (see below) was discovered near the interface of Layer VI and Layer VII. Layer VI was much thicker in the east wall than in the west wall, the reverse of the situation documented in Layers III and V. The boundary with Layer VII was clear with a smooth topography.

Layer VII was a 20-50 cm thick 10 YR 5/4 (Yellowish brown) granular medium to coarse grained loamy sand. Shell and sub-rounded coral gravel (less than 5 percent of the matrix) continued to be found in addition to faunal bone. The defining characteristic of the layer was a combustion feature with a high density of fire altered basalt fragments situated in the eastern end of the unit (Feature 8; 35x15x10 cm). Particulate charcoal was less frequent than in Layer VI, though larger pieces of charcoal were observed, especially in and around Feature 8. Charcoal from this context was dated (Beta-332861, 2σ AD 1408-1452). The boundary with Layer VIII was diffuse, making it difficult to identify precisely where the next layer began. In profile, the topography of the transition appeared wavy.

Layer VIII was a 10 YR 7/3 (Very pale brown) coloured culturally sterile granular coarse grained sand. Some possible culturally deposited shell was found near the top of the layer, but no artefacts or features were encountered. Rounded to sub-rounded coral was also identified near the top of the layer (~5-10 percent of the matrix). Charcoal, while found, was less frequent and may have been displaced from the larger features above the layer. The unit was terminated after coring revealed no additional strata below.

Summary and Interpretation. The layers in this unit were fairly uniform exhibiting a high percentage of medium to coarse grained calcareous sands (Figs. 5.7, 5.8 and Tables 5.2, 5.3). A clay component of terrigenous origin was identified in three layers, Layers VI, IV, and II, though terrigenous sediments constituted a significant portion of the matrix in only Layer VI. Finer sands of calcareous origin and large unweathered pieces of coral were identified in Layer V. Layers III and VII exhibited a high percentage of coarse grain sands of calcareous origin, relative to other layers.

The top two layers are historic, developing as a result of human transportation of calcareous sediments to the area and the continued natural deposition of both terrigenous and calcareous sediments. Layer III is likely the result of storm deposition based on coarse grain sized calcareous sand, cultural sterility, and the changing thickness of the layer from seaward to inland. Layer IV is the most recent prehistoric cultural layer, though it is ephemeral. Cultural sterility, the presence of large unweathered corals, and decreased layer thickness with increased distance from the shore imply that storm activity was the chief depositional agent that resulted in Layer V. Layer VI represents a layer of colluvium. Several factors could have contributed to increased terrigenous sedimentation causing this layer of colluvium, but I interpret the primary reason to be the clearance of vegetation on the slopes inland of the unit, perhaps for cultivation. This is indicated by increased particulate charcoal frequency and the lack of evidence relating to residential activities on steep slopes inland of the unit. However, a climatic influence cannot be ruled out, as increased precipitation would have exacerbated erosion after vegetation clearance. Human occupation was initiated on the sterile Layer VIII, with subsequent human land use evidenced by materials in Layer VII. From the base of the unit through to Layer VI, there is a trend of increased terrigenous sediment deposition. In no layer was artefact material present in large quantities. In fact, only 13 basalt flakes and one shell fishhook were recovered from the prehistoric layers even though 100 percent of sediments were screened.

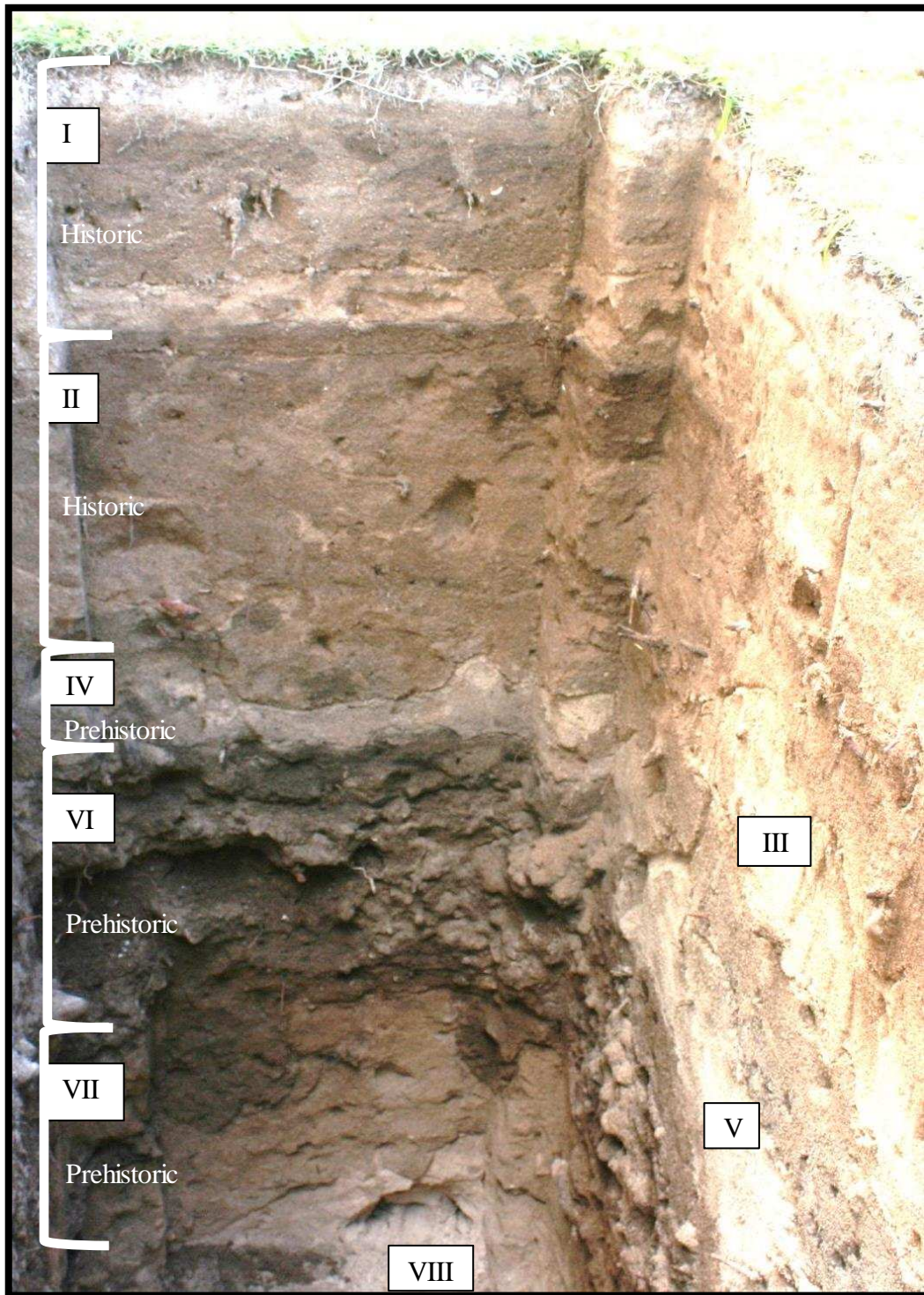


Figure 5.7 Eastern wall of XU-1. Note the presence of a thick colluvial layer (VI near the bottom and the absence of sand layers (III and V) that can be seen on the southern wall. 1 m across

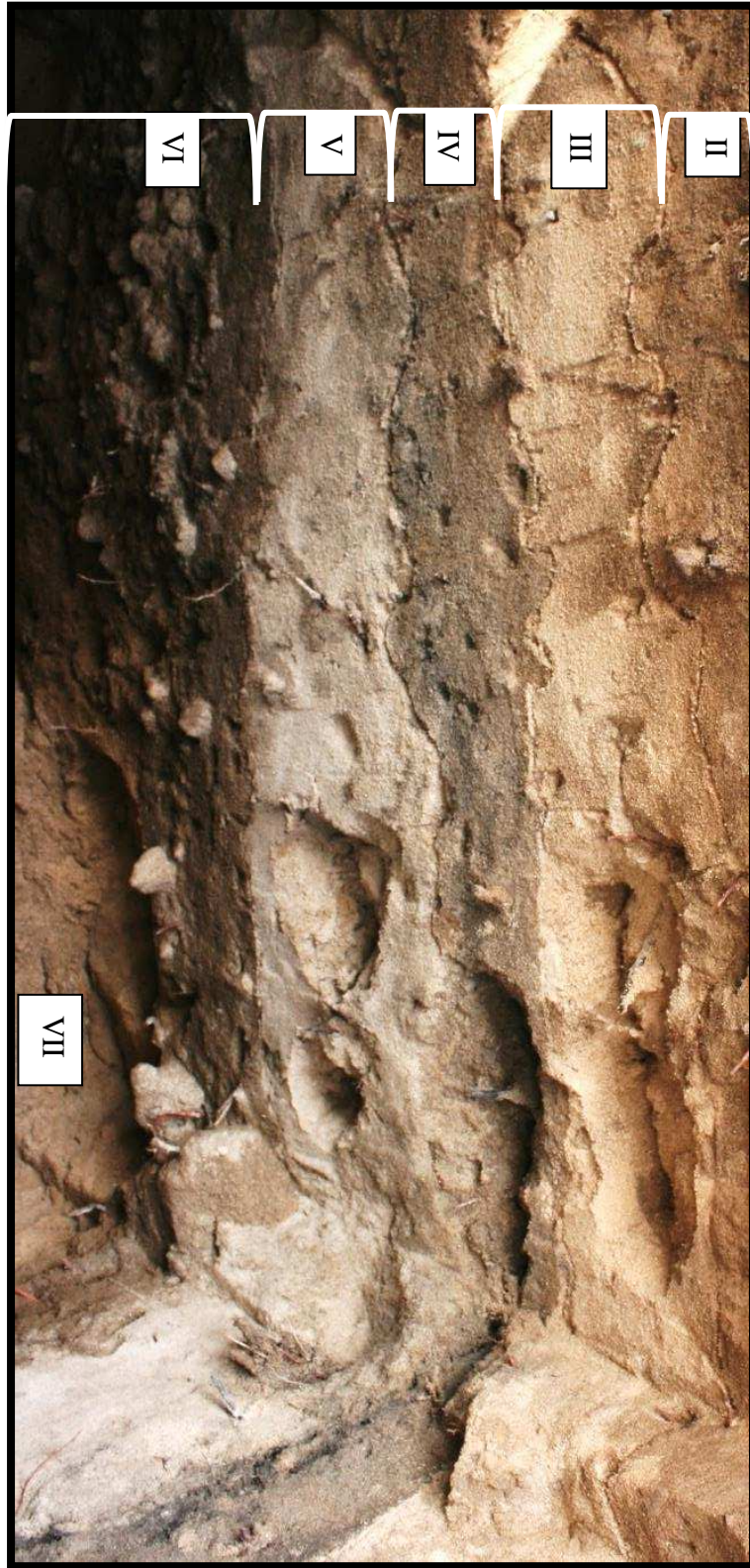


Figure 5.8 Southern wall at the boundary with western wall. Note the thickening sand layers and the thinning colluvial layer. Top layer is Layer II, which quickly transitions to Layer III. 1 m across

Table 5.2 Summary of XU-1 strata

	Thickness	Colour	Texture	Structure	Clastics (percent of total matrix)	Cultural Material
I	35-45 cm	10 YR 4/3 (Brown)	Loamy Sand	Granular	<5% sub-rounded coral and stone gravel	Historic
II	20-35 cm	10 YR 3/2 (Very dark brown)	Loamy Sand	Granular	<5% sub-rounded coral and stone gravel	Historic
III	0-25 cm	10 YR 5/4 (Yellowish brown)	Sand	Granular	5-10% sub-rounded to sub-angular coral and stone gravel	Sterile
IV	15-35 cm	10 YR 4/2 (Dark grayish brown)	Loamy Sand	Granular	10-15% sub-rounded to angular coral and stone gravel and cobbles	Prehistoric
V	0-40 cm	10 YR 6/3 (Pale brown)	Sand	Granular	<5% angular and unweather coral	Sterile
VI	15-55 cm	5 YR 3/2 (Dark reddish brown)	Sandy Clay	Sub-angular blocky	15-20% rounded to sub-rounded coral and stone gravel	Prehistoric
VII	20-50 cm	10 YR 5/4 (Yellowish brown)	Loamy Sand	Granular	<5% sub-rounded coral and stone gravel	Prehistoric
VIII	uncertain	10 YR 7/3 (Very pale brown)	Sand	Granular	5-10% rounded to sub-rounded coral and stone gravel and cobbles	Sterile

Table 5.3 Summary of prehistoric cultural feature in XU-1

No.	Function	Layer	Dimensions (cm) L, W, D	Profile Shape	Contents
Feature 5	Combustion	IV	>110x>85x10	Shallow Basin	FCR, coral, charcoal
Feature 6	Combustion	VI	70x40x10	Shallow Basin	Charcoal, coral
Feature 7	Combustion	VI	20x20x10	Shallow Basin	Charcoal, coral
Feature 8	Combustion	VII	35x>15x10	Shallow basin	FCR, charcoal

XU-2

XU-2 (2x1 m) is situated between XU-3 and XU-4 near Core 4 of Transect 1. The unit was dug primarily with a shovel and pick axe, a method chosen based on the nature of the deposit (terrigenous sediments), the density of coral inclusions, and the lack of cultural material. Twenty-five percent of the sediments excavated, or every fourth bucket, was screened through ¼" mesh. All but the top two layers, out of a total of six layers, exhibited high proportions of terrigenous sediments, each with high densities of coral and basalt gravel. The unit was terminated at 210 cmbd as continued digging became difficult and potentially dangerous because of depth and the instability of unit walls (Fig. 5.9).

Layer I was a 15-20 cm thick heterogeneously coloured sandy loam layer with a granular structure. Multiple lenses of sand and clay were identified from the surface to the base of the layer. Historic materials (e.g., glass and food wrappers) were found, and a metal pipe stretched across the eastern wall. Shell, sub-rounded basalt gravel, and sub-rounded coral gravel were present in low densities (~5-10 percent of the matrix). The boundary with Layer II had a gradual transition and a wavy topography.

Layer II was a 5-15 cm thick 10 YR 7/6 (Yellow) medium grained sand with a granular structure. The layer was shallow and thin with few inclusions. Some shell, charcoal, and sub-rounded coral gravel was identified, but constituted less than 5 percent of the matrix. There was significant root activity reaching into terrigenous sediments near the bottom of the layer.

Layer IIb, was gray soil identified in the north wall. Throughout the layer historic materials (e.g., glass) were found, though in lower quantities compared to Layer I. The boundary with Layer III was abrupt and had a wavy topography.

Layer III was a 10-15 cm thick 10 YR 2/2 (Very dark brown) sub-angular blocky sandy clay loam. The layer had a high organic matter content based primarily on colour. Numerous sub-rounded basalt and coral gravel inclusions were noted in the matrix (~15-20 percent of the matrix). Charcoal and shell were found in higher amounts than the previous two layers, with shell increasing as the layer deepened. Ash and charcoal were identified in pockets near the bottom of the layer. Historic material was identified. The transition to Layer IV had a clear boundary with a smooth topography.

Xu-2
North Wall

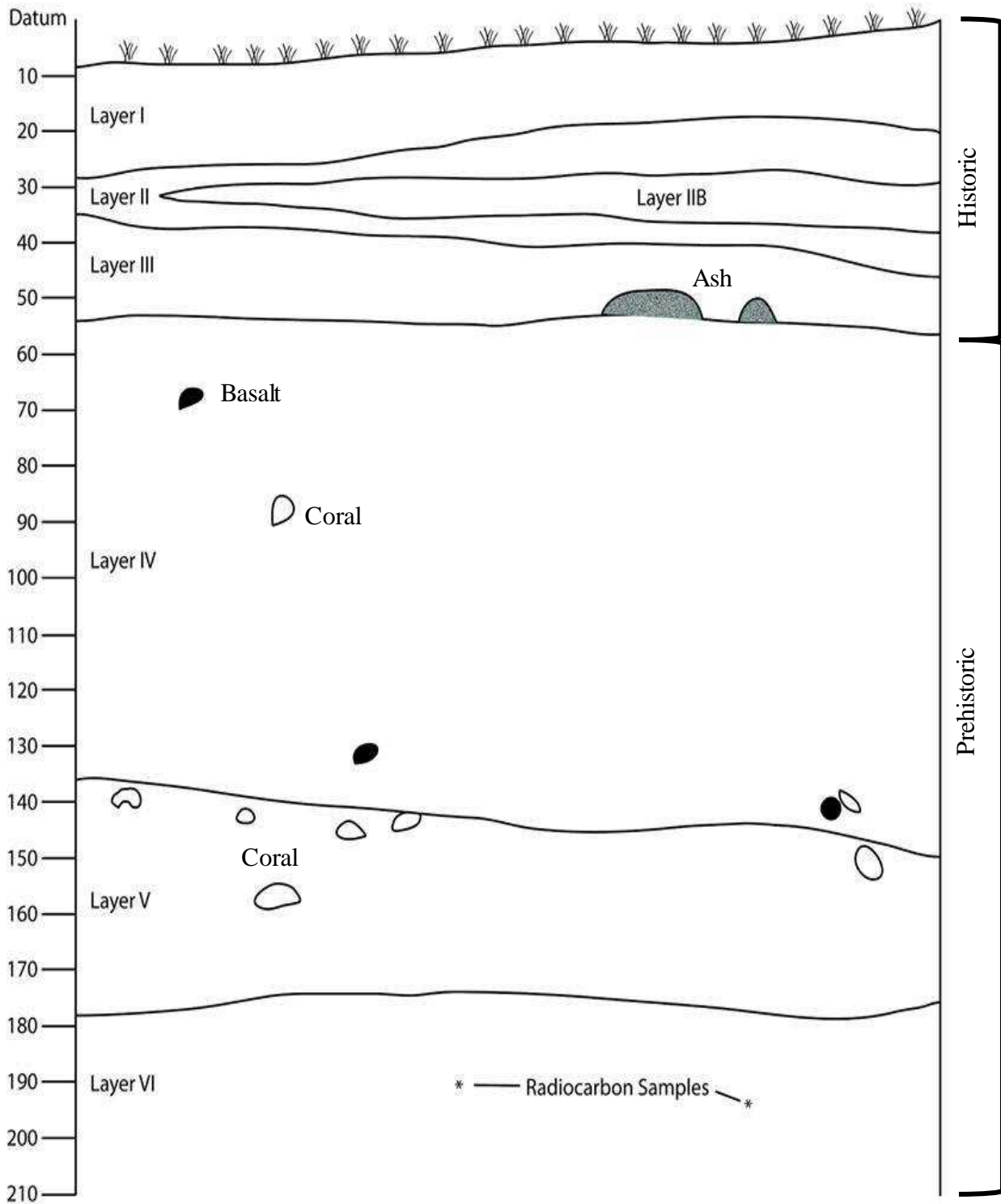


Figure 5.9 Profile of the northern wall of XU-2. Only larger clastics are noted in this drawing

Layer IV, the thickest in the unit at 80-95 cm, was a 5 YR 3/2 (Dark reddish brown) sub-angular blocky clay layer with many inclusions (Figs. 5.10, 5.11). Degraded shell was located throughout the matrix, including *Turbo*, *Cellena*, *Trochus*, *Tectus*, *Cypraea*, and *Tridacna*. Sub-angular cobble and gravel sized basalt was identified, along with a high density of sub-rounded coral gravel (~20-30 percent of the matrix). Charcoal was very common, particularly small pieces which were quite dense in some areas (Fig 5.10). A few historic artefacts, specifically food wrappers, were recovered during screening of sediments, but these were never found *in situ* and appear to have been displaced from the unstable layers above during excavation. Calcareous sand became more visible in the matrix toward the bottom of the layer. The layer thickens toward the inland side of the unit. The boundary with Layer V was gradual, exhibiting a smooth topography.

Layer V was a 25-45 cm thick 10 YR 2/2 (Very dark brown) sub-angular blocky clay loam layer (Fig. 5.12). There was a continuation of high quantities of sub-rounded coral and basalt in the matrix (~15-20 percent of the matrix), with a similar density of charcoal flecking and shell as the previous layer. No cultural material was noted in context. Cinder stone became common, at least more common than in previous layers. Calcareous sand-sized sediments, too, became more common, but by no means did these make up a significant portion of the matrix. In general, the layer was extremely poorly sorted. Several non-marine molluscs were noted in the screen and the layer appears organically enriched based on colour. The boundary with Layer VI was diffuse with a wavy topography.

Layer VI was a homogenous 7.5 R 3/4 (Dusky red) granular fine to medium grained sandy loam (Fig. 5.13). There was a continuation of dense sub-rounded coral and basalt gravel inclusions (~10-15 percent of the matrix), though these became fewer with increasing depth. Degraded sea urchin spines were present along with highly fragmentary shell, similar to the top of Layer VI in XU-4 (see below). Roughly half of all sediments were screened, but no cultural material was identified. Charcoal was abundant, and two samples were collected from the interface with Layer V, one of them dated (Beta-380263, 2 σ AD 895-1021). The west half of the unit was dug deeper in an attempt to reach sterile beach sand as the depth of the unit became a safety issue, but no such layer was identified. The unit was terminated at 2.1 m, still within Layer VI.

Summary and Interpretations. Because this excavation was terminated prior to the identification of a sterile calcareous sand layer, a complete stratigraphic sequence cannot be proposed (Table 5.4). However, a preliminary assessment based on what was excavated can be presented (Figs. 5.14). Historic materials were confidently identified in the first three layers. The top two layers are made up of sand, largely of calcareous origin, which was likely brought into the site to aid in house construction. The third layer represents the historic period as well, indicated by the presence of historic material. However, this layer is different than the previous two in that terrigenous sediments constituted the majority of the matrix. Based on the dark colour of the layer signifying a high organic matter content that is characteristic of plant growth in the tropics, the layer might be evidence of garden activity (A_P horizon). This interpretation is discussed at length below in reference to Layer V.



Figure 5.10 Distribution of charcoal flecking and coral in Layer IV of XU-2. Area roughly 50 cm across.

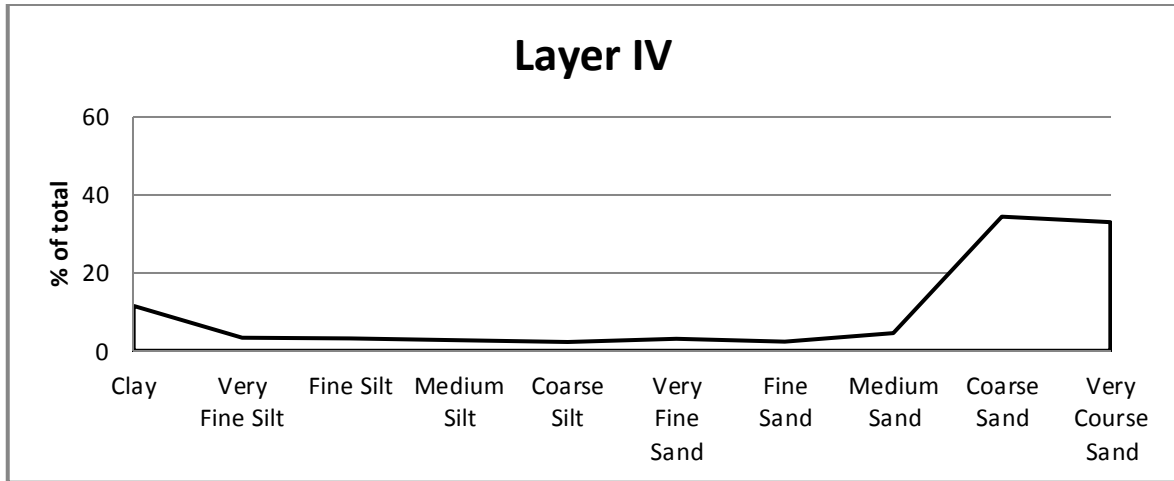


Figure 5.11 Particle size distribution for Layer IV of XU-2. Distribution of coarse grained sediments is a reflection of the fraction of degraded coral in the deposit. Very similar to Layer IV of XU-4 (see below)

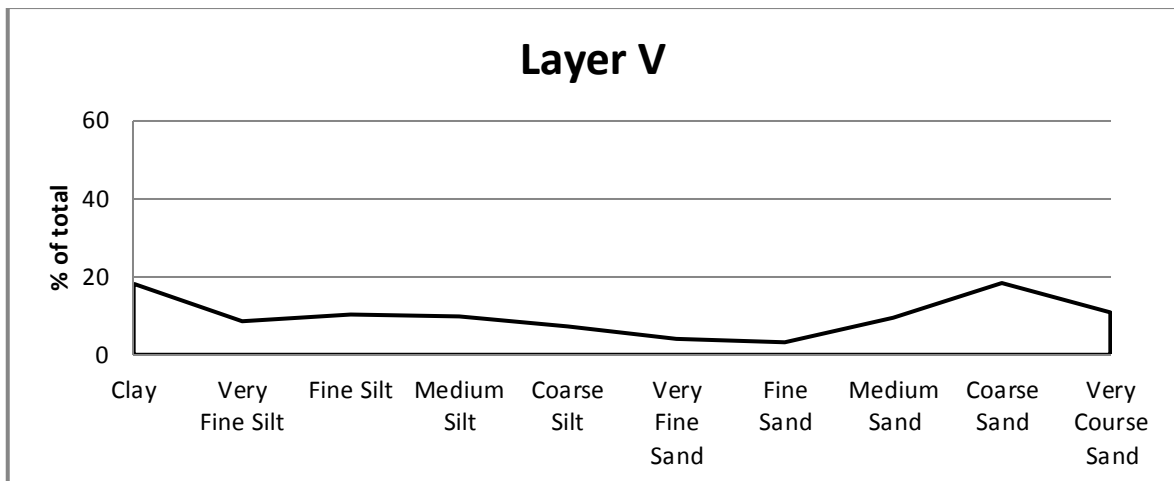


Figure 5.12 Particle size distribution for Layer V of XU-2. Large grain sizes are a reflection of the amount of degrading coral gravel in the layer

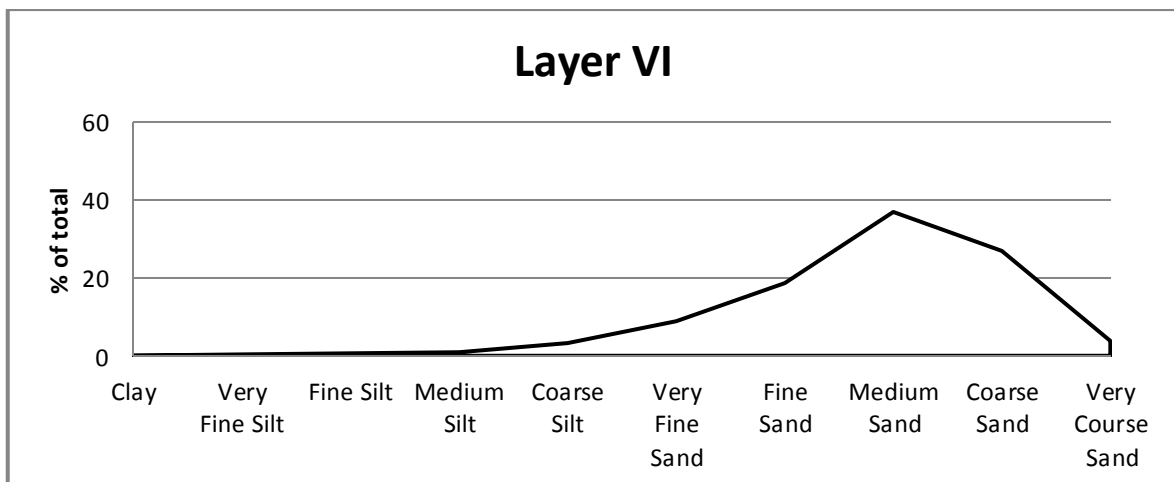


Figure 5.13 Particle size distribution for Layer VI of XU-2

Table 5.4 Summary of XU-2 strata

	Thickness	Colour	Texture	Structure	Clastics (percent of total matrix)	Cultural Material
I	15-20 cm	Heterogeneous	Sand	Granular	5-10% sub-rounded coral and stone gravel	Historic
II	5-15 cm	10 YR 7/6 (Yellow)	Sand	Granular	<5% sub-rounded coral gravel	Historic
III	10-15 cm	10 YR 2/2 (Very dark brown)	Sandy Clay Loam	Sub-angular blocky	15-20% sub-rounded coral and stone gravel	Historic
IV	80-95 cm	5 YR 3/2 (Dark reddish brown)	Clay	Sub-angular blocky	20-30% rounded to sub-angular coral and stone gravel and cobbles	Uncertain (likely prehistoric)
V	25-45 cm	10 YR 2/2 (Very dark brown)	Clay Loam	Sub-angular blocky	15-20% sub-rounded coral and stone gravel	Uncertain (likely prehistoric)
VI	Uncertain	7.5 R 3/4 (Dusky red)	Sandy Loam	Granular	10-15% sub-rounded coral and stone gravel	Dated (prehistoric)

The bottom three layers are likely prehistoric in age based on similarities with XU-4. The thickest, Layer IV, is the consequence of terrigenous deposition from the inland slopes. That forest clearance upslope played a role in the deposition of this layer is supported by the density of particulate charcoal in the matrix. The coral in this layer could represent 1) coral that was originally distributed on the slopes, to create living or working floors, which eroded along with the sediments; 2) multiple attempts at rebuilding structures in this area as the deposition of terrigenous sediments continued; 3) intentional additions to the soil to improve drainage capacity; or 4) evidence of high energy marine deposition in the area. Though historic artefacts were identified while screening sediments from Layer IV, these were never found *in situ* and are interpreted to have been displaced from layers above (unstable sand).

Layer V is in large part made up of terrigenous sediments as well, and, in part, is the result of erosion from the surrounding inland slopes. Layers IV and V are similar in their inclusion of fragmented shell, angular basalt gravel, and a high density of rounded to sub-rounded coral gravel. This layer, however, is richer in organic material than Layer IV attested to by its darker colour. The nature of this layer, along with Layer III in this unit, Layer III and V in XU-4, and Layer II of Trench 3 (see below), is remarkably similar to descriptions of anthropogenic garden soils documented on Niuaotupapu (*fasifasi'ifeo*):

Dark loams 20-50 cm thick, containing broken igneous stones eroded down from the slopes of the central volcanic ridge mixed with pieces of coral and shell brought up together with the underlying coralline sand. (Rogers 1974:312)

On Niuaotupapu, these soils are an important zone for the cultivation of root crops (Kirch 1988:38-41), and the soils themselves “are cultural artifacts reflecting at least 1,500 years of occupation on a former beach” (Kirch 1988:41). The shared characteristics between dark loams on Ofu and *fasifasi'ifeo* soils imply that soils on Ofu are buried garden soils (A_p horizon). In general, then, Kirch’s above description of the formation of *fasifasi'ifeo* would hold for the formation of the dark clay loam layers on Ofu.

The basal layer of XU-2 was Layer VI. Calcareous sand in the layer indicates that at least some marine deposition continued in the area to the interface of Layers V and VI. A charcoal sample from the top of Layer VI signifies that this change occurred around the 9th-11th centuries AD. Faunal material, specifically shell and sea urchin spines, hints at cultural activity in the area, but no artefacts were identified. Unfortunately, a culturally sterile layer was not uncovered in this unit, and it is likely that a cultural deposit is situated below the termination point of the unit based on similarities with XU-4 (see below).

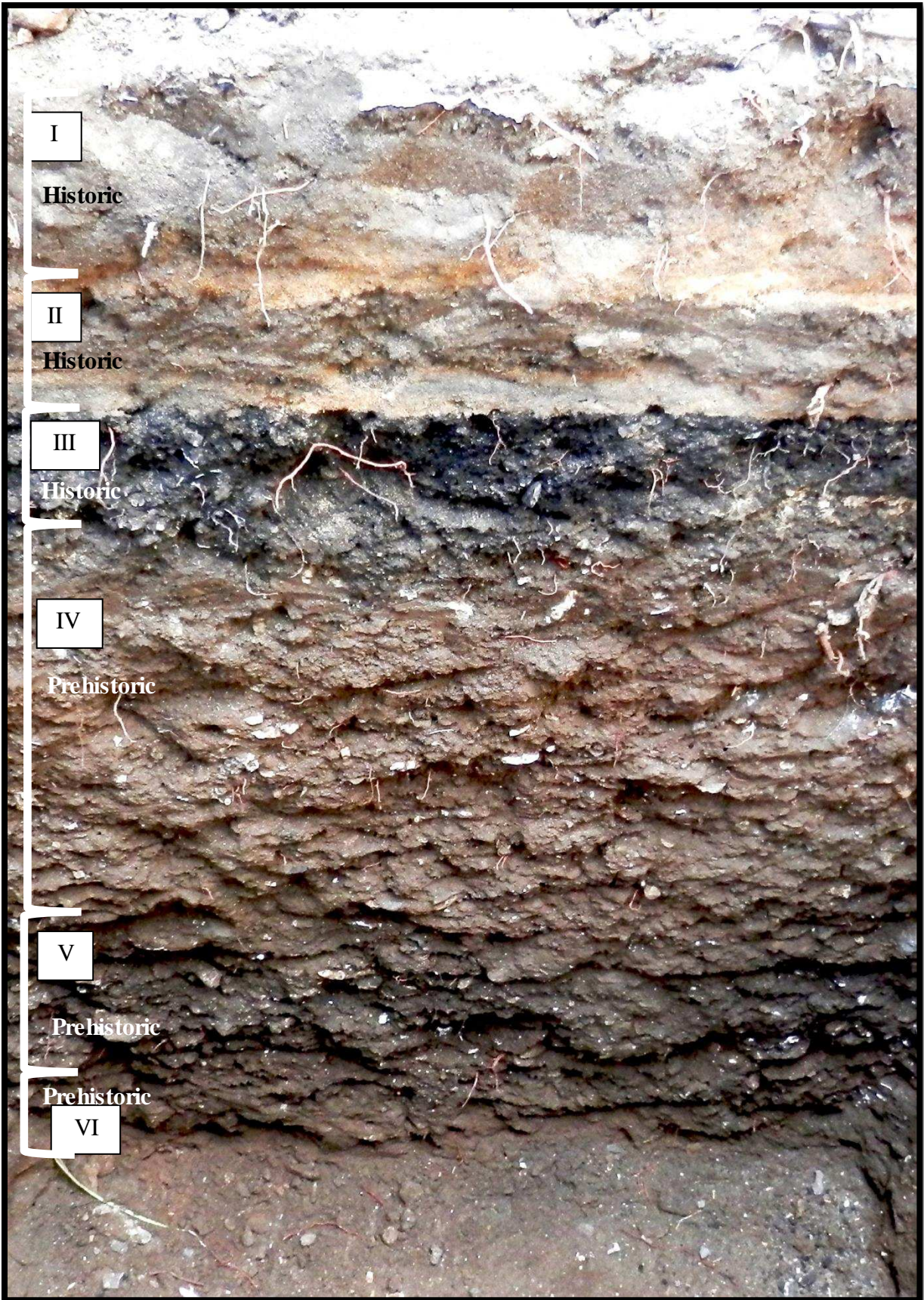


Figure 5.14 Western wall of XU-2. Note the density of coral in the colluvial layers. 1 m across

XU-3

This unit was the most seaward of the controlled units dug in the middle of Ofu Village. Prior to the identification of prehistoric materials, the unit was excavated with shovel and pick axe, with 25-50 percent of sediments screened through ¼" mesh, as determined by screening every second or fourth bucket. After prehistoric artefacts were recovered, controlled digging with trowel was conducted and all excavated sediments were screened through ¼" mesh. The unit was terminated at 198-203 cmbd, within sterile calcareous sand (Fig. 5.15). A shovel pit was dug to 250 cmbs revealing no further layers but several large coral boulders.

Layer I was a 0-5 cm thick 10YR 7/2 (Light gray) medium to coarse grained structureless sand with many fine roots and few coral inclusions (less than 5 percent of the matrix) (Fig. 5.16). Modern and historic artefacts were common, which included glass and plastic. The boundary with Layer II was abrupt with a smooth topography.

Layer II was a 5-10 cm thick organic rich 10YR 1/1 (Black) medium to coarse grained sandy loam with a granular structure (Fig. 5.17). Many fine roots were noted, along with some coral and basalt gravel (less than 5 percent of the matrix), charcoal, and a few unidentified non-marine molluscs. Historic materials (e.g., glass) were present throughout layer. The boundary with Layer III was clear with a smooth topography.

Layer III was a 10-15 cm thick 10YR 4/3 (Dark brown) coarse grained sand with a granular structure and few coral and basalt gravel inclusions (less than 5 percent of the matrix) (Fig. 5.18). Charcoal flecking was noted, associated with cultural artefacts from the historic/modern period (e.g., glass and plastic). The boundary with Layer IV was clear with a smooth topography.

Layer IV was a 0-5 cm thick 10YR 5/3 (Brown) medium to coarse grained granular sand with some coral and stone gravel (less than 5 percent of the matrix) (Fig. 5.19). Charcoal rubble was common, and a possible historic combustion feature, defined by dark ash and fire cracked rock, was noted in the south end of the unit. Historic artefacts (e.g., plastic) were again identified. The boundary with Layer V was abrupt with a somewhat wavy topography.

Layer V was a 10-15 cm thick historic *ili'ili* paving (structural paving) of small sub-rounded coral gravels, ~80-90 percent of the matrix, with many fine roots and some charcoal. The surrounding soil was a 10 YR 3/2 (Very dark grayish brown) loamy sand. Limited historic

cultural material (e.g., glass) was identified. The boundary with Layer VI was abrupt with a smooth topography.

Layer VI was a 10-15 cm thick 10YR 8/4 (Very pale brown) structureless medium to coarse grained sand (Fig. 5.20). These characteristics, specifically the colour, are similar to those of beach sand. Few roots or any other inclusions were identified; coral and basalt gravel constituting less than 5 percent of the matrix. Clay of terrigenous origin increased with depth based on visual interpretation and soil stickiness. The boundary with Layer VII was abrupt with a wavy topography.

Layer VII was a 10-20 cm thick 10YR 2/2 (Very dark brown) sandy clay loam with a granular structure and many sub-angular to sub-rounded coral gravel and cobbles (~35-40 percent of the matrix) (Fig. 5.21). This was the first layer encountered where terrigenous sediment constituted a sizable portion of the matrix. Coral was so dense that it was originally believed to be another paving, but it was thicker than other pavings, over 20 cm in some areas. Reports indicate that coral was transported to this area after being dredged from the modern wharf, and this layer might represent such an event (Fig. 5.22). Historic material was noted (e.g., wrappers), and a crab disturbance was situated in the northern wall. The transition to Layer VIII was abrupt with a smooth topography.

Layer VIII was a 15-30 cm thick 10YR 3/3 (Dark brown) sandy clay loam with a granular structure (Fig. 5.23). A high density of sub-rounded coral cobbles and gravel was noted in the layer (~30-35 percent of the matrix), but it did not reach proportions identified in Layers V or VII. Some charcoal and historic artefacts, including a cellophane wrapper, were recovered. Additionally, medium mammal bone was noted in the north and west walls. Crab disturbances continued through this layer and just into Layer IX. The boundary with Layer IX was gradual with a wavy topography.

Layer IX was a 5-20 cm thick heterogeneous 10YR 3/3 (Dark brown) medium to coarse grained granular sandy loam with sub-rounded coral gravel (~15-20 percent of the matrix) (Fig. 5.24). The layer was very thin at times, particularly in the west half of the unit. One feature, Feature 1, was recorded dug into Layer X that measured 62 x 25 x 26 cm. The function of the feature is unknown and was differentiated from the rest of the layer by its soil texture and very pale brown colour. The contents of the feature were no different than the rest of the layer and it could represent a bioturbation. Red, wet clay of terrigenous origin was identified in pockets, especially in the northeast corner of the unit. Calcareous sand particles

increased in density as the layer deepened, but, similar to the red clay, the sand was commonly only encountered in pockets and probably represent bioturbation from the layers below. Some shell was noted in the matrix, and two basalt flakes were recovered. The boundary with Layer X was gradual with a wavy topography.

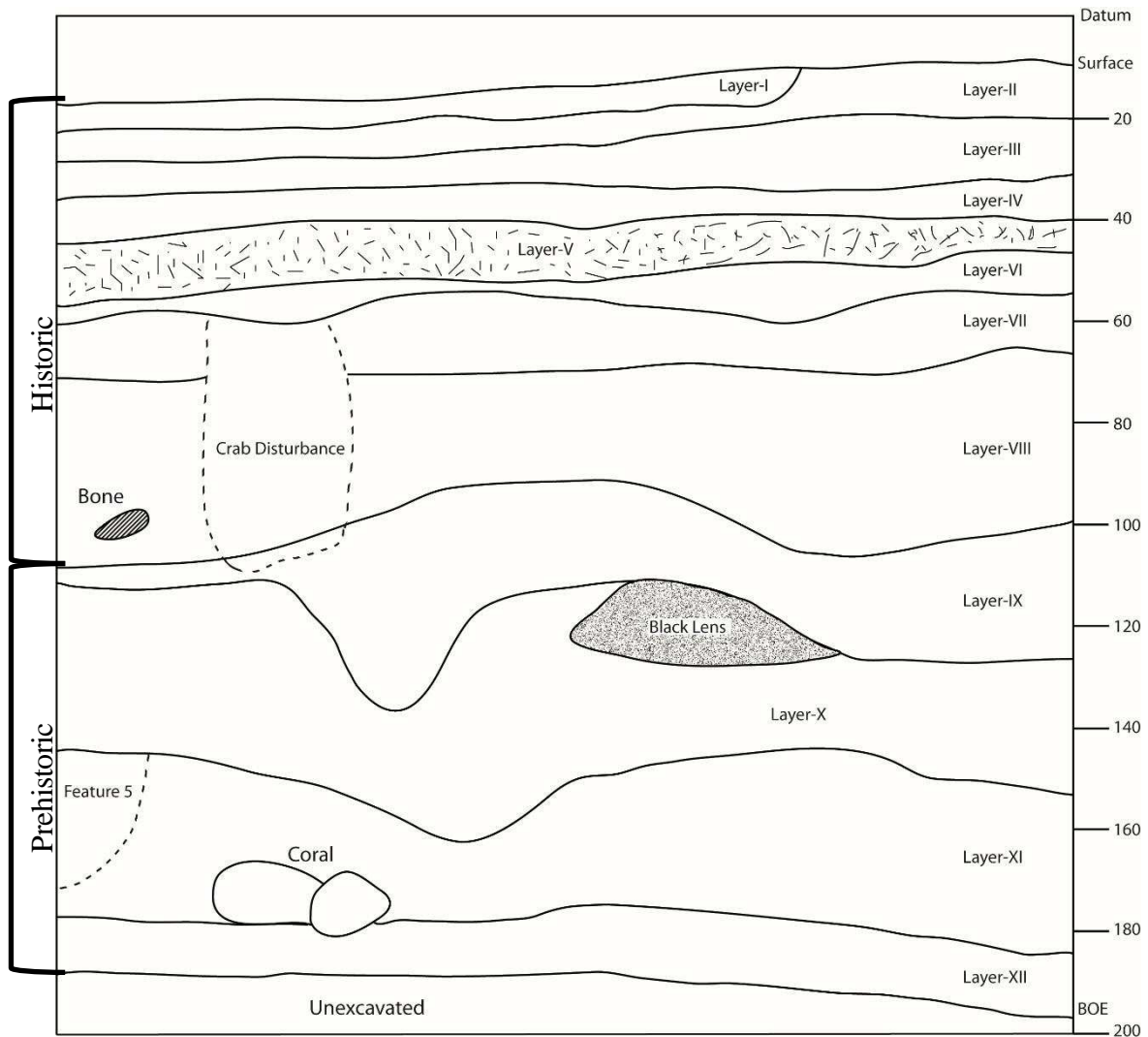


Figure 5.15 Profile of the northern wall of XU-3. Hatching in Layer V denotes the presence of a coral paving in the layer

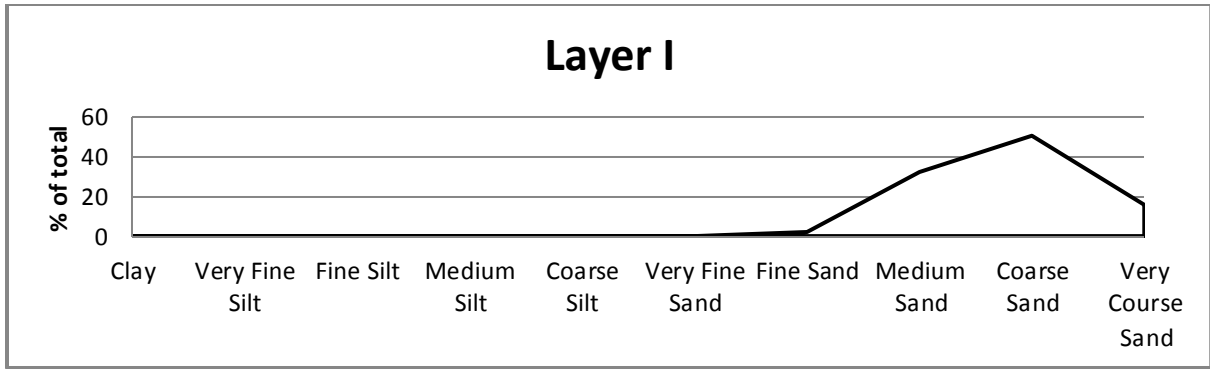


Figure 5.16 Particle size distribution for Layer I of XU-3

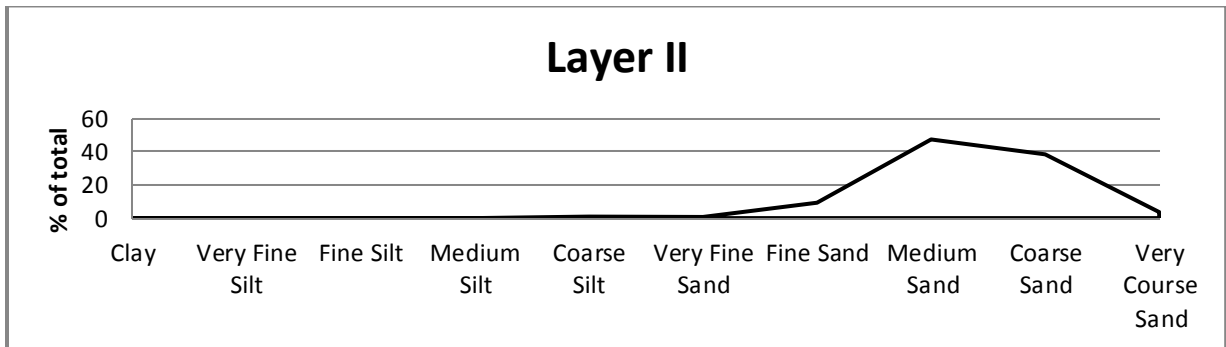


Figure 5.17 Particle size distribution for Layer II of XU-3

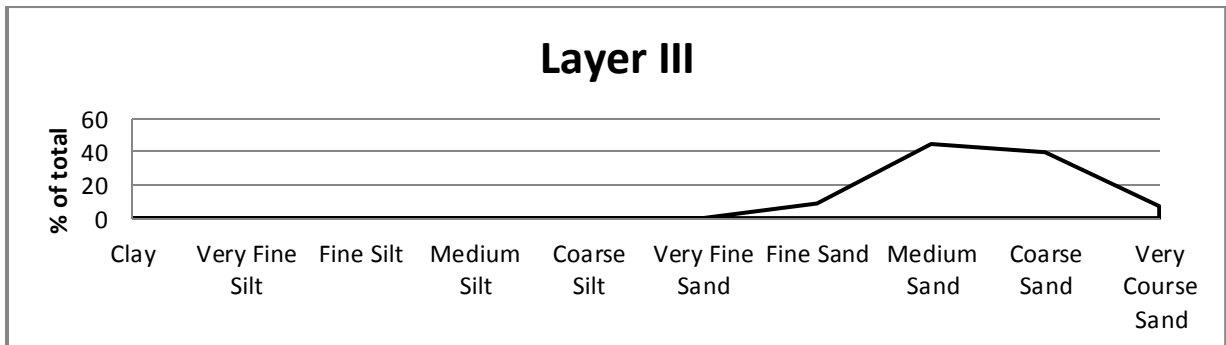


Figure 5.18 Particle size distribution for Layer III of XU-3

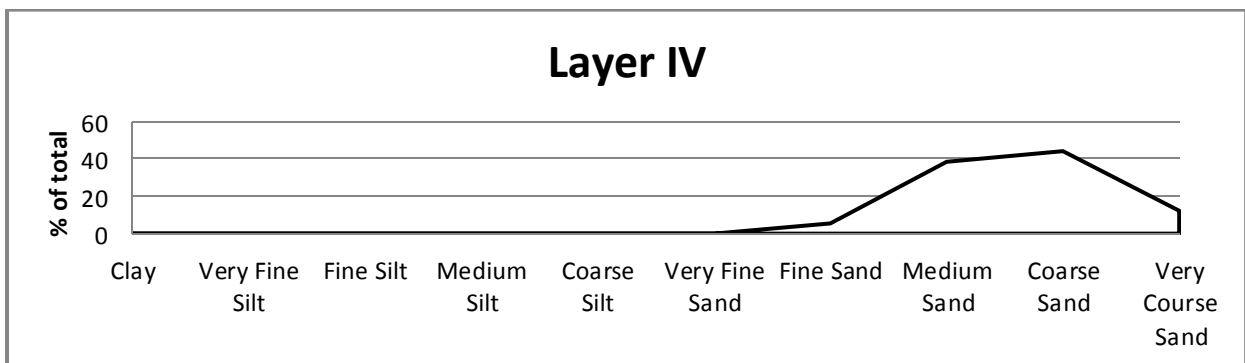


Figure 5.19 Particle size distribution for Layer IV of XU-3

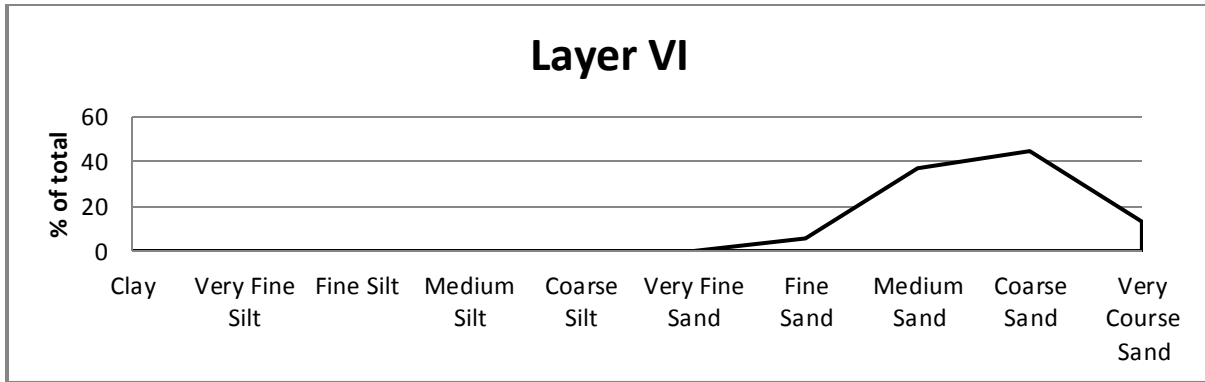


Figure 5.20 Particle size distribution for Layer VI of XU-3

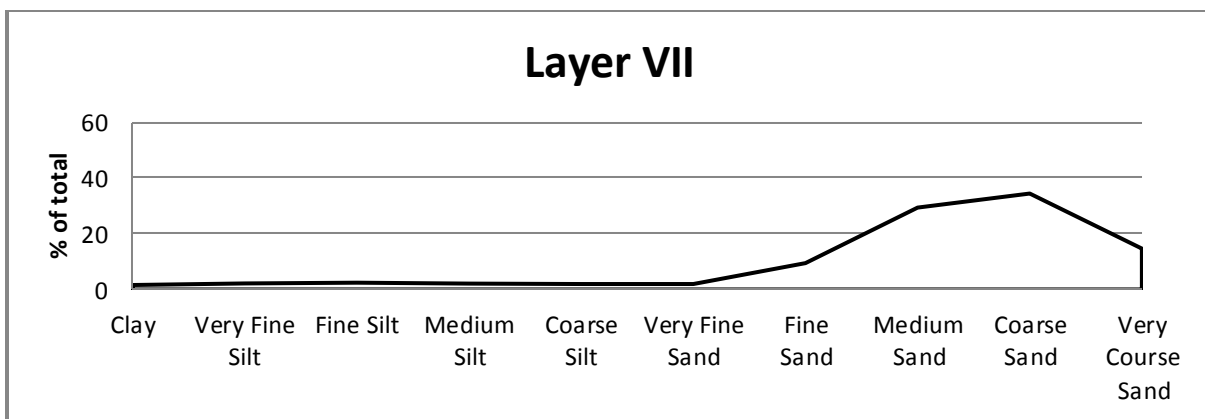


Figure 5.21 Particle size distribution for Layer VII of XU-3. The proportion of coarse grained sediments is a reflection of the amount of coral gravel in the matrix



Figure 5.22 Sample of coral taken while excavating XU-3. Most of this coral came from Layers VII and VIII

Layer X was a 30-40 cm thick 10YR 3/3 (Dark brown) granular sandy clay loam with numerous sub-rounded coral and sub-angular basalt inclusions (Fig. 5.25) (~20-30 percent of the matrix). These inclusions ranged in size from gravel to boulders (over 20 cm in length). Prehistoric artefacts, basalt flakes, were found and collected (n = 10). Artefacts, however, continued to be rare. Faunal remains were also rare, though some small shell and bone was noted. Charcoal was common throughout the matrix. A black soil lens was noted in the northern wall beginning at the transition between Layers IX and X, stretching to the midway point of Layer X. A small portion of the layer, labelled as Feature 2, extended into Layer XI. There was no clear difference between the matrix of the feature and that of the surrounding Layer X, and function is unknown. The boundary with Layer XI was abrupt with a wavy topography.

Layer XI was a 15-40 cm thick 10YR 4/4 (Dark yellowish brown) medium to coarse grained sand with a granular structure (Fig. 5.26). Inclusions were less common than in the previous layer, sub-rounded coral and sub-angular basalt gravel constituting an estimated 5-10 percent of the matrix. Shell and bone continued to be identified and collected. Basalt flaking debris was noted (n = 11). Light coloured calcareous sand pockets and red terrigenous clay pockets were present within the matrix. A slight colour change was noted at ca. 150 cmbs resulting in a designation of **Layer XIb**. This colour change appears to be associated with a reduction in the terrigenous component of the matrix. Charcoal continued to be frequently encountered and one sample from near the interface with Layer XII was dated (Beta-372699, 2 σ AD 1261-1387). Features 3, 4, 5, and 6 were uncovered in the layer, differentiated from the surrounding matrix by colour and texture, and Feature 6 extended into Layer XII. However, the contents of each did not differ significantly from the surrounding matrix. The boundary with Layer XII was diffuse with a wavy topography.

Layer XII was a loose 10YR 6/5 (Light yellowish brown) medium to coarse grained structureless sand of uncertain thickness (Fig. 5.27). Some terrigenous sediment was noted at the top of this layer, but the matrix was constituted by calcareous sands especially after the first 10 cm. No cultural material was identified, and most shell and bone was interpreted to be naturally deposited given their weathered appearance. Boulders of coral, some as large as 50 cm in length, were noted at the transition between Layers XI and XII, and small cobbles of sub-rounded coral and waterworn basalt continued to be found throughout the matrix (~10-15 percent of the matrix). The unit was terminated after a shovel test pit to 250 cmbs failed to identify any additional layers.

Summary and Interpretations. The stratigraphic sequence of XU-3 was markedly different than others on the coast (Tables 5.5, 5.6). A deep historic sequence was identified, which encompassed the first eight layers to a depth of 1 m. The top four layers, all of which display soil lensing, were interpreted as fill brought into the area from the beach to level the living surface. Layer V (*ili'ili* paving) and Layer VI (sterile sand) could represent phases of modern house construction, though the low density of cultural material is not consistent with prolonged residential use. The formation of Layers VII and VIII is more difficult to interpret. Coral gravel and pebbles were found in their highest density within these two layers, particularly in Layer VII where the matrix is predominantly coral. Historic material was recovered from both layers and discussion with local villagers indicated the surface had been levelled with material dredge from the wharf in the last 60 years. These layers may have formed by way of that activity. Layer VIII features a higher clay content, which, if at least portions of this matrix derived from dredged materials, would indicate mixing with terrigenous sediments already at the site.

No historic artefacts were identified in the bottom four layers, and prehistoric artefacts were identified in all (n = 24 basalt artefacts). Terrigenous sediments, in the form of clay particles, were more common in Layer IX and X than any layer below. In both cases, though, the proportion of clay in the matrix, as a whole, did not resemble the colluvial layers of XU-1 (Layer VI), XU-2 (Layer IV), or XU-4 (Layer IV). The most similar soil matrix to these colluvial layers was identified in the west wall within Layer X. The proportion of calcareous sediments increased with depth in Layer XI, marking a trend of increased terrigenous sedimentation over time. Artefacts were infrequently encountered, as was culturally deposited shell and bone, reflecting a low intensity of prehistoric land use. The bottom layer, Layer XII was sterile sand. The location of large coral boulders at the interface between Layers XI and XII implies a high energy depositional environment. The rate of calcareous deposition appears to have declined through Layers XI-IX.

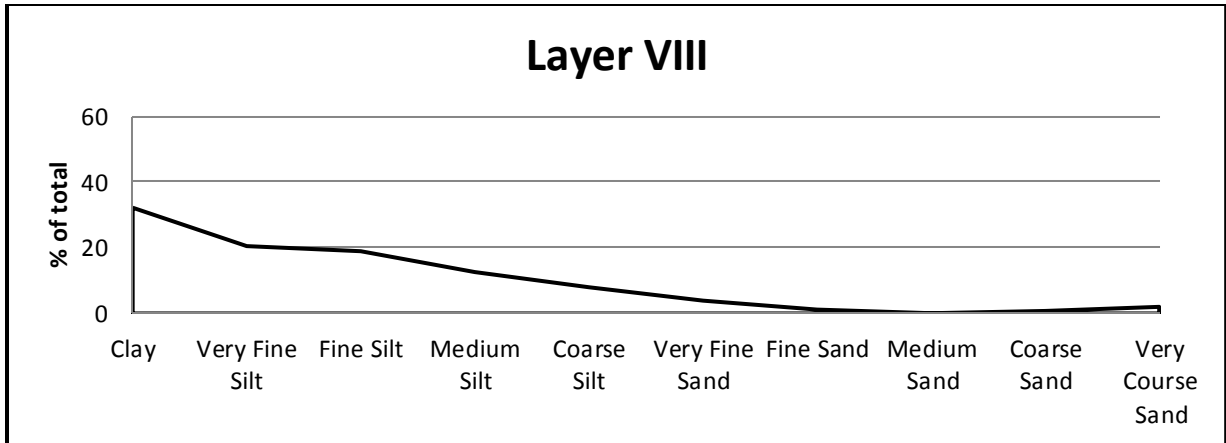


Figure 5.23 Particle size distribution for Layer VIII of XU-3

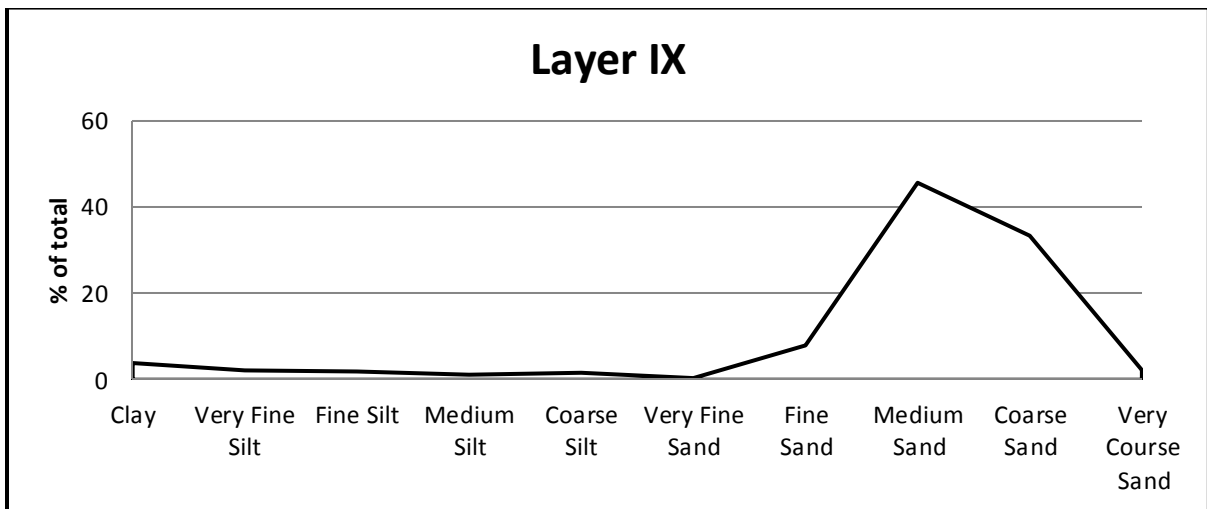


Figure 5.24 Particle size distribution for Layer IX of XU-3

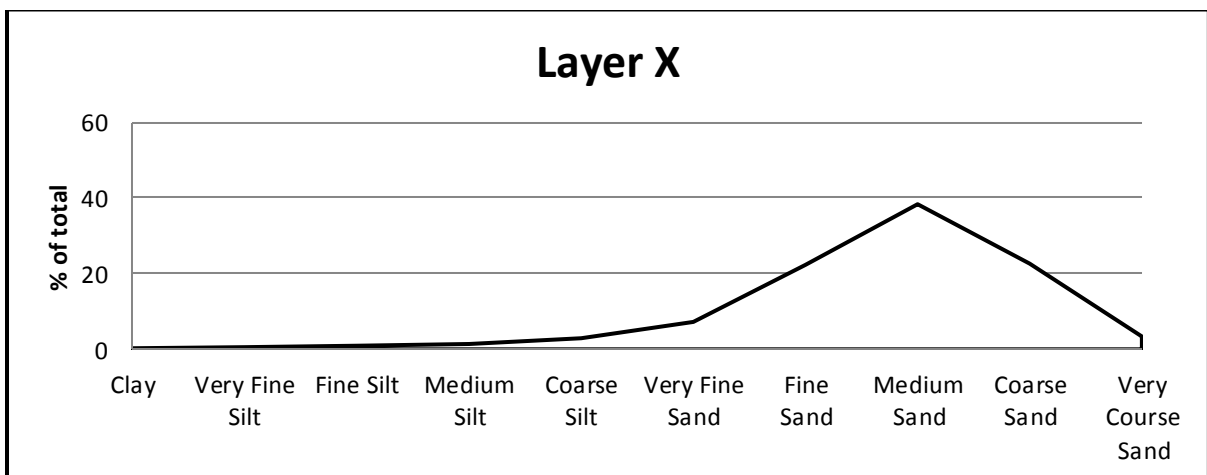


Figure 5.25 Particle size distribution for Layer X of XU-3

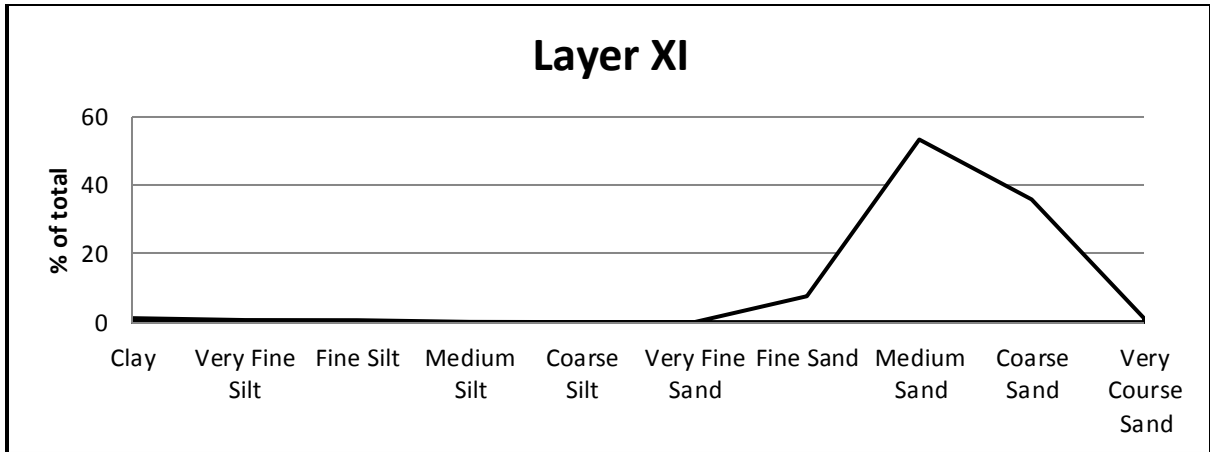


Figure 5.26 Particle size distribution for Layer XI of XU-3

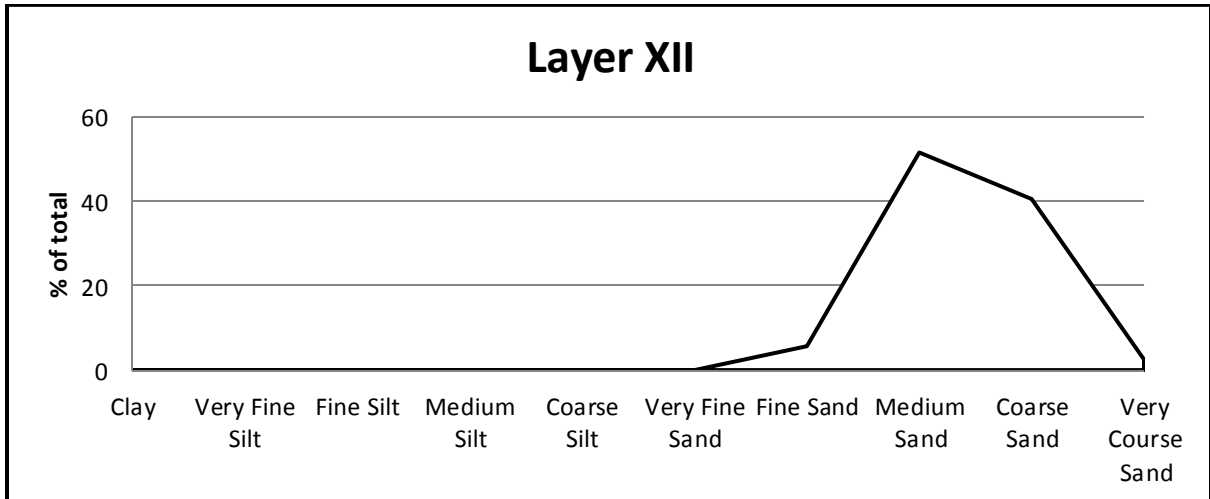


Figure 5.27 Particle size distribution for Layer XII of XU-3

Table 5.5 Summary of XU-3 strata.

	Thickness	Colour	Texture	Structure	Clastics (percent of total matrix)	Cultural Material
I	0-5 cm	10 YR 7/2 (Light gray)	Sand	Structureless	<5% sub-rounded coral gravel	Historic
II	5-10 cm	10 YR 1/1 (Black)	Sandy Loam	Granular	<5% sub-rounded coral and basalt gravel	Historic
III	10-15 cm	10 YR 4/3 (Dark brown)	Sand	Granular	<5% sub-rounded coral and basalt gravel	Historic
IV	0-5 cm	10 YR 5/3 (Brown)	Sand	Granular	<5% sub-rounded coral and basalt gravel	Historic
V	10-15 cm	10 YR 3/2 (Very dark graysih brown)	Coral	Structureless	80-90% rounded to sub-rounded coral gravel	Historic
VI	10-15 cm	10 YR 8/4 (Very pale brown)	Sand	Structureless	<5% sub-rounded coral and basalt gravel	Historic
VII	10-20 cm	10 YR 2/2 (Very dark brown)	Sandy Clay Loam	Granular	35-40% sub-rounded to sub-angular coral gravel and cobbles	Historic
VII I	15-30 cm	10 YR 3/3 (Dark brown)	Sandy Clay Loam	Granular	30-35% sub-rounded to sub-angular coral gravel and cobbles	Historic
IX	5-20 cm	10 YR 3/3 (Dark brown)	Sand Loam	Granular	15-20% sub-rounded coral gravel	Uncertain
X	30-40 cm	10 YR 3/3 (Dark brown)	Sandy Clay Loam	Granular	20-30% rounded to sub-angular coral and basalt gravel and cobbles	Prehistoric
XI	15-40 cm	10 YR 4/4 (Dark yellowish brown)	Sand	Granular	5-10% sub-rounded coral and basalt gravel	Prehistoric
XII	Uncertain	10 YR 6/5 (Light yellowish brown)	Sand	Structureless	10-15% rounded to sub-rounded coral and basalt gravel and large cobbles	Sterile

Table 5.6 Summary of prehistoric features identified in XU-3. Features 1 and 2 are not included as they are historic in age

No.	Function	Layer	Dimensions (cm) L, W, D	Profile Shape	Contents
Feature 1	Uncertain	IX	62x25x26	Tapered	Light brown sand and coral
Feature 2	Uncertain	X	35x32x17	Square	Coral
Feature 3	Uncertain	XI	40x35x11	Tapered	Coral, matrix similar to layer above
Feature 4	Combustion?	XI	30x35x49	Tapered	Ash and coral
Feature 5	Uncertain	XI	15x15x17	Tapered	Coral
Feature 6	Uncertain	XI	45x51x>30	Tapered	Three large water worn stones

XU-4

XU-4 (2x1 m) was the closest unit to the talus slope excavated on the western coast. Similar to the methodology employed to excavate XU-2 and XU-3, historic layers, based on artefact type, were dug with a pick and shovel whereas prehistoric layers were dug with a trowel. Twenty-five percent of historic sediments, every fourth bucket, and all prehistoric sediments were screened through ¼" mesh. Seven layers were identified, one of which had multiple sublayers. The highest densities of artefacts and fauna of any deposit excavated were found in Layer VI, and five intact cultural features were identified within the bottom four layers. The unit was terminated within culturally sterile sand at 330 cmbs (Fig. 5.28).

Layer I was a 35-45 cm thick 10YR 3/3 (Dark brown) medium to coarse grained sandy loam with a granular structure (Fig. 5.29). Many fine and medium roots were noted as well as some sub-rounded coral and basalt inclusions (~5-10 percent of the matrix). The matrix was heterogeneous, representing several decades of fill to flatten the surface. Some historic era glass, porcelain, and *umu* (oven) stones were identified. Some fish bone was present, but in a low density. Small basalt boulders were situated in the western half of the north wall. The boundary with Layer II was gradual with a wavy topography.

Layer II was a 10-35 cm thick sandy loam with a 5YR 3/3 (Dark reddish brown) hue and a sub-angular blocky structure (Fig. 5.30). A small proportion of sub-rounded coral and basalt gravel was recorded in the matrix (~5-10 percent of the matrix). Particulate charcoal was present, though in low quantities, and the basalt boulders identified in Layer I protruded into this layer. Some fish bone was documented, but no other culturally deposited material was noted. The boundary with Layer III was diffuse with a broken topography.

Layer III was a 0-25 cm thick homogenous 10YR 2/2 (Very dark brown) sub-angular blocky clay loam with a high density of sub-rounded coral gravel (~15-20 percent of the matrix) (Fig. 5.31). Charcoal was found in large quantities, likely one factor in the layer's colour. Burnt coral was identified in the north wall near a point at which the layer pinches out seaward and Layers II and IV converge. Some fishbone and shell was identified, but in no greater quantity than in previous layers and no other cultural material was noted. This layer is similar to Layer III of XU-2. There was a gradual boundary with Layer IV that had a broken topography.

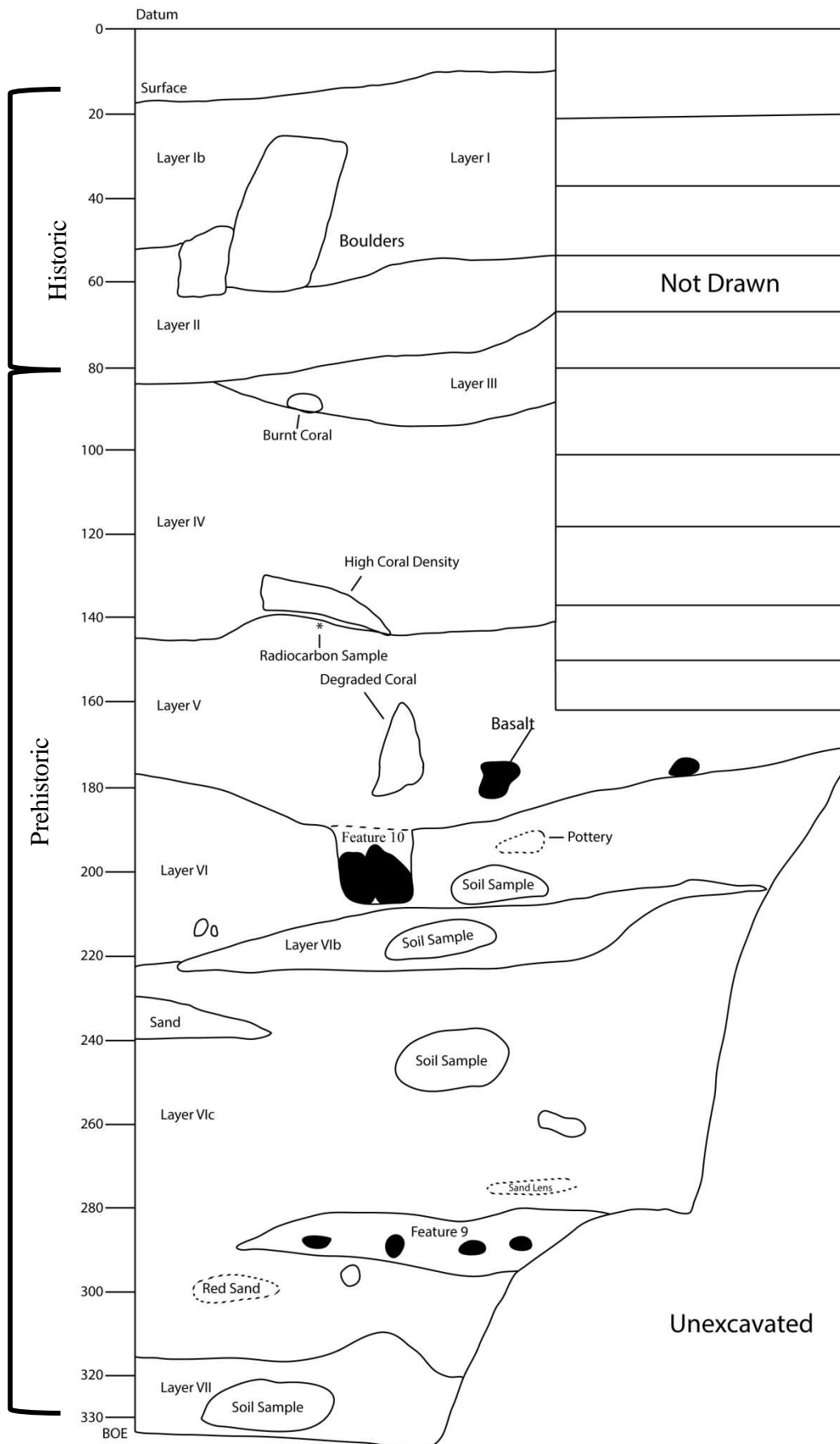


Figure 5.28 Profile of the northern wall of XU-4. Upper 140 cm drawn at 1 m width

Layer IV was a 50-60 cm thick sub-angular blocky clay layer with some sand inclusions and a 5YR 3/2 (Dark reddish brown) hue (Fig. 5.32). Few fine and medium roots were identified along with charcoal flecking, coral, and basalt. Most of the latter two inclusions were of gravel or pebble size, but cobbles were also encountered. Based on a volume measurement of two soil samples of 2600 mL and 2000 mL, coral represented roughly 16 percent of the matrix while basalt represented another 11 percent. A single feature was identified, Feature 7 measuring 100 x 60 x 15 cm, at which time a trowel began to be utilised and 100 percent of the sediment was screened. The area around the feature was stained from charcoal with a scatter of fire cracked rock. A sample from this context was dated (Beta-372700, 2σ AD 1498-1795). Ceramics were found in proximity to the feature at 114 cmbs, but, given their small size and eroded nature, these artefacts are interpreted to have been in secondary contexts. Additionally, an eroded and fragmented human tibia was identified, and subsequently reburied following the completion of the unit, and two basalt flakes were collected. This is all evidence of significant sediment mixing through erosion. The nature of this layer was similar to Layer IV of XU-2 and Layer XI of XU-1. The boundary with Layer V was clear and had a wavy topography.

Layer V was a 30-50 cm thick 10YR 2/2 (Very dark brown) sub-angular blocky clay loam with highly weathered sub-rounded coral gravel, the impact of an acidic clay matrix (~10-15 percent of the matrix) (Fig. 5.33). Field tests indicate that the layer texture is similar to that of Layer V in XU-2, but the higher density of weathered coral fragments resulted in a higher proportion of large particles being reported by particle size analysis. In general the layer poorly sorted. Fragmented shell inclusions were common, especially near the bottom of the layer, and white calcareous sand grains were noted at an increasing density as the layer deepened. Particulate charcoal continued to be encountered frequently. A small number of artefacts were collected from the bottom of the layer. All of these were prehistoric in nature and included a small number of eroded ceramic sherds ($n < 10$) and two shell fishhooks. Three features were identified, Features 8, 10, and 11. Feature 8 was a large, at least 100 cm long and 80 cm wide, pit-like feature that stretched at least 120 cm into all layers below¹. Twenty-five stone and coral cobbles, the mean of which was 17 cm and the largest was 23 cm, were excavated out of the feature. Few, if any, of these were fire altered. Small fish and bird bone was abundant within the feature fill. Features 10 and 11 were much smaller tapered

¹ The bottom was never uncovered as excavation of the eastern half of the unit was terminated earlier than the western half so to create a step, which was necessary given the depth of the deposit.

features. No charcoal, artefacts, or faunal remains were identified within their boundaries, though small basalt cobbles were found at the bottom of Feature 10. The nature of the matrix is similar to Layer V of XU-2. The boundary with Layer VIa was gradual to diffuse with a wavy topography.

Layer VI was a 100-145 cm thick loamy sand, which was divided into three sublayers (Fig. 5.34, 5.35, 5.36). All three sublayers were characterised by similar inclusions and cultural material. Small sub-rounded coral and basalt cobbles were distributed within the matrix, with gravels present in a lower density. All clastics together constituted an estimated 10-15 percent of the matrix. The first sublayer (7.5YR 3/3, Dusky red), Layer VIa, was 20-40 cm thick and was defined by a slightly higher terrigenous sediment content and sub-angular blocky structure. Scattered white calcareous sand inclusions and a more granular structure characterised the 0-20 cm thick Layer VIb (7.5 YR 3/4, Dusky red). Finally, a granular coarse to very coarse grained calcareous sand made up the 1 m thick Layer VIc (7.5 YR 4/4, Weak red). Boundaries between sublayers were diffuse.

Cultural material was more abundant in this layer than any other in Ofu Village, consisting of plainware ceramics (over 700 sherds) with limited decoration (e.g., notched rims, slipping, applique), shell fishhooks, shell ornaments, volcanic glass flakes (n = 100), and basalt flakes and tools (n = 22). Faunal remains were plentiful, consisting mainly of marine invertebrates. Fish, unidentified terrestrial or marine mammal, and bird bone was also identified. Shellfish and sea urchin in the upper portion of the layer (Layer VIa) were highly degraded, very similar to the situation in Layer VI of XU-2, but preservation improved as the layer deepened. A single combustion feature measuring 85 x 20 x 15 cm was excavated near the bottom (Feature 9) (Fig. 5.37). This feature consisted of 66 mostly fire-cracked basalt and small pieces of coral, the largest of which was 17 cm long with a mean of 8 cm. No cultural material, neither artefacts nor fauna, was noted within or around the feature.

Characteristics of the layer's matrix, particularly colour, began to change below this feature. As this colour shifted, larger clastics were noted, and a coral boulder, at least 50 cm long and wide was encountered in the south wall, but was never fully uncovered. Two charcoal samples were dated from Layer VIc, one from the top and one from the near the base. The samples were indistinguishable, with the same conventional radiocarbon determination (Beta-354137 and Beta-383081, 2σ 781-511 BC). Based on matrix similarities between XU-2 and XU-4, the top of Layer VIa in XU-4 probably dates to the late 1st

millennium AD (Beta-380263; 2σ AD 895-1021). The boundary between Layer VIc and Layer VII was diffuse with a wavy topography.

Layer VII was a mostly sterile 10 YR 7/3 (Pale brown) coarse to very coarse grained structureless sand (Fig. 5.38). The colour of the layer was darker near the top, likely a result of terrigenous sediment percolation from the above layer, but quickly lightened with increased depth. Sub-rounded coral and basalt inclusions were noted, constituting ~5-10 percent of the matrix, ranging in size from gravel to boulders. The coral boulder in the southern wall, uncovered at the bottom of the overlying layer, continued to the base of excavation. Cultural material found near the top of the layer consisted of small pieces of ceramics, some volcanic glass, and a fishhook. These were perhaps pushed into the sand at the onset of human occupation. The density of faunal material, which was more weathered than in the previous layer, decreased with depth and much of the shell looked naturally deposited based on its weathered appearance. Human metacarpals and phalanges were discovered near the large coral boulder. All human bone was reinterred after completion of the unit. Excavation was terminated well within sterile calcareous sand at ~330 cmbs.

Summary and Interpretations. The sequence of XU-4 is similar to that of XU-2, with the addition of two layers at the bottom of the unit (Fig. 5.39; Table 5.7, 5.8). The first three layers were deposited after European contact. Layer I is sand fill transported to the area and Layer II is the consequence of terrigenous sediment erosion from the inland slopes. Layer III is a dark, presumably organic rich, clay loam layer similar to Layers III and V of XU-2. Characteristics such as colour, lack of cultural features, and evidence of sediment mixing are all evidence that the layer was partially formed by gardening activity (buried A_p horizon). No artefacts were identified, but similarities with Layer II of XU-2 imply an historic age.

The bottom four layers of XU-4 are prehistoric. Layer IV is colluvium similar to Layer VI of XU-1 and Layer IV of XU-2. This layer, like the others, is the result of erosion most likely caused by vegetation clearance upslope based on the presence of particulate charcoal. The poorly sorted Layer V is a 30-50 cm thick dark clay loam with coral and basalt inclusions overlying a productive cultural deposit (Layer VI). The few artefacts identified in the layer were collected from the bottom, and the only *in situ* features were noted at the interface between Layers V and VI. Faunal material, too, was denser at the bottom of the layer. Like Layer V of XU-2, these characteristics are markedly similar to anthropogenic garden soils on the Niuatoputapu (Kirch 1988), implying that this layer is also a buried

garden soil (A_p horizon). The presence of some artefacts in the layer may be linked to sediment mixing with the top of the underlying Layer VI. The two features at the bottom might reflect garden activity (e.g., tool impressions?). The formation of this layer signifies increasing geomorphological stability based on the reduction in calcareous sedimentation, before the deposition of colluvium (Layer IV).

The archaeologically most productive layer in Ofu Village was Layer VI. The layer is the only one on the western coast within which was found ceramics ($n > 700$) and volcanic glass ($n = 100$). More basalt artefacts were found in this layer than others ($n = 22$), and the faunal material is qualitatively similar to assemblages recorded from To'aga (Nagaoka 1993) and Va'oto (Aakre 2014). Calcareous sediment constituted a higher proportion of the matrix as depth decreased, which indicates an increased terrigenous component to the sediment budget over time. The contribution of terrigenous sediment, clay and silt particles, to the sediment budget markedly decreases with depth in Layer VI alone (Figs. 5.34, 5.35, 5.36). The large coral boulder identified at the interface between Layer VI and Layer VII might mark the presence of a high energy beach or, alternatively, it could mark a burial from which the human hand bones derived.

The stratigraphic sequence and the nature of XU-2 and XU-4 are very similar. These similarities suggest that a cultural deposit is likely located beneath the termination point of XU-2, and that the formation of these deposits was temporally consistent. Based on this, the top of Layer VIa in XU-4 probably dates to a similar time as the top of Layer VI in XU-2 (9th-11th century AD). Additionally, the stratigraphic sequence is evidence that layers of colluvium observed in both units (Layer IV) were deposited at similar times (15th to 18th century AD). These dates are discussed in more detail in a later section of this chapter.

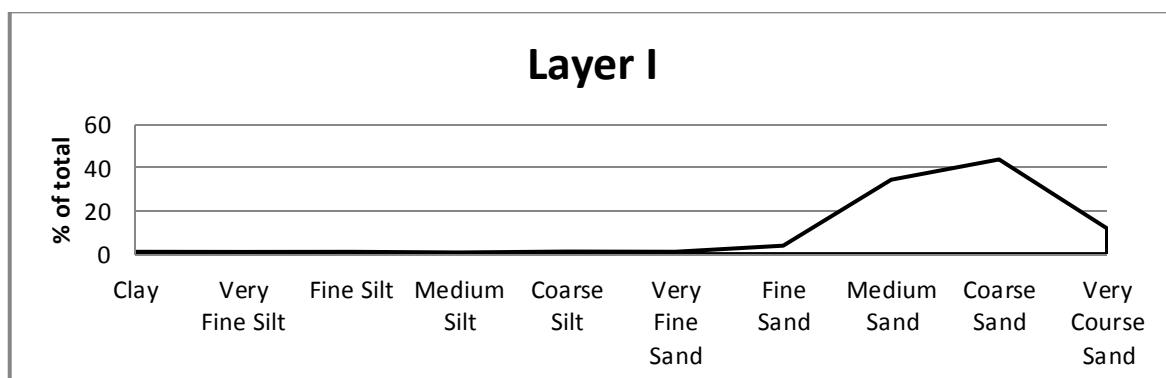


Figure 5.29 Particle size distribution for Layer I of XU-4

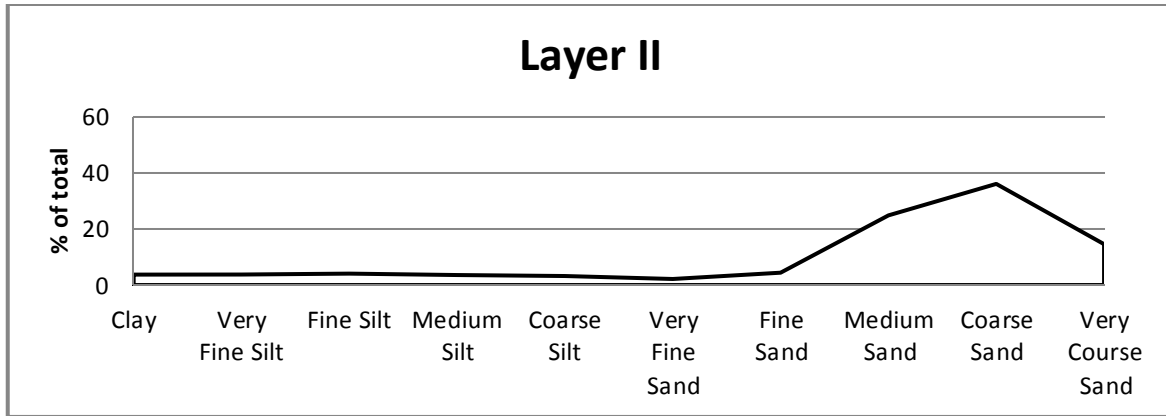


Figure 5.30 Particle size distribution for Layer II of XU-4

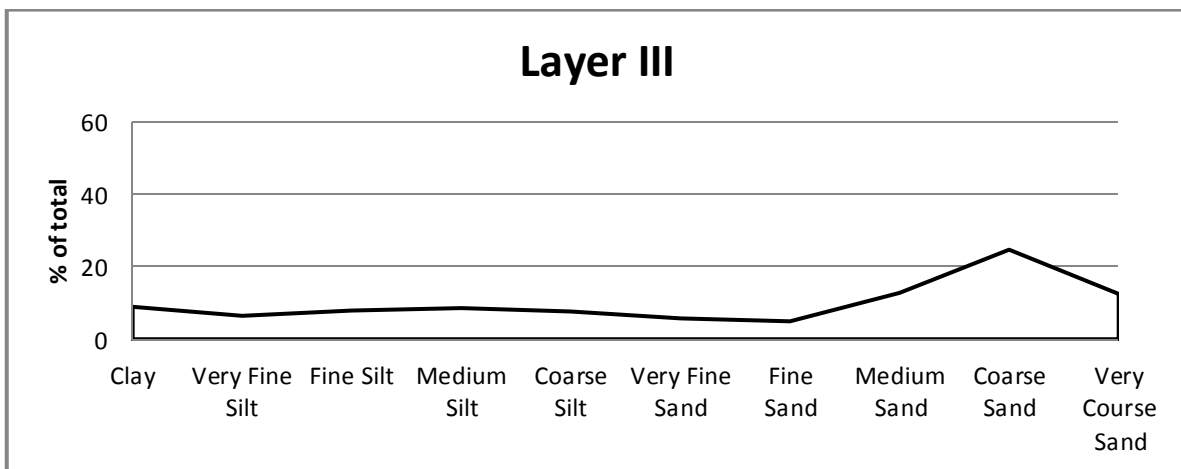


Figure 5.31 Particle size distribution for Layer III of XU-4

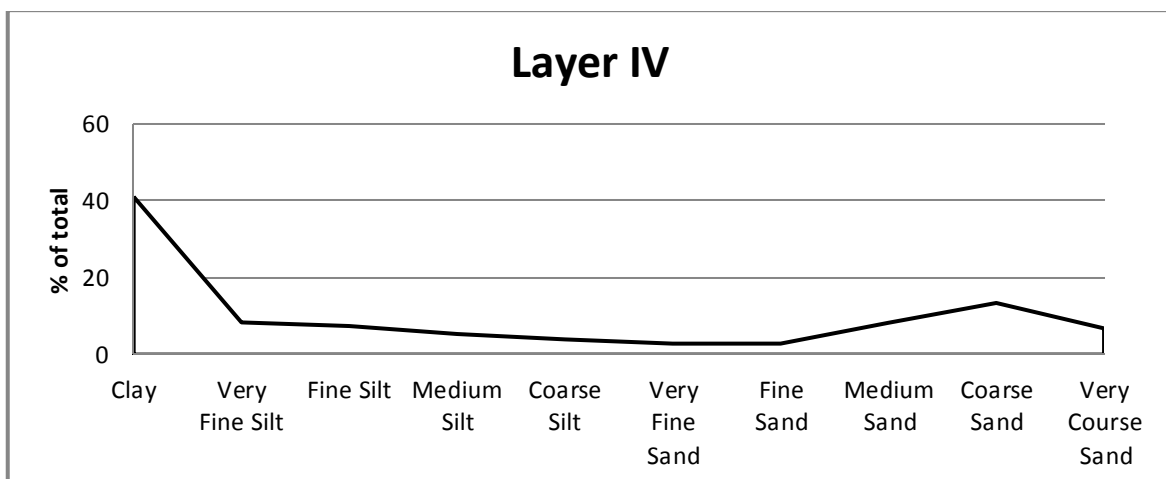


Figure 5.32 Particle size distribution for Layer IV of XU-4. The coarse grained sediments in this layer stem from the breakdown of the coral gravel identified throughout the clay matrix

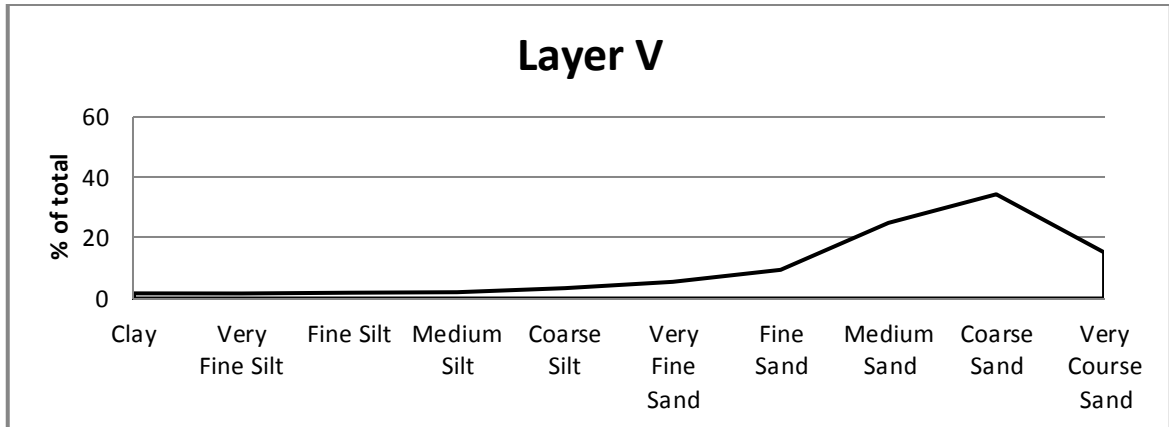


Figure 5.33 Particle size distribution for Layer V of XU-4. This may be somewhat inaccurate given the density of large coral and basalt clastics. In the field, this layer was indistinguishable from Layer V of XU-2 (above)

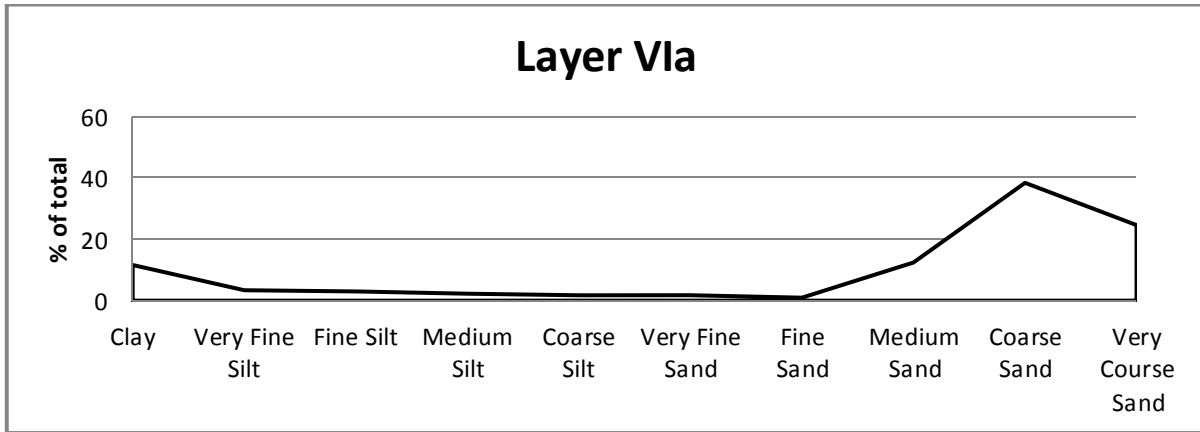


Figure 5.34 Particle size distribution for Layer VIa of XU-4

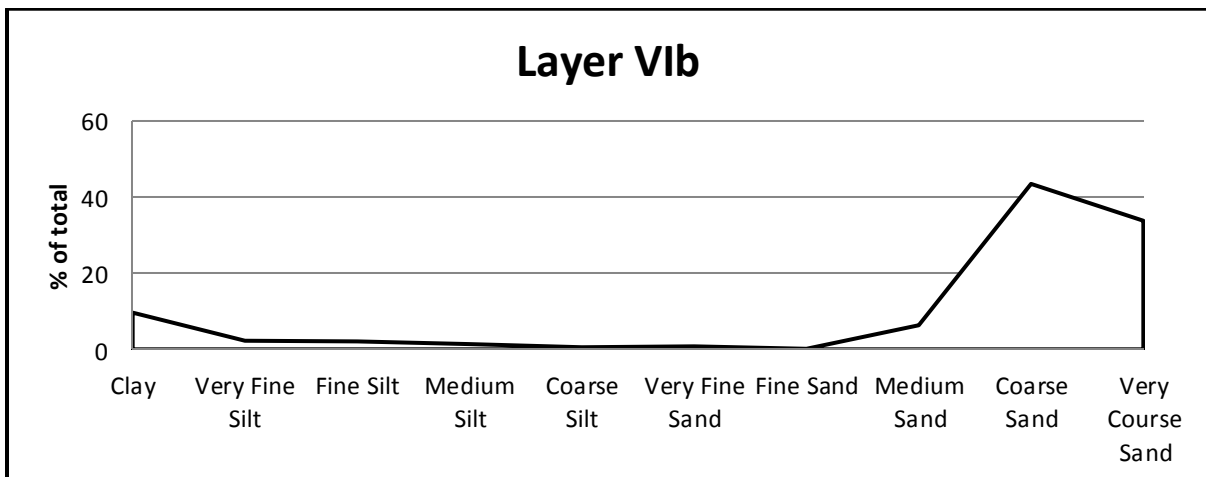


Figure 5.35 Particle size distribution for Layer VIb of XU-4

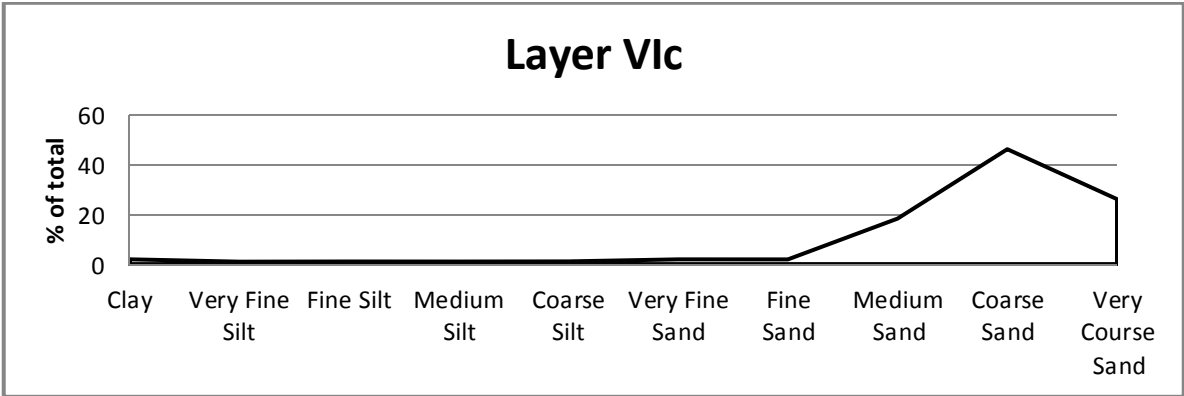


Figure 5.36 Particle size distribution for Layer VIc of XU-4

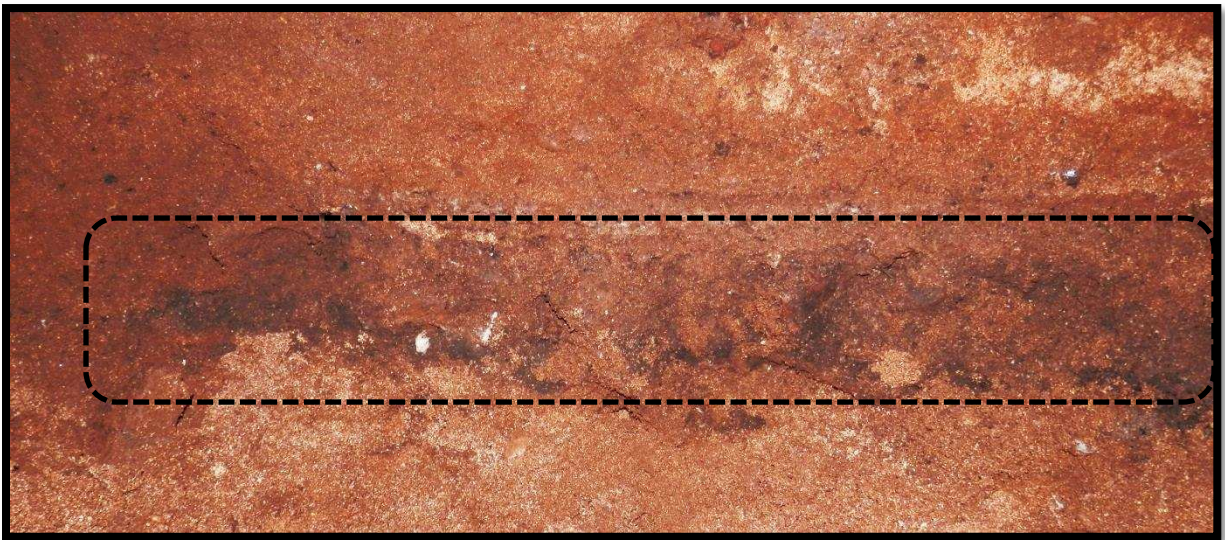


Figure 5.37 Thin combustion feature, Feature 9 (outlined by dotted line), at the bottom of XU-4. Notice the colour gradation below the feature

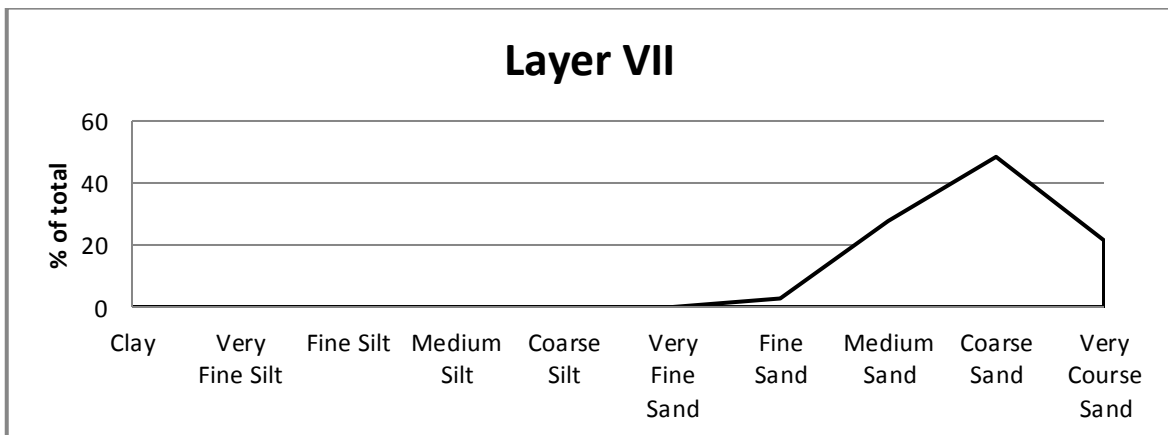


Figure 5.38 Particle size distribution for Layer VII of XU-4

Table 5.7 Summary of XU-4 strata

	Thickness	Colour	Texture	Structure	Clastics (percent of total matrix)	Cultural Material
I	35-45 cm	10 YR 3/3 (Dark brown)	Sand	Granular	5-10% sub-rounded coral and stone gravel; stone boulder	Historic
II	10-35 cm	5 YR 3/3 (Dark reddish brown)	Sandy Loam	Sub-angular blocky	5-10% sub-rounded coral and stone gravel; stone boulder	Historic
III	0-25 cm	10 YR 2/2 (Very dark brown)	Clay Loam	Sub-angular blocky	15-20% sub-rounded coral and stone gravel; stone boulder	Historic
IV	50-60 cm	5 YR 3/2 (Dark reddish brown)	Clay	Sub-angular blocky	20-30% sub-rounded to angular coral and stone gravel and cobbles	Prehistoric
V	30-50 cm	10 YR 2/2 (Very dark brown)	Clay Loam	Sub-angular blocky	10-15% sub-rounded coral and stone gravel and cobbles	Prehistoric
VI	100-145 cm	7.5 YR 3/4 (Dusky red)	Loamy Sand	Granular	10-15% sub-rounded to angular coral and stone gravel and cobbles	Prehistoric
VII	Uncertain	10 YR 7/3 (Pale brown)	Sand	Structureless	5-10% sub-rounded coral and stone gravel and cobbles; one coral boulder	Sterile

Table 5.8 Summary of prehistoric features identified in XU-4

No.	Function	Layer	Dimensions(cm) L, W, D	Profile Shape	Contents
Feature 7	Combustion	IV	>100x>60x15	Basin	FCR, charred tree root, eroded ceramics, human tibia (in vicinity)
Feature 8	Refuse Pit?	V	>100x80x>120	Basin	Basalt and coral cobbles, charcoal, lithics, pottery, fishhooks, bird and fish bone
Feature 9	Combustion	VI	85x>20x15	Shallow basin	FCR, charcoal, oxidised base
Feature 10	Garden Activity?	V	L15xD20 (in profile)	Tapered	Two stone cobbles
Feature 11	Pit?	V	L50xD40 (in profile)	Shallow Basin	Coral and basalt cobbles

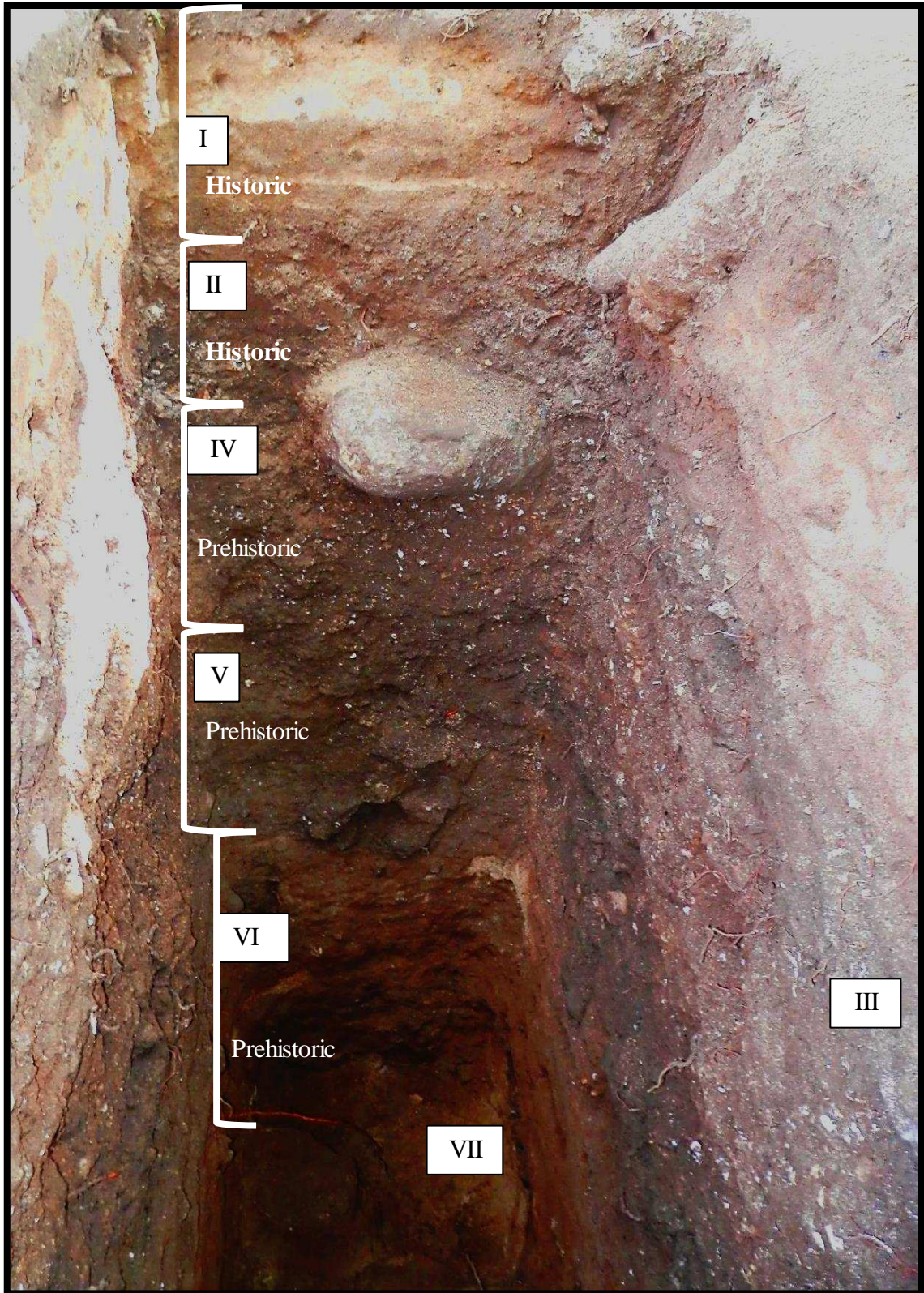


Figure 5.39 Western wall of XU-4. The unit is 1 m across and 3.3 m deep

Trench Excavations

The acquisition of a back-hoe after controlled excavation had been conducted enabled quick access to subsurface stratigraphic profiles (Fig. 5.40). These trenches were dug in three locations in place of controlled excavation units. Trench 1 and Trench 2 were dug to examine two additional areas of the village near the inland slopes. The location of Trench 3 was chosen to extend the very rough coastal-inland transect of subsurface excavation in the middle of the village. Below is a summary of the stratigraphy identified in these trenches, followed by an interpretation of that stratigraphy.

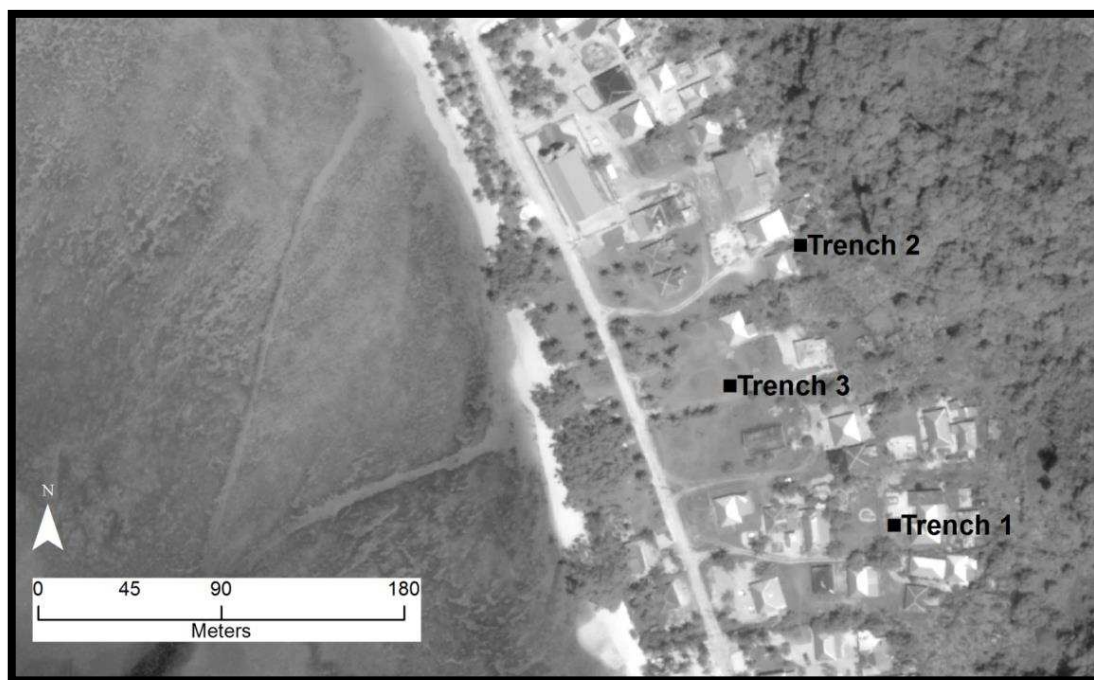


Figure 5.40 Location of trench excavations in Ofu Village

Trench 1

The first backhoe trench, which measured approximately 2 x 1.5 m, was dug south of all the controlled units, and was located atop an area naturally raised ~4.5 masl. Five layers were encountered reaching a depth of ca. 165 cmbs, and the trench was terminated within a possible C-Horizon or pseudo C-horizon (a terrigenous clay layer featuring a high density of saprolites and evidence of *in situ* weathering and soil formation) (Fig. 5.42). Charcoal was common in the trench profile and intact subsurface features were recorded. The layers closest to the surface were predominantly calcareous sand and coral, while those nearer the base were terrigenous clays with basalt inclusions.

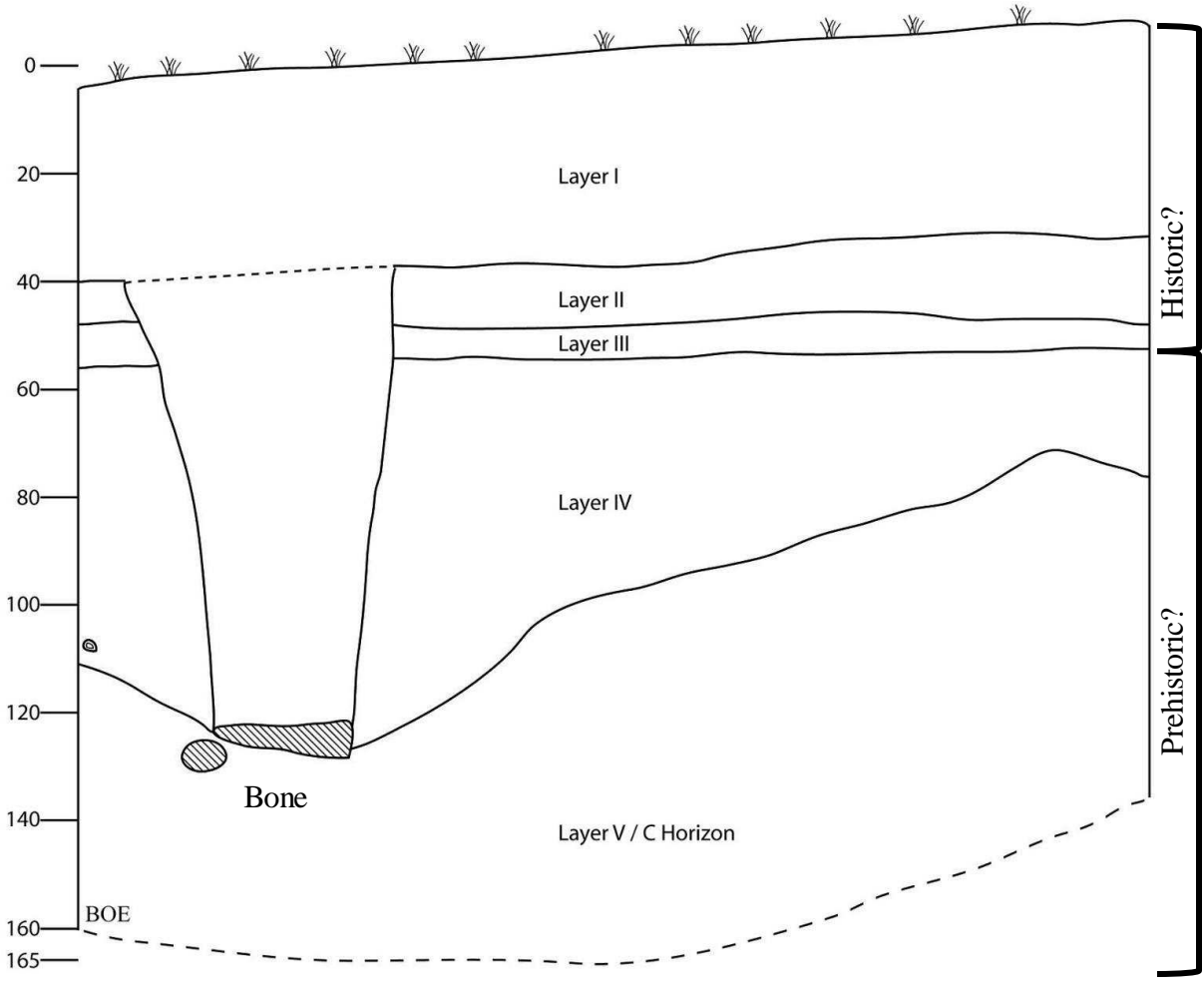


Figure 5.41 Profile of the west wall of Trench 1

Layer I was a 35-40 cm thick medium to coarse grained 10 YR 6/3 (Pale brown) structureless sand with few coral inclusions (less than 5 percent of the matrix). No cultural material was identified in the matrix (Fig. 5.42). The layer was heterogeneous, with sand lensing common. The transition to Layer II had an abrupt boundary with a wavy topography.

Layer II was a 10-15 cm thick loose sandy loam with a 10YR 4/2 hue (Dark grayish brown) and a granular structure (Fig. 5.43). Coral gravel was noted as constituting ~15-20 percent of the matrix. Some charcoal was also observed in profile. A pit feature was identified that measured 50 cm wide and 80 cm deep cut from within this layer through to Layer V. Bone was present near the bottom of this feature. The boundary with Layer III was abrupt with a wavy topography.

Layer III was a 5-10 cm thick coral gravel and pebble layer, which appears to represent a paving (*ili'ili*). No other inclusions and very little sediment were identified within the matrix, though some light coloured calcareous sand was noted. The large pit feature originating in Layer II continued. The boundary with Layer IV was abrupt with a smooth topography.

Layer IV was a 20-70 cm thick sub-angular blocky 10 YR 3/2 (Very dark grayish brown) clay loam with shell and coral inclusions (Fig. 5.44). These inclusions are estimated to constitute 20-25 percent of the matrix. Some medium mammal bone was identified in two locations in the west wall. No artefacts or other cultural material were noted, but the density of charcoal increased with depth. The pit feature that originated in Layer II continued and expanded within this layer. The boundary with Layer V was gradual with a wavy topography.

Layer V was a 5 YR 3/3 (Dark reddish brown) angular blocky clay with highly weathered sub-rounded to angular basalt inclusions (~15-20 percent of the matrix) (Fig. 5.45). The layer was markedly different than interpreted colluvial layers on the coastal flats or soils presently situated on the slopes. The basalt inclusions were in different stages of weathering, though most pieces were easily broken by hand and can be classified as saprolites. The matrix was very heterogeneous stemming from the differential breakdown of these saprolites, resulting in pockets of red and yellow clay indicative of oxidisation that suggests *in situ* soil development. Charcoal and coral were identified within the top ~10 cm of the layer, but evidence of cultural activity was non-existent below. The trench was terminated at 165 cmbs.

Summary and Interpretations. The stratigraphic sequence of Trench 1 was somewhat unique (Table 5.9). The area in which it was dug is slightly higher than the surrounding coastline, gently sloping seaward. The first layer was calcareous sand fill originating from the historic period, exhibiting a number of lenses indicative of multiple fill events. The second layer was darker sandy clay, which does not appear to be fill. With its richer organic content, it could mark a period of vegetation growth or garden activity. Along with the first two layers, the third layer appears to be historic in nature.

The fourth layer is a dark clay loam significantly different than clays on the slopes surrounding the coastline. A gradual boundary is present between Layer IV and V, which suggests some mixture of sediments. Like similar dark loam layers elsewhere on the coastline, this evidence is consistent with the deposit representing a garden soil (A_P horizon). Both Trench 1 and Trench 2 were unique in the nature of their basal layers, terrigenous clay layers with degrading parent material. The presence of such a basal layer in concurrence with a lack of marine derived sediments immediately on top of the layer implies that the area may never have been submerged for a sufficient amount of time to allow for the build-up of a calcareous sand deposit. Additionally, it is evidence that the area was always sufficiently elevated to preclude the deposition of marine sediments during storm events. An alternative explanation is that this is a pseudo C-horizon deposited on the coast during a landslide. Further testing should evaluate these alternatives.

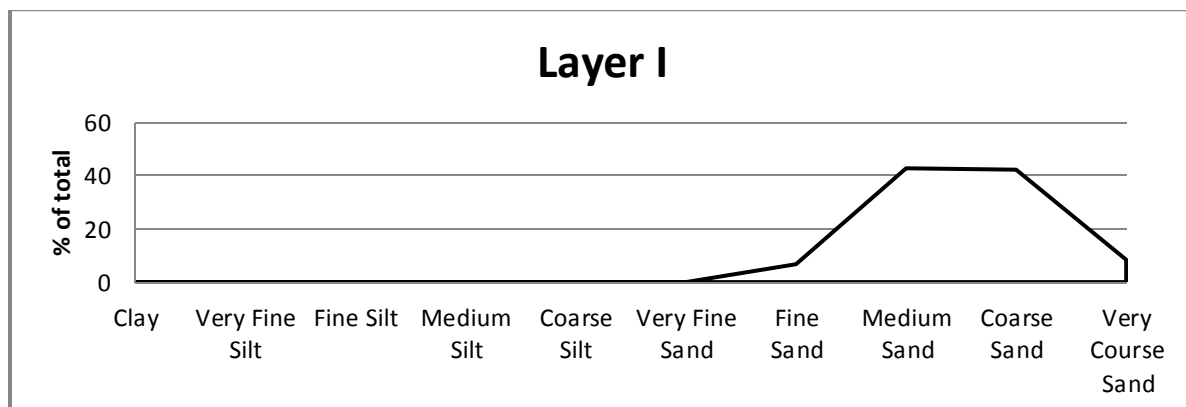


Figure 5.42 Particle size distribution for Layer I of Trench 1

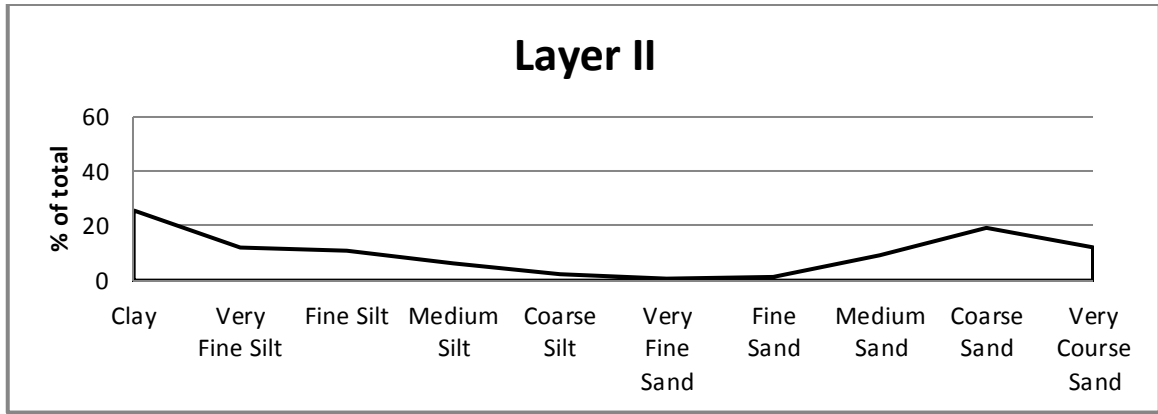


Figure 5.43 Particle size distribution for Layer II of Trench 1

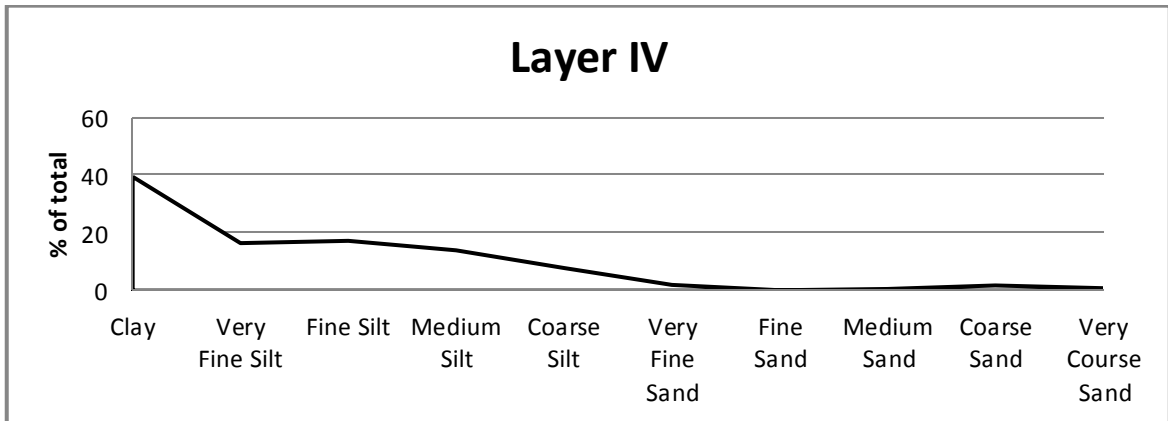


Figure 5.44 Particle size distribution for Layer IV of Trench 1

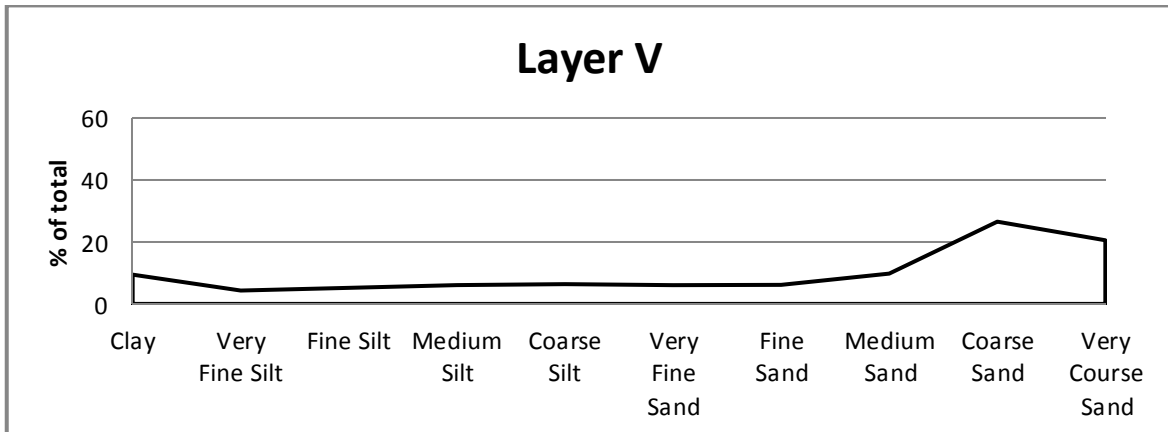


Figure 5.45 Particle size distribution for Layer V of Trench 1

Table 5.9 Summary of Trench 1 stratigraphy

	Thickness	Colour	Texture	Structure	Clastics (percent of total matrix)	Cultural Material
I	35-40 cm	10 YR 6/3 (Pale brown)	Sand	Structureless	<5% rounded to sub-rounded coral pebbles and gravel	Historic
II	10-15 cm	10 YR 4/2 (Dark grayish brown)	Sandy loam	Granular	15-20% sub-rounded coral gravel	Historic
III	5-10 cm	Coral gravel	Coral	Structureless	90-99% rounded to sub-rounded coral gravel	Historic
IV	20-70 cm	10 YR 3/2 (Very dark grayish brown)	Clay loam	Sub-angular blocky	20-25% sub-rounded coral and stone gravel	Uncertain
V	Uncertain	5 YR 3/3 (Dark reddish brown)	Clay	Angular blocky	15-20% sub-rounded to angular stone gravel and cobbles	Uncertain

Trench 2

Trench 2 was located to the north of the controlled unit transect and measured approximately 2 x 1.5 m. Similar to Trench 1, the area in which the trench was dug was naturally raised, though not as high as Trench 1. A possible C-Horizon or pseudo C-horizon formed the basal layer at 143 cmbs (Fig. 5.46, 5.47). No cultural materials were identified within the deposit, though intact features and charcoal flecking were noted.

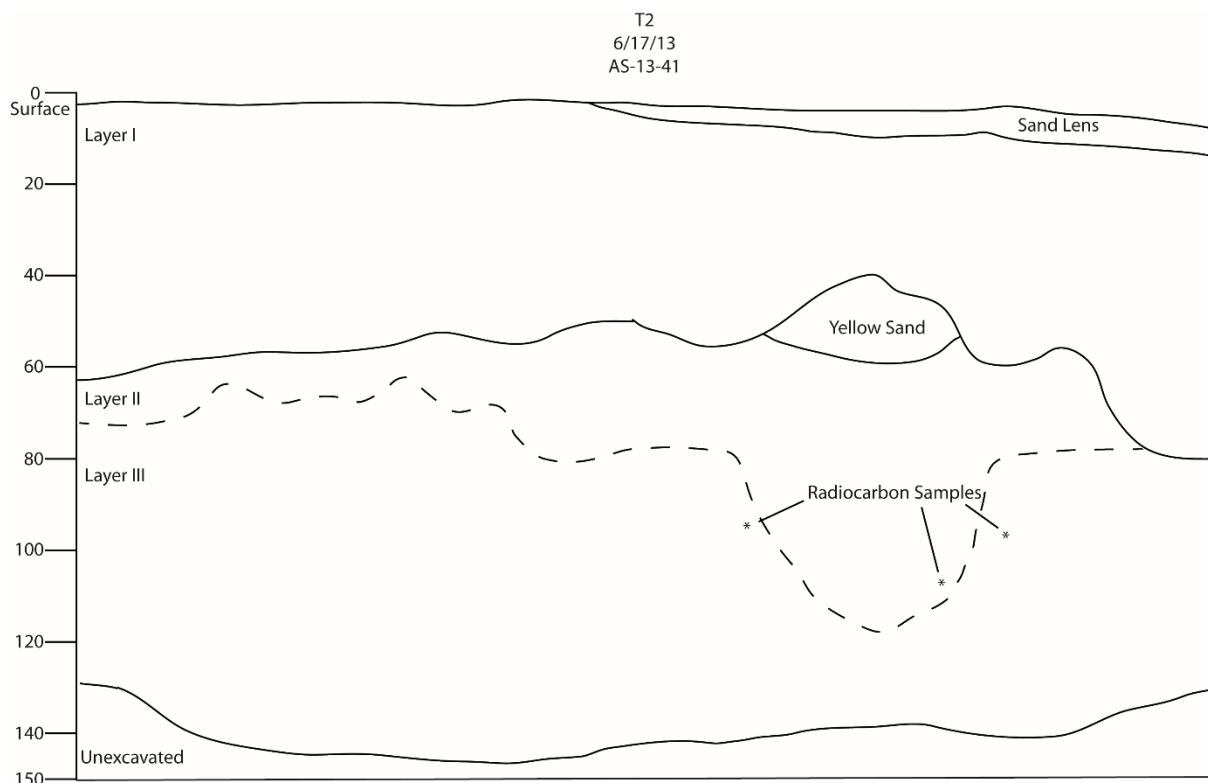


Figure 5.46 Profile of the east (inland) wall of Trench 2

Layer I was a 50-70 cm thick heterogeneous (in terms of colour and inclusions) sandy loam with a high density of coral inclusions (~20-25 percent of the matrix). Numerous soil lenses were identified that reflect several fill events by the present landowner. No cultural material was identified and charcoal density was low. The boundary with Layer II was abrupt and the topography was wavy.

Layer II was a 10-60 cm thick granular 10 YR 3/1 (Very dark gray) clay loam with sub-rounded coral gravel inclusions (15-20 percent of the matrix). The dark colour differentiated the terrigenous matrix of this layer from that of the surrounding slopes, suggesting an

increased organic content. No shell or cultural material was identified, but some charcoal was collected near the transition with Layer III. One of these charcoal samples was dated (Beta-372698, 2 σ AD 1695-1919). A rounded pit feature was identified exhibiting a matrix consistent with that of the surrounding layer (differentiation as a feature based on extension into the layer below). Outside of this feature, the boundary with Layer III was gradual with an irregular topography.

Layer III was a 5 YR 3/3 (Dark reddish brown) angular blocky clay with sub-rounded to angular basalt and coral gravel and cobbles (~10-15 percent of the matrix). The nature of the layer was similar to Layer V of Trench 1, but this layer exhibited basalt inclusions that were more heavily weathered. Coral was identified near the top of the layer, suggesting at least some mixture with above layers. No cultural material was identified in the wall profile. The unit was terminated at 145 cmbs.



Figure 5.47 Stratigraphy of Trench 2

Summary and Interpretations. Trench 2 displays a simple stratigraphic sequence (Table 5.10). Layer I was historic calcareous sand brought in by the present land owner to level the surface. Layer II was similar to Layer IV of Trench 1, in that it was a dark organic rich matrix that featured some mixture with Layer III. This evidence may imply that the layer is a buried garden soil (A_p horizon). Layer III is constituted by a matrix of terrigenous clay and degrading basalt. However, this layer exhibited fewer basalt inclusions relative to Layer V of Trench 1, and the basalt in this layer was more heavily weathered. The layer might represent either an intact C-horizon or one deposited during a landslide episode.

Trench 3

The final back-hoe trench measured 2 x 1.5 m and was dug seaward (west) of all units in the centre of the village. Eight layers were documented reaching a depth of 152 cmbs (Fig. 5.48). High densities of charcoal were found throughout, and an intact combustion feature was discovered near the termination point of the trench. No other cultural materials were noted, but the trench was terminated prior to reaching a sterile calcareous sand layer due to the presence of coral boulders interpreted by field workers as grave markers.

Layer I was a loose, 30-40 cm thick coarse grained structureless sand with a 10YR 5/3 (Brown) hue (Fig. 5.49). The layer exhibited significant soil lensing, and some sub-rounded coral gravel was identified that constituted less than 5 percent of the matrix. In profile, charcoal was rare. The boundary with Layer II was gradual with a smooth topography.

Layer II was a 15-30 cm thick 10 YR 3/1 (Very dark gray) sandy clay loam with a granular structure and some sub-rounded coral pebble and gravel inclusions (~10-15 percent of the matrix) (Fig. 5.50). Charcoal and shell were more common in this layer than in the previous one, and organic content increased. No artefacts were noted. The transition to Layer III had a gradual boundary and a wavy topography.

Layer III was a 30-40 cm thick 10 YR 3/4 (Dark yellowish brown) clay with a blocky structure (Fig. 5.51). The colour of the layer was similar to that of Layer IV of XU-2 and XU-4 and Layer VI of XU-1, exhibiting concentrated areas of charcoal flecking. Shell and coral inclusions were noted, though in lower densities than in Layer II (~5-10 percent of the matrix). Again, no cultural material was identified. The boundary with Layer IV was clear with a wavy topography.

Table 5.10 Summary of Trench 2 soil stratigraphy

	Thickness	Colour	Texture	Structure	Clastics (percent of total matrix)	Cultural Material
I	50-70 cm	Heterogeneous	Sand	Structureless to Granular	20-25% sub-rounded coral gravel	Historic
II	10-60 cm	10 YR 3/1 (Very dark gray)	Clay loam	Granular	15-20% sub-rounded coral gravel	Uncertain
III	Uncertain	5 YR 3/3 (Dark reddish brown)	Clay	Angular blocky	10-15% sub-rounded to angular coral and stone gravel and cobbles	Uncertain

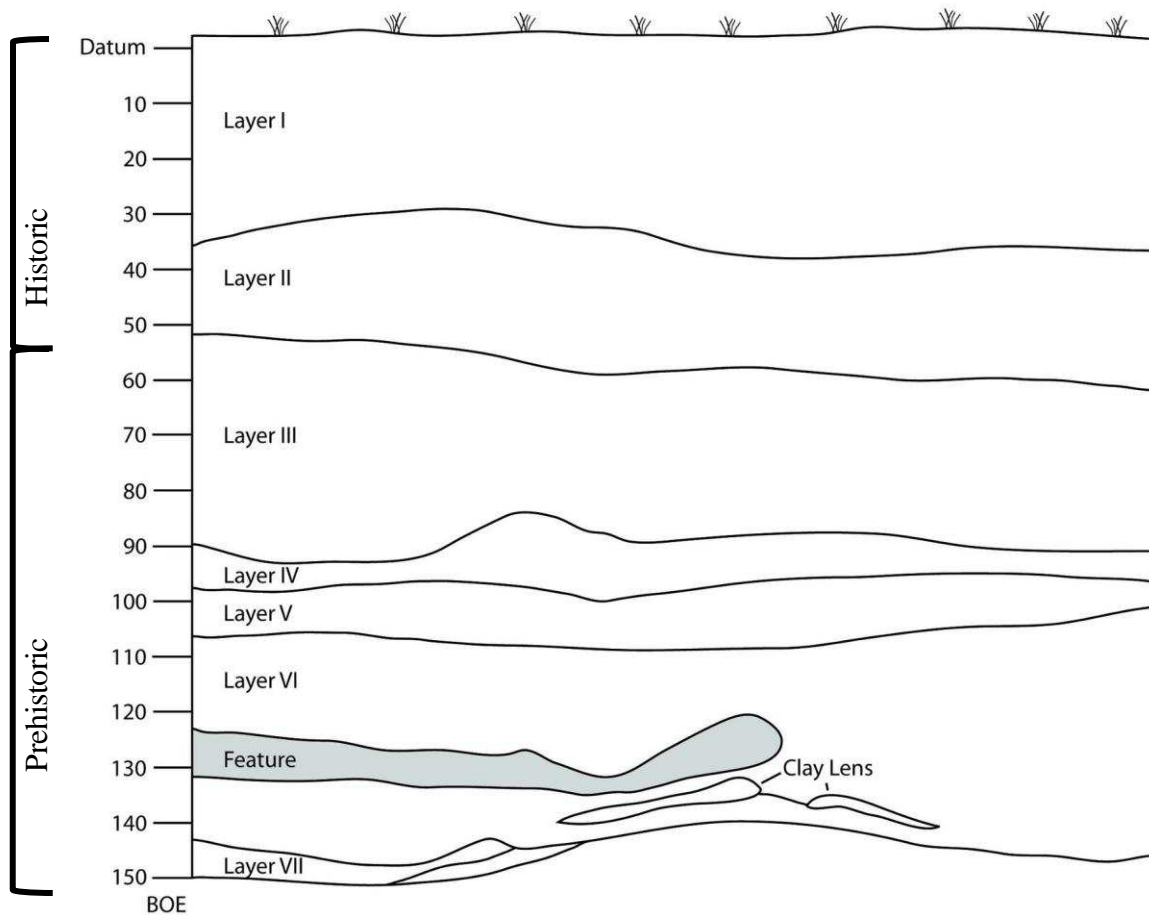


Figure 5.48 Profile of the south wall of Trench 3

Layer IV was a thin (5-10 cm thick) medium to coarse grained structureless sand with sub-rounded coral gravel inclusions and a 10YR 4/3 (Brown) hue (Fig. 5.52). The layer pinched out toward the inland side of the trench and was bounded on both the top and bottom by terrigenous clay. No cultural material was noted, with few coral, charcoal, and shell inclusions (less than 5 percent of the matrix). Similar to the top boundary with Layer III, the boundary with Layer V was abrupt with a wavy topography.

Layer V had the same characteristics as Layer III, though was thinner (5-15 cm thick). Like Layer III, some shell and coral, constituting less than 5 percent of the matrix, was noted along with areas of concentrated charcoal flecking. The boundary with Layer VI had a smooth topography and a clear transition.

Layer VI was a 30-40 cm thick 10 YR 4/2 (Dark grayish brown) medium to coarse grained loamy sand with a granular structure and sub-rounded coral gravel and shell inclusions (less than 5 percent of the total matrix) (Fig. 5.53). A combustion feature was identified 10 cm above the lower boundary of the layer that measured 105 cm long and 10 cm deep in profile.

The feature was a shallow basin with ashy inclusions and some fire altered basalt. One charcoal sample was collected from just below the feature and dated (Beta-366731, 2 σ AD 1299-1413). This feature was similar to others documented in XU-1 and XU-4. Thin (>5 cm) terrigenous clay lenses, exhibiting similar characteristics as Layers V and III but with fewer inclusions, were uncovered beneath the combustion feature. A coral boulder was situated at the interface between Layer VI and VII, encountered in the floor to the west of the combustion feature. The boundary with Layer VII was gradual with a wavy topography.

Layer VII was a medium to coarse grained structureless sand with a 10 YR 5/3 (Brown) hue (Fig. 5.54). Small pieces of charcoal were noted in the matrix as well as some sub-rounded coral gravel (less than 5 percent of the matrix). Only a small section of the layer was uncovered beneath the combustion feature identified within Layer VI, as coral boulders were found situated in the western half of the trench. These were thought to mark a grave by field workers and excavation was terminated at 150 cmbs.

Summary and Interpretations. The stratigraphic sequence of Trench 3 was more similar to XU-1 than any other sequence (Table 5.11, 5.12). Layer I appears to be fill used to level the surface for modern house construction. Layer II is similar to Layer III of XU-2 and XU-4, Layer IV of Trench 1, and Layer II of Trench 2, in terms of its dark colour and loamy texture. Because of these similarities, the layer may be a buried garden soil (A_p horizon). Layers III and Layer V were the only terrigenous clay deposits in the sequence, separated by a layer of medium to coarse grained sand that is similar in colour and texture to beach or dune sand. I interpret the clay layers as colluvium forming tongues thinning out seawards (cf. Kirch 1993c; Kirch and Hunt 1993a). Layer IV, between these clay layers, is interpreted to represent a storm surge, though no large coral clastics were identified in profile. An intact cultural feature was situated in the loamy sand Layer VI, which possessed a matrix similar to Layer VII in XU-1. The bottom layer was not fully exposed, and the exact nature of the layer is unclear. Similarities of the particle size distributions between Layer VII and the basal sand layer of XU-3 hints that Layer VII might represent, or be close to, a similar culturally sterile layer. This is also suggested by the presence of coral boulders. Instead of marking a grave, these may be remnants of a high energy depositional environment. Altogether, a sequence of increased terrigenous deposition over time is indicated, though calcareous sand sediments continued to be deposited through the sequence, possibly by storm activity.

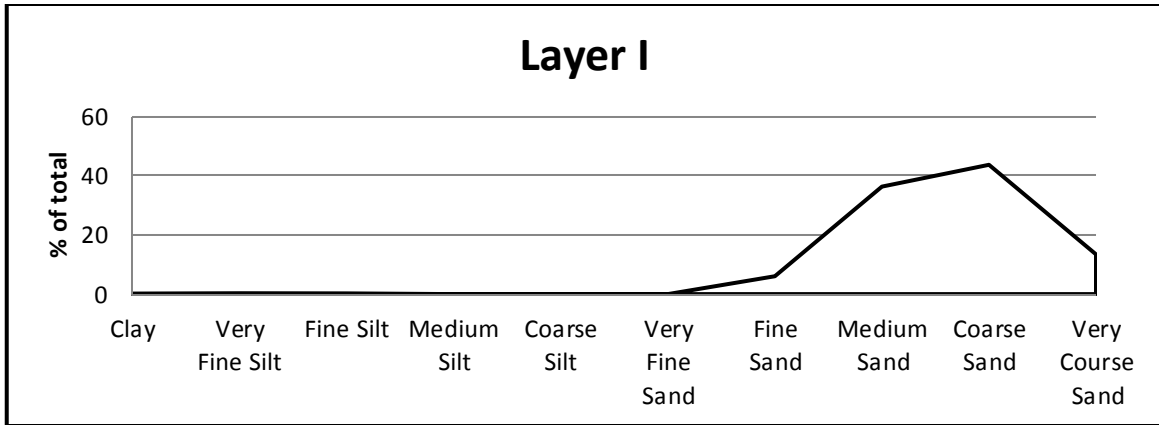


Figure 5.49 Particle size distribution for Layer I of Trench 3

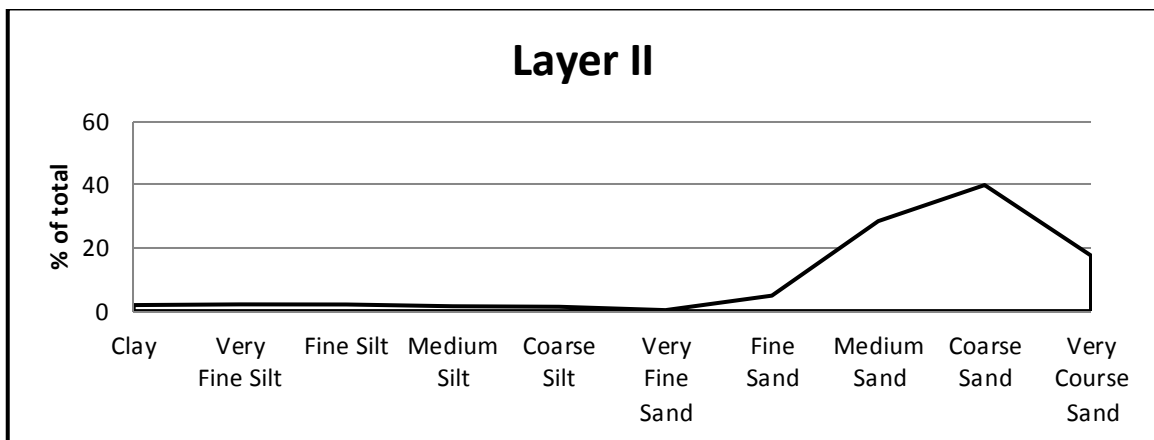


Figure 5.50 Particle size distribution for Layer II of Trench 3

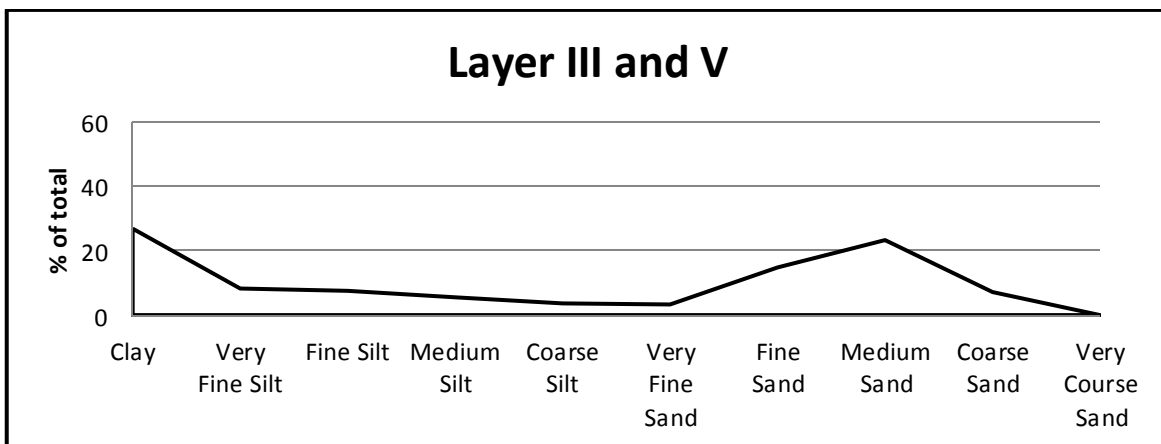


Figure 5.51 Particle size distribution for Layer III and V of Trench 3

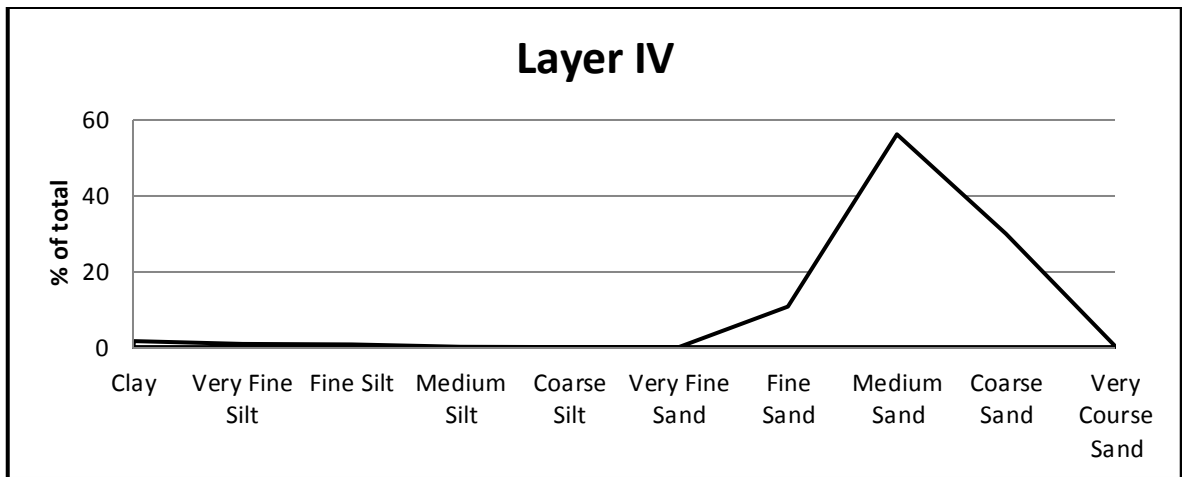


Figure 5.52 Particle size distribution for Layer IV of Trench 3

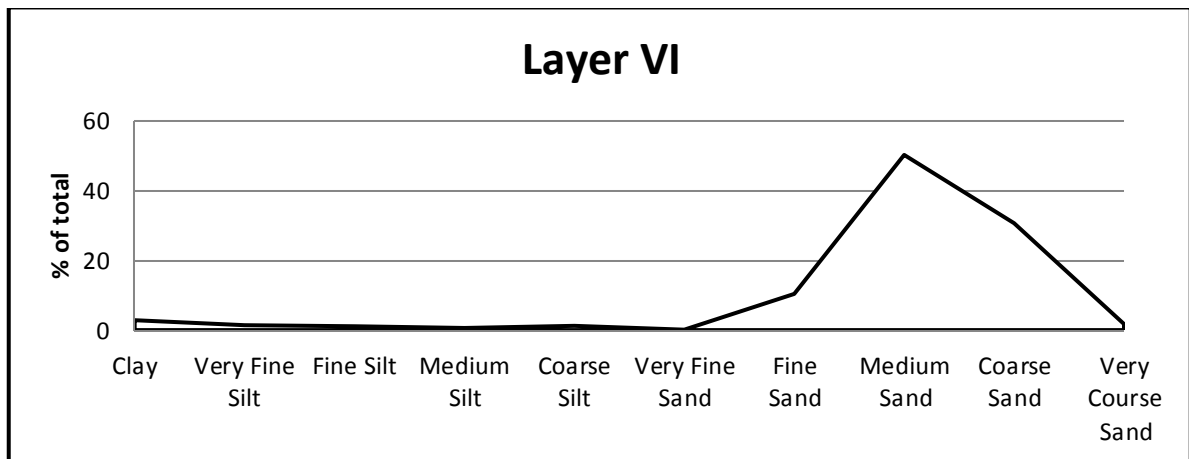


Figure 5.53 Particle size distribution for Layer VI of Trench 3

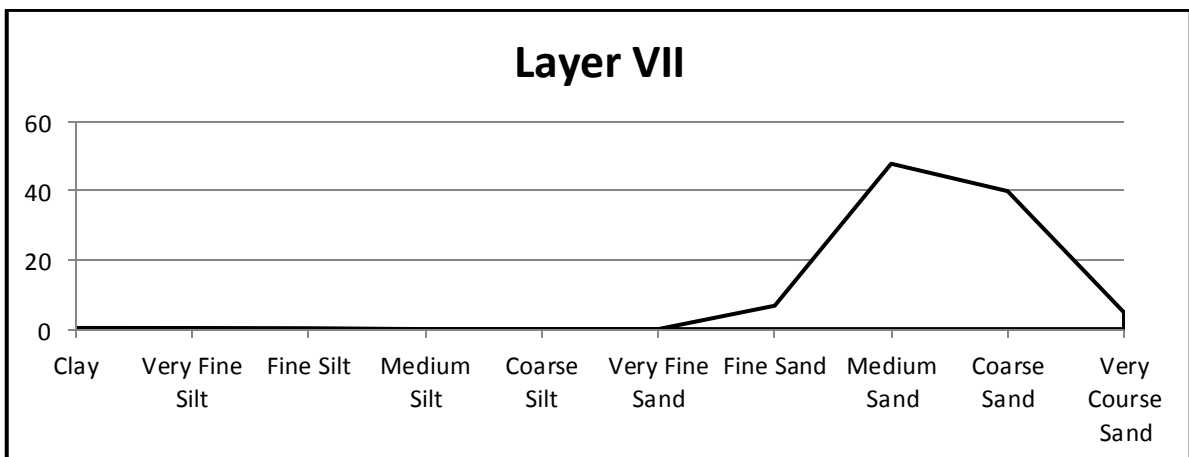


Figure 5.54 Particle size distribution for Layer VII of Trench 3

Table 5.11 Summary of the Trench 3 soil stratigraphy

	Thickness	Colour	Texture	Structure	Clastics (percent of total matrix)	Cultural Material
I	30-40 cm	10 YR 5/3 (Brown)	Sand	Structureless	<5% sub-rounded coral gravel	Historic
II	15-30 cm	10 YR 3/1 (Very dark gray)	Clay loam	Granular	10-15% sub-rounded coral pebbles and gravel	Historic
III	30-40 cm	10 YR 3/4 (Dark yellowish brown)	Clay	Blocky	5-10% sub-rounded coral gravel	Uncertain
IV	5-10 cm	10 YR 4/3 (Brown)	Sand	Structureless	<5% sub-rounded coral gravel	Uncertain
V	5-15 cm	10 YR 3/4 (Dark yellowish brown)	Clay	Blocky	<5% sub-rounded coral gravel	Uncertain
VI	30-40 cm	10 YR 4/2 (Dark grayish brown)	Loamy sand	Granular	<5% sub-rounded coral pebbles and gravel	Prehistoric
VII	Uncertain	10 YR 5/3 (Brown)	Sand	Structureless	<5% sub-rounded coral gravel	Prehistoric

Table 5.12 Summary of the prehistoric feature identified in Trench 3

No.	Function	Layer	Dimensions (cm) L, W, Depth	Profile Shape	Contents
NA	Combustion	VI	>105x10 (in profile)	Shallow basin	FCR, charcoal, ashy base

Chronology

Samples for dating were collected from all controlled units and backhoe trenches. Those sent to Beta Analytic Inc. to be dated were identified by Jennifer Huebert to ensure the dating of short-lived samples. However, short-lived species could not be found in the charcoal recovered from some deposits. Charcoal of economic plants was used in these circumstances with the recognition that some inbuilt age could influence the determinations. Because this project sought to examine the chronology of geomorphological change on the coast as well, an extensive sampling approach was selected where eight charcoal samples were dated from six separate units. All conventional radiocarbon determinations were calibrated via OxCal v.4.2 (Bronk Ramsey 2013) utilising the IntCal 2013 calibration curve (Reimer et al. 2013). The following is a description and discussion of the radiocarbon determinations from the coast (summarised in Fig. 5.55, 5.56; Table 5.13).

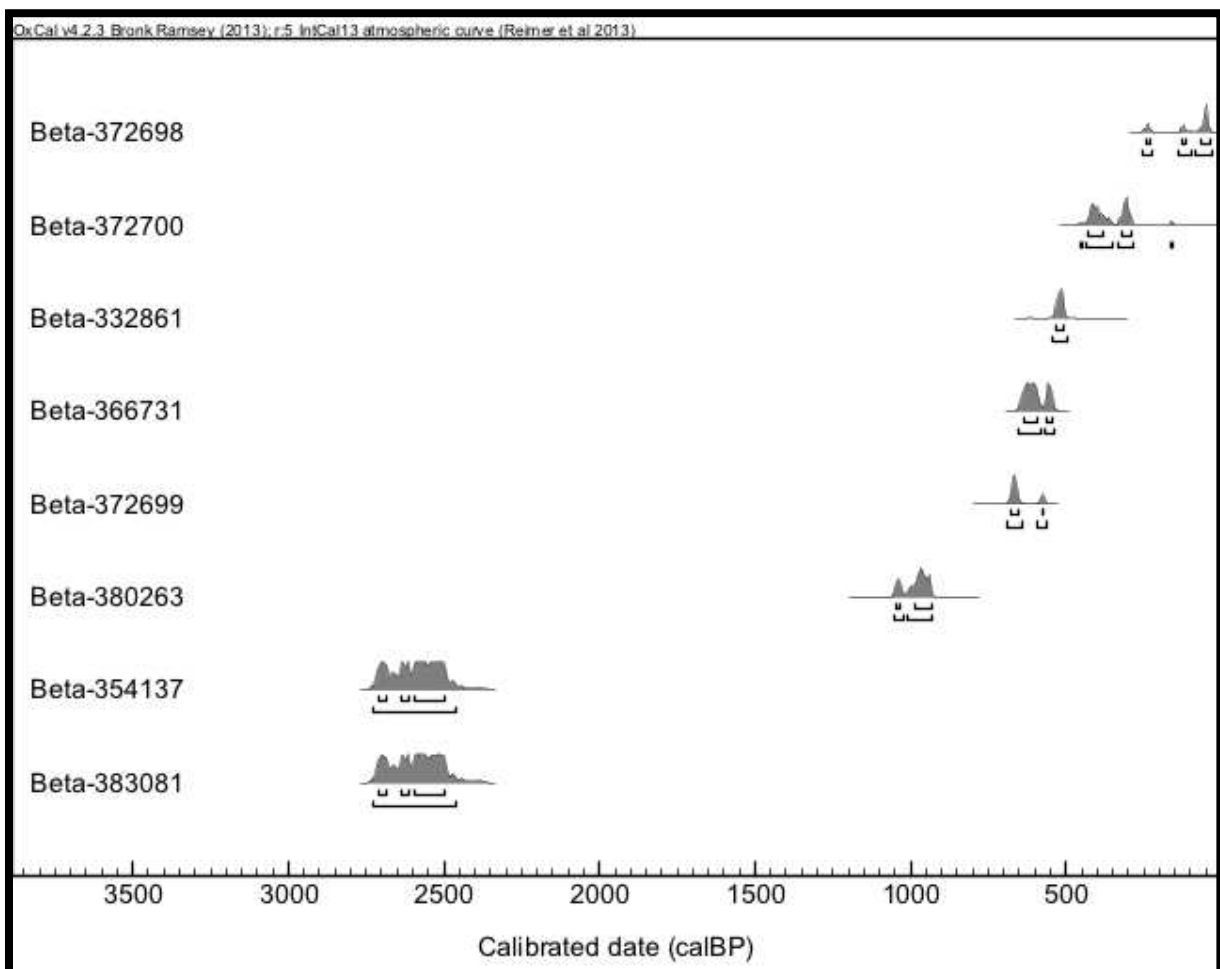


Figure 5.55 Calibration of dates from Ofu Village

Table 5.13 Summary information for radiocarbon dates in Ofu Village (Beta Analytic Inc.)

Sample Number	Unit	Layer	Level	Depth	Material	$\delta^{13}C$	Conventional Date	Calendar Dates
Beta-332861	XU-1	VII	22	206 BD	Small Diameter wood	-28.3	480±30	AD 1408-1452
Beta-380263	XU-2	VI	*	190 BD	<i>Cocos nucifera</i> wood	-25.8	1070±30	AD 895-1021
Beta-372699	XU-3	XI	5	174 BD	Rubiaceae, cf. <i>Tarenna</i>	-23.5	700±30	AD 1261-1387
Beta-354137	XU-4	VI	12	301 BD	<i>Cocos nucifera</i> endocarp	-23.0	2490±30	BC 781-511
Beta-383081	XU-4	VI	6	226 BD	<i>Cocos nucifera</i> endocarp	-23.4	2490±30	BC 781-511
Beta-372700	XU-4	IV	*	120 BD	Unidentified small tree root	-26.1	280±30	AD 1498-1795
Beta-372698	Trench 2	II	*	93 BS	<i>Cocos nucifera</i> wood	-25.5	30±30	AD 1695-1919
Beta-366731	Trench 3	VI	*	133 BS	<i>Artocarpus altilis</i> wood	-24.8	590±30	AD 1299-1413



Figure 5.56 Distribution of dated deposits in Ofu Village

Beta-332861 (XU-1, small diameter wood) 480 ± 30 (2σ AD 1408-1452)

This sample was a single piece of small diameter unidentified wood collected from the transition between Layer VI and VII in XU-1. The charcoal was located within the layer matrix, but given its proximity to an intact combustion feature it may stem from rake out of that feature (Feature 8). The sample is influenced by minimal inbuilt age since small diameter woods (twig or a small tree) are short-lived. The sample is interpreted to date prior to the onset of colluvial deposition in the area (Layer VI XU-1).

Beta-380263 (XU-2, *Cocos nucifera* wood) 1070 ± 30 (2σ AD 895-1021)

This sample was a single piece of coconut wood taken from the wall within Layer VI of XU-2, very close to the transition with Layer V. Coconut trees can live up to a century (Allen and Huebert 2014), and an inbuilt age effect cannot be ruled out. This sample is interpreted to date an event at the top of Layer VI, immediately prior to the deposition of Layer V (garden soil). Given the stratigraphic similarities between of XU-2 and XU-4, this determination is also interpreted to date the top of Layer VIa in XU-4.

Beta-372699 (XU-3, Rubiaceae, cf. *Tarennia*) 700±30 (2σ AD 1261-1387)

This sample was a single piece of wood from a species of the Rubiaceae family, perhaps in the *Tarennia* genus, collected from Layer XI of XU-3. Trees in the Rubiaceae family are small to medium sized and do not live more than a few decades (J. Huebert per. comm. 2014), restricting inbuilt age. This sample is interpreted to date the deposition of Layer XI; the first cultural use of this area or activity shortly thereafter.

Beta-354137 (XU-4, *Cocos nucifera* endocarp) 2490±30 (2σ 781-511 BC)

This sample was a single piece of coconut endocarp collected from within the matrix of Layer IVc near the base of XU-4. Coconut endocarp is a short lived material and inbuilt age is minimal. The sample is interpreted to date the deposition of Layer IVc, the layer atop a culturally sterile deposit. Therefore, this sample dates, or dates slightly later than, initial settlement of the area.

Beta-383081 (XU-4, *Cocos nucifera* endocarp) 2490±30 (2σ 781-511 BC)

This sample was a single piece of coconut endocarp from near the top of Layer VIc, 226 cmbd of XU-4. Coconut endocarp is a short-lived material, and inbuilt age is minimal. The determination is indistinguishable from the other sample from this layer, hinting that the lower determination dates somewhat earlier. These two determinations suggest that either the deposition of Layer VIc was rapid, instantaneous in radiocarbon terms, or that there was sediment movement in the layer. This determination is interpreted to date the top of Layer VIc.

Beta-372700 (XU-4, small or medium tree root of an unidentified species) 280±30 (2σ AD 1498-1795)

This sample was a single piece of charred tree root collected from within Layer IV of XU-4 at 120 cmbd. The tree root was from an unidentified species, but the size of the root, small to medium, suggests that inbuilt age would be modest (J. Huebert per. comm.). This determination is the only one taken from within, and not below, a layer of colluvium.

Beta-372698 (Trench 2, *Cocos nucifera* wood) 30±30 (2σ AD 1695-1919)

This sample was a single piece of coconut wood from the bottom of Layer II of Trench 2 at 93 cmbs. Coconut trees can live for up to a century (Allen and Huebert 2014),

and inbuilt age cannot be ruled out. The nature of the calibration curve at this period creates multiple intercepts within both the historic and prehistoric period. No restrictions can be made on the date range as this area is known to have been utilised through the prehistoric and modern period. No material culture was identified in the deposit that could restrict the range either. This determination dates the deposition of Layer II of Trench 2 (possible garden soil).

Beta-366731 (Trench 3, *Artocarpus altilis* wood) 590±30 (2σ AD 1299-1413)

This was a determination on a single piece of *Artocarpus* wood collected from just above the interface between Layers VI and VII in Trench 3. *Artocarpus* can live several decades (Allen and Huebert 2014), so inbuilt age cannot be ruled out. This determination is interpreted to date prior to the beginning of substantial terrigenous deposition, which resulted in the formation of Layers III and V. The sample may also date the initial use of the area atop sterile sand based on similarities between the particle size distribution of XU-3 and Layer VII of this trench.

Summary

Charcoal from Layer VI of XU-2 and XU-4 are the only samples that dated prior to the last 800 years (n = 3) (Figs. 5.57, 5.58). Layer VI in XU-4 was the archaeologically most productive deposit found on the west coast, yielding large faunal and artefact assemblages, specifically pottery and shellfish. The base of Layer VIc in XU-4 dates to the beginning of the Samoan cultural sequence (2σ BC 781-511), while the top dates to the end of the 1st millennium AD if Layer VI of XU-2 is similar to Layer VIa of XU-4 (2σ AD 895-1021). It is after this point that dark clay loam layers formed in XU-2 and XU-4. All other samples dated to the last 800 years (n = 5). Initial human use in all units seaward of XU-2 dated to the 13th century AD or later (2σ AD 1261-1387, AD 1299-1413, AD 1408-1452), and colluvial layers were then deposited as early as the 15th century AD (2σ AD 1498-1795). Only a single radiocarbon determination was taken from one of these layers of colluvium, but determinations from immediately below these layers in XU-1, XU-3, and Trench 3 are consistent with terrigenous deposition in the 15th century AD or later. This implies that the deposition of colluvium was spatially extensive. Dark loam soils are found above these layers of colluvium in multiple units, and one of these was dated to the 18th century AD or later (2σ AD 1695-1919).

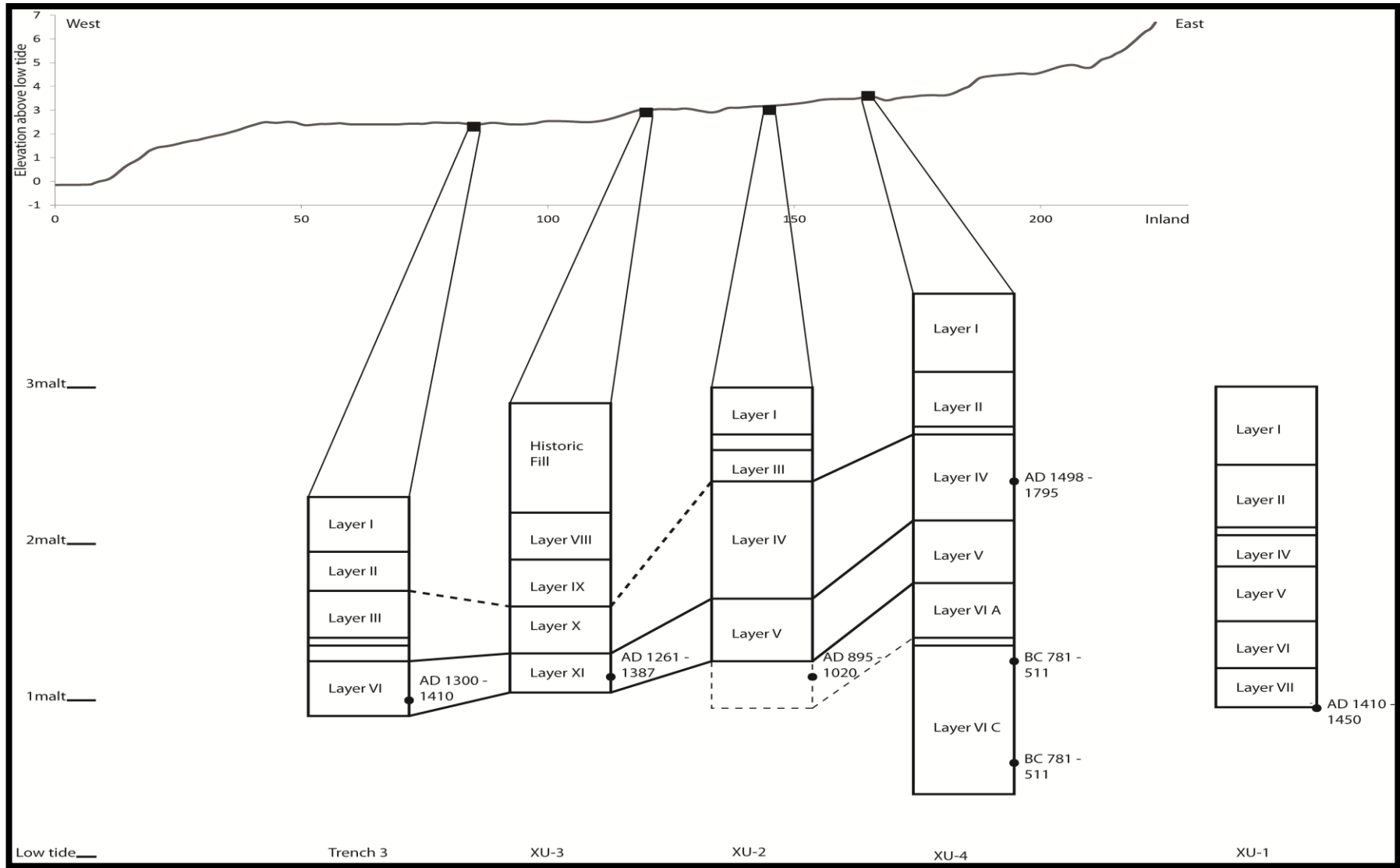


Figure 5.57 Proposed stratigraphic relationships between subsurface units in the centre of Ofu Village. Less certain relationships are made with dashed lines. XU-2 was terminated prior to the exposure of a sterile sand layer and Layer VI likely extends deeper than shown in this drawing

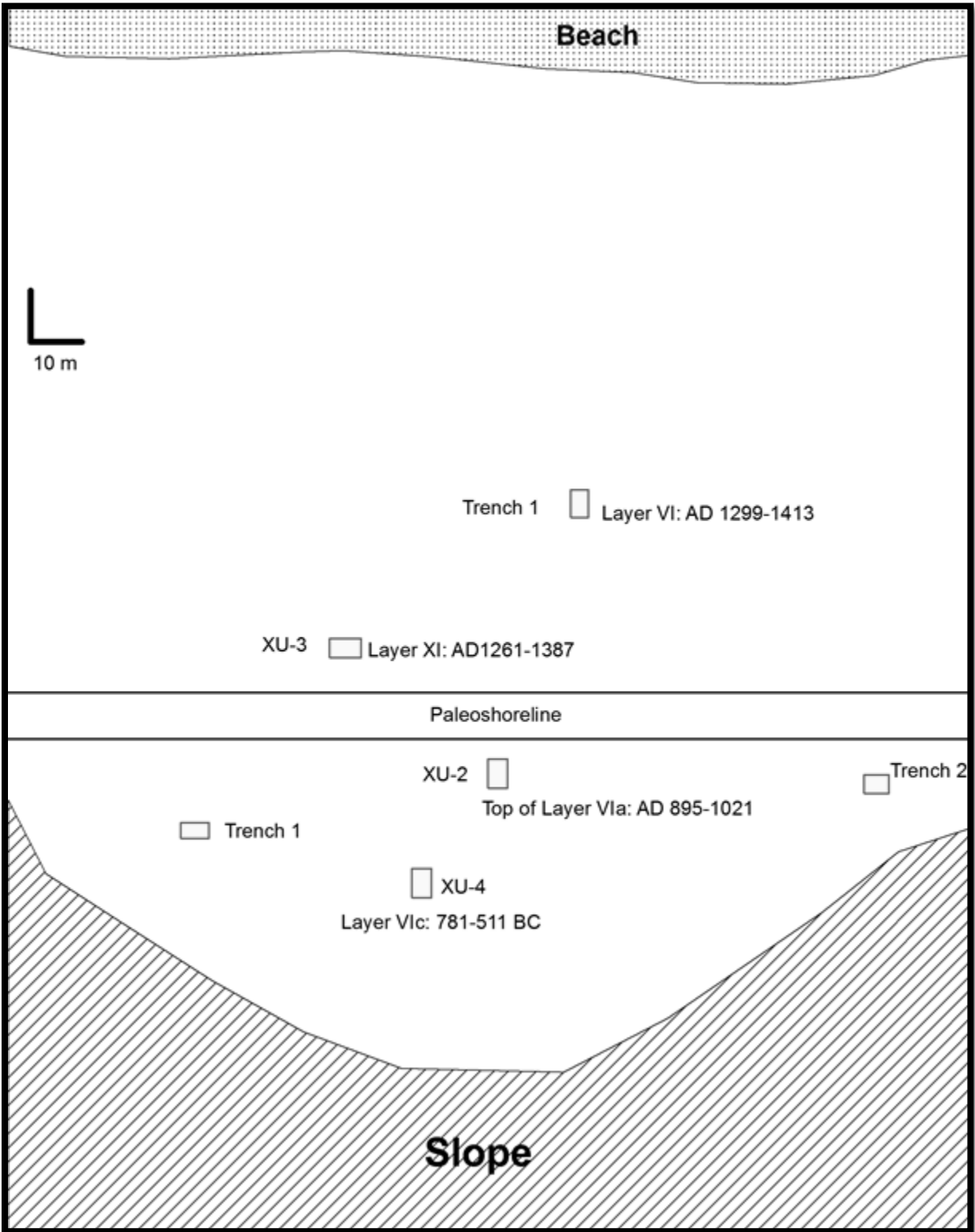


Figure 5.58 Schematic representation of the middle of Ofu Village and dated deposits. Given these dates, this figure also includes an approximation of a paleoshoreline

Discussion: Landscape Evolution and Settlement in Ofu Village

This chapter has presented the results of excavation conducted on the western coastal flat of Ofu. Four controlled units and three backhoe trenches were dug as part of this study. Multiple stratigraphic layers were identified in each unit or trench that, together, spanned the entire cultural sequence of the island. Interpretations of local geomorphological changes were presented for each unit in the previous sections. In this section, these interpretations will be synthesised with the above chronology to create a sequence of geomorphological change.

Based on the distribution of early deposits (see Fig. 5.58), only a small coastal flat had formed abutting the interior slopes at the time of human settlement. Land suitable for initial settlement included the area around XU-2, inferred from stratigraphic similarities between XU-2 and XU-4. That the basal cultural layer of XU-3 is dated to the 13th century AD indicates that the shoreline was somewhere between XU-3 and XU-2 at initial colonisation. The fact that two samples dated from Layer VIc are indistinguishable suggests that the formation of Layer VIc was probably rapid (Beta-354137, -383081; 2σ 781-511 BC). The deposition of calcareous sand implies that the reef adjacent to the coastline was actively eroding during this time. Based on the continued deposition of calcareous sand in Layer VI of XU-4 and XU-2, aggradation of the coastal flats and the formation of a beach ridge continued until the end of the 1st millennium AD (Layer VI of XU-2; 2σ AD 895-1021). The rate of calcareous sand deposition is unlikely to have been constant, and might have been declining by Layer VIa in XU-4 and Layer VI in XU-2, which may be evidence of beach ridge stabilisation.

The terrigenous component of the matrix of XU-4 increased from Layer VIc to VIa, accompanied by an increase in charcoal. I assert that this is evidence of erosion that occurred after the interior slopes inland of these units were cleared of vegetation. This clearance appears to have been done to create garden space given the lack of evidence of permanent residential occupation in the interior unit the 2nd millennium AD (next chapter) and the extreme rarity of natural fires. The rate of deposition is unknown, but it was not rapid given the length of time apparently represented by Layers VIb and VIa. The deposition of calcareous sediments in XU-4 and XU-2 decreased at the transition between Layers V and VI, with a large portion of the matrix of Layer V (XU-2 and XU-4) constituted by terrigenous clay. This decrease in the deposition of marine derived sediments is most plausibly explained by the progradation of the shoreline, the source of marine sediments. The exact timing of

landscape evolution is somewhat imprecise because the deposition of calcareous sediments likely declined in Layer VIa and VIb of XU-4 as well, which might represent the formation of a stable beach ridge. It can be posited, though, that the transition between Layer V and Layer VI of XU-2, which dates to the end of the 1st millennium AD (Beta-380263; 2 σ AD 895-1021), represents a *minimum* date for marine regression and coastal progradation.

The marked similarities between the dark organically enriched clay loam Layer V (XU-2 and XU-4) and anthropogenic soils identified elsewhere in the region (Kirch 1988; Kirch and Yen 1982) supports the idea that garden activity occurred in the area at the end of the 1st millennium AD or later (after Beta-380263; 2 σ AD 895-1021). The mixing of past occupation refuse from Layer VI with terrigenous sediments created a productive environment that could drain easily because of the presence of sub-rounded coral gravel. Whether these additives were the result of intentional human action or not is unknown. The formation of these layers is also modest evidence of relative geomorphological stability in back beach areas, in the sense that garden activity and organic matter build-up was occurring.

The timing of initial land use seaward of XU-2, which does not occur until at least the 13th century AD (Beta-372699, 2 σ AD 1261-1387), further supports a process of shoreline progradation. Dated deposits seaward of XU-2 is evidence that shows a process of progradation and aggradation of the coastal flats that continued into the beginning of the 2nd millennium AD (Beta-332861, 2 σ AD 1405-1452; Beta-366731, 2 σ AD 1299-1413) (see Fig. 5.58). The chronological consistency in which the land seaward of XU-2 in Ofu Village was settled is evidence of a progradation process that made available a wide stretch of land over a relatively short temporal span (~200 years). Substantial deposition recorded within the last 500-600 years demonstrates continued coastal instability. Multiple culturally sterile calcareous sand layers have been noted (Layer IV of Trench 1, Layer III and V of XU-1), and may be evidence of high energy storm deposition. Significant terrigenous deposition occurred beginning in the 15th century AD or later, which created tongues of colluvium thinning seaward (Layers III and V in Trench 3, Layer VI in XU-1, Layer IV in XU-2 and XU-4, and Layer X in XU-3). These deposits display high densities of particulate charcoal, a characteristic of deposits eroded from the interior slopes as a result of vegetation clearance. Only one of these layers was dated (Beta-372700, 2 σ AD 1498-1795), but two other colluvium layers lie atop deposits that date to the early 15th century AD or before (Beta-332861, 2 σ AD 1405-1452; Beta-366731, 2 σ AD 1299-1413). This pattern indicates the relative consistency of the timing of prehistoric terrigenous deposition across much of the

western coastline. After the deposition of colluvium, dark clay loam layers formed in the late 17th century or later (Layer III of XU-2 and XU-4; Layer IV of Trench 1; Layer II of Trench 2, and Layer II of Trench 3) (Beta-372698, 2 σ AD 1695-1919). Like Layer V of XU-2 and XU-4, the dark colour, thickness, evidence of admixture with lower layers, and lack of cultural material suggests that these layers represent garden soils.

Ofu Village, To'aga, and the Morphodynamic Model

A similar sequence of stratigraphic change to that documented above for Ofu Village has been recorded in all archaeological deposits across the coastal flats (Clark 2011; Kirch and Hunt 1993b). This sequence is characterised by a trend from sand to clay loams; or, from admixture of basaltic and calcareous sand to higher percentages of clay and silt particles of terrigenous origin. These transitions are part of a morphodynamic model developed at To'aga (Kirch 1993d). This morphodynamic model can now be evaluated and modified.

Coastal evolution on Ofu can be partially linked to region-wide sea level fluctuations during the Holocene (Dickinson 2001, 2003, 2009). The coastal flats of Ofu would not have formed before 5,000 years ago, as rising sea levels abutted the island's volcanic mass (Kirch 1993d:38; Stice and McCoy 1969). The stabilisation and subsequent drawdown of sea level at the peak of the mid-Holocene highstand allowed for the formation of narrow coastal flats, and all early cultural deposits have been identified on culturally sterile sands that represent these coastal flats (Clark 2011, 2013; Kirch and Hunt 1993a; Ofu Village XU-4). Calcareous sand sediments continued to be deposited on these narrow coastal flats as sea level fell and wave action eroded paleoreef formed during highstand conditions (Kirch 1993d:38-39; this project, XU-4). Kirch (1993d) also argues that Ofu was subsiding, which slowed or completely restricted the seaward expansion of the shoreline during some periods. Evidence of subsidence is provided by the location of ceramic-bearing deposits (e.g., Layer VIc XU-4), which are only slightly above the present sea level (see Fig. 5.57). Given that sea level was 1-2 m higher when these areas were used, the deposits would have been under water if the present configuration was extended back. No evidence of stilt house use has been noted and intact cultural features have been recorded in the lowest cultural deposits. Therefore, the most plausible explanation is that the island is subsiding.

The distribution of ceramic bearing deposits in both Ofu Village and at To'aga suggests that progradation occurred in the 1st millennium AD. This is in line with the posited sea level crossover, at which time ambient high tide fell below the low tide point of high

stand conditions (Dickinson 2003:492). Reaching a crossover point allowed sedimentation on former shallow marine environment to occur more readily as former paleoreef flats became supratidal (Dickinson 2004). The crossover point is posited to have occurred in the Fiji-Tonga-Samoa area around the 6th century AD (Dickinson 2003:494, 2009), through, given localised island subsidence, this crossover point may have been later on Ofu. On Ofu, the progradation of the shoreline seaward of old beach ridges had begun by at least the end of the 1st millennium AD on the west coast (end of Layer VI and the beginning of stable Layer V of XU-2) and at To'aga (e.g., Units 3 and Unit 17; Kirch 1993c:88), marked by land use seaward of ceramic bearing deposits. On the western coast, such land use began in the 13th century and later (Beta-332861, 2 σ AD 1405-1452; Beta-366731, 2 σ AD 1299-1413; Beta-372699, 2 σ AD 1261-1387) (Figs. 5.57, 5.58). In comparison, populations began utilising landforms seaward of ceramic deposits at the middle or end of the 1st millennium AD along the south coast (Kirch and Hunt 1993a:55-56, 60-62, 68, 88; Beta-26463 (marine shell found below cultural layer), 1 σ AD 561-663; Beta-26465 (marine shell found below cultural layer), 1 σ AD 828-1000). Even at To'aga, some areas probably did not form until the 2nd millennium AD (Kirch and Hunt 1993b:234). Nevertheless, the most plausible explanation for the documented distribution of dates from basal archaeological deposits (Fig. 5.57, 5.58, 5.59) is a process of progradation that created additional land that had been unavailable when the island was first colonised. Given above evidence, the process is most pronounced in the 1st millennium AD. Variability suggests two possibilities: the process of landscape evolution 1) was not rapid, or 2) was rapid but occurred at slightly different times along the coastlines.

Landscape evolution might also have impacted marine environments. That a reef was present at island colonisation is indicated by the faunal assemblages (Aakre 2014; Nagaoka 1993). The modern reef flats are situated on a shallow landform skirting the island between 250 and 700 m wide on the south and west coast, and the range of the elevation of this marine environment is less than 1 m across the extent of these reef flats. Given this elevation range, it can be expected that the timing of initial reef growth was consistent along the landform. This evidence suggests that the seaward extent of the reef at the time of human colonisation was similar to the modern situation. Coastal progradation might have reduced the total area of shallow marine environment by as much as 25-50 percent through calcareous sediment infilling. Large coral boulders at the interface between sterile sand and cultural layers in XU-3 and Trench 3 might be evidence of high energy depositional environments.

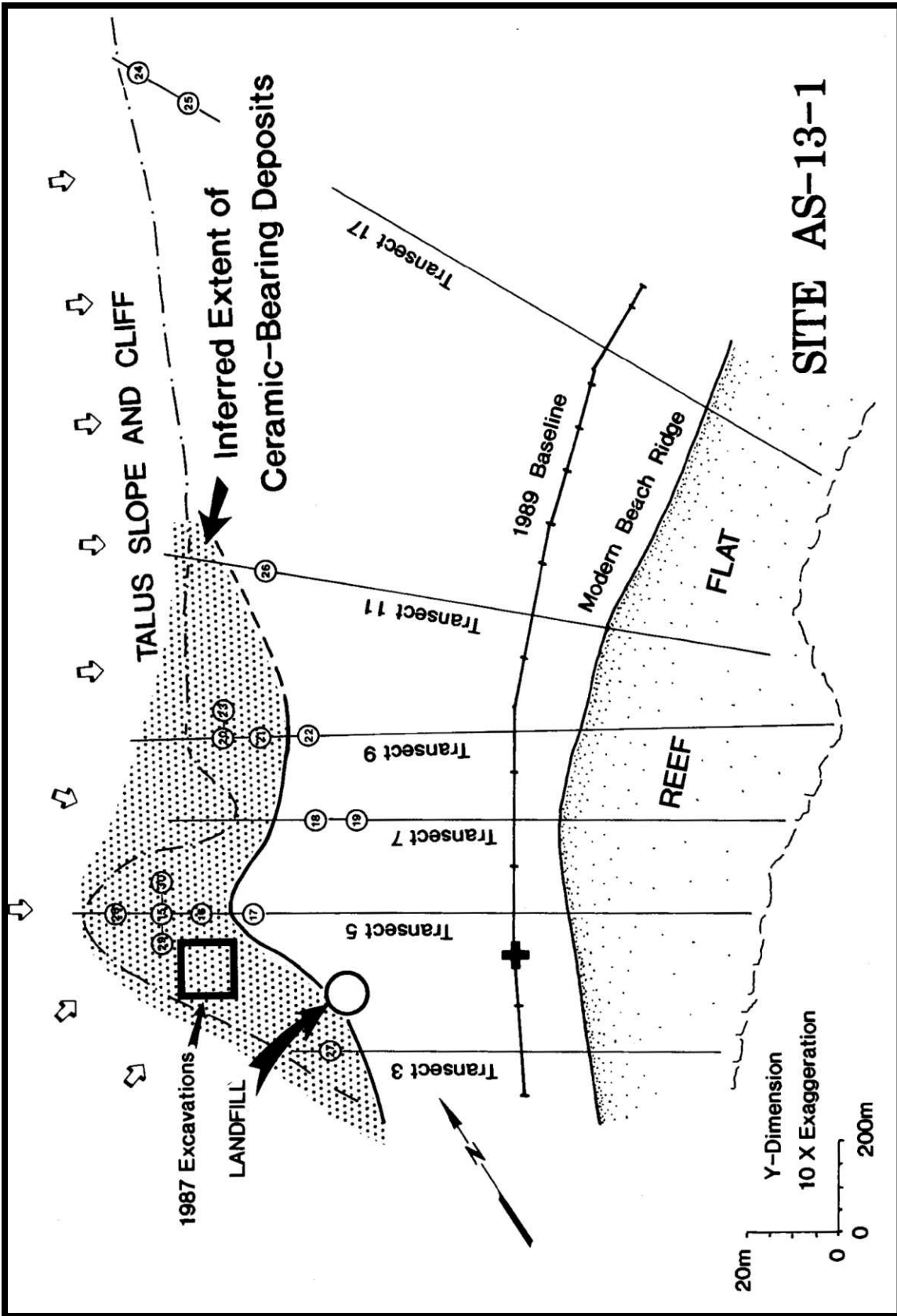


Figure 5.59 Diagram highlighting the extent of early prehistoric cultural deposits on the To'aga plain. Areas not shaded likely represent post-2000 BP progradation (From Kirch and Hunt 1993b:233)

Synthesis of Coastal Settlement on Ofu

Based on present evidence, colonisation of the Samoan Archipelago occurred near Mulifanua on the western end of 'Upolu in the 9th-10th century BC (Petchey 2001:67). No other comparable site, in terms of material culture, has been documented. Roughly contemporaneous settlement, in the 9th century BC, has been posited on Tutuila, in 'Aoa Bay (Clark and Michlovic 1996), and on Ofu, along the southern coastline in To'aga (Kirch 1993c). Radiocarbon dates from both these sites have been criticised on the basis of material culture disconformity (lack of dentate stamped pottery) and potential problems with inbuilt age, and removed from consideration (e.g., Addison and Asaua 2006; Addison and Morrison 2010; Cochrane et al. 2013; Rieth 2007; Rieth and Hunt 2008; Rieth et al. 2008). Instead of the contemporaneous human colonisation of all islands in the archipelago, these researchers proposed the possibility of discontinuous settlement. In this model, first settlement is represented by Mulifanua followed by subsequent settlement of Tutuila, and Manu'a by a different group(s) in the 5th century BC (Addison and Morrison 2010:369; Rieth et al. 2008:226).

Recent evidence calls these latter interpretations into question, at least on Ofu. Dates from Va'oto, Coconut Grove, and Ofu Village demonstrate colonisation of Ofu by the 6th century BC and more likely earlier (Va'oto (Clark 2011, 2013) Beta-249327, 2 σ 798-521 BC, Beta-297824, 2520 \pm 30, 2 σ 795-542 BC; Ofu Village Beta-354137, -383081, 2 σ 781-511 BC; Coconut Grove (Clark 2013) Beta-307473, 2 σ 768-431 BC). Unidentified charcoal was the most commonly dated material from Va'oto, but short-lived material has been dated to this same period from Ofu Village (XU-4, Beta-354137, -383081, 2 σ 781-511 BC) and Coconut Grove (Clark 2013, unpublished data., Beta-307473, 2 σ 768-431 BC). Like To'aga (Hunt and Erklens 1993), no Lapita ceramics were identified in any of the above listed locations. Therefore, sites for which dates have been discounted based on material culture incongruences, specifically To'aga and A'oa, need to be re-evaluated with the understanding that the lack of dentate stamped pottery does not itself indicate that any deposit dates after 6th century BC in Samoa.

Land use in each area persisted through to the end of the 1st millennium BC, at which time the sequences at Va'oto and Coconut Grove end or are ephemeral. This does not imply that these areas were abandoned, but, rather, bulldozer activity has disturbed the rest of the deposit at Va'oto and garden activity has disturbed the deposit at Coconut Grove. Cultural

activity continued at To'aga (Beta-26465, 1 σ AD 828-1000; Beta-35600, 1 σ AD 694-943) and Ofu Village (suggested by the date of the top of Layer VI in XU-2, Beta-380263, 2 σ AD 895-1021). Some stylistic changes in fishhooks (Kirch 1993a), the disappearance of bird species (Steadman 1993), and a cessation of ceramic technology (Hunt and Erklens 1993) occurred between colonisation and the end of the 1st millennium AD.

Structural features in subsurface deposits have been dated to the 1st millennium AD, including a coral pavement (Kirch and Hunt 1993a:67, Beta-35600, 1190 \pm 70, 1 σ AD 694-943). Surface features might date to this period as well, specifically a surface house mound (Kirch and Hunt 1993a:56, 88 Beta-26465, 1 σ AD 828-1000), but an argument can be made that the radiocarbon date thought to be associated with the feature does not date the event of house construction. Historic material was found within the paving associated with the structure (Kirch and Hunt 1993a:55), the sample was *Turbo* shell with a utilised marine correction value different than those now used in the archipelago (e.g., Petchey and Addison 2008; Phelan 1999), the location of the shell within the deposit is not precise (Kirch 1993c:88), and the date stems from the layer below the one representing the structure. Given this evidence, it may be that the house was built in the early historic or late prehistoric period (17-18th century AD), a time that To'aga was the primary occupation on the island according to oral tradition.

There remains a paucity of evidence for residential or domestic activities on the coast in the last 1,000 years. Cultural deposits that have been found generally lack artefacts and fauna relative to earlier occupations. For instance, a total of 3.8 kg of shell was recovered from XU-1 in Ofu Village (post-AD 1400), which is far less, in both abundance and density, to that found in one layer of one unit at Va'oto (14.2 kg Layer IV of 37E/9N; 2200-2400 BP; unpublished data 2014). The majority of artefacts recovered at To'aga came from ceramic-bearing deposits (Kirch 1993a; Kirch and Hunt 1993a), and there is a clear difference in Ofu Village between the lone known ceramic-bearing *layer* (Layer VI XU-4, Ceramics > 700, Basalt = 22, Volcanic Glass = 100, Shell \approx 10) and those *units* that date to the 2nd millennium AD (XU-1, Basalt = 13, Shell = 1; XU-3, Basalt = 24). Isolated subsurface cultural features, notably combustion features, have been found distributed along the modern road from the south coast (ASPA site files) to Ofu Village. Surface features, identified by Hunt (1993) and assumed to date to this period, have not been directly dated other than the one discussed above. It is plausible, and perhaps likely given the evidence of significant terrigenous deposition in the last 1,000 years, that these were built in the late prehistoric or early historic

occupation of To'aga (e.g., the Tui Ofu well and burial mound), or are associated with events within that period (particularly warfare with neighbouring Olosega).

Still, activity was occurring on the coast. The modest faunal material found in XU-1 and XU-3 of Ofu Village indicates that some marine resource exploitation and processing was occurring. Possible storage pits and evidence of cultivation have been identified by Kirch and Hunt (1993a:70-71; Hunt 1993:24-26), and the dark organically enriched clay loam soils in XU-2 and XU-4 on the west coast demonstrate the use of back beach areas for cultivation. Nevertheless, the collection of this evidence might suggest that the nature of coastal land use was different in the last 1,000 years relative to earlier periods, and I propose that permanent residential use of the coast was, at the very least, more dispersed in the last 1,000 years before European contact relative to previous periods.

Chapter Summary

This chapter has presented the results of subsurface investigations undertaken on the western coast of Ofu island. Promising deposits were excavated in two locations. In each area, sequences of cultural and geomorphological change were identified. Only one unit included a deposit representative of the early period of the cultural sequence, located near the talus slopes leading to the interior. The dated basal layers of all other units place initial use of areas seaward of XU-2 in Ofu Village (~145 m from present beach) in the last 1,000 years. Evidence of an increased terrigenous component to the sediment budget was noted in all deposits. Garden layers that date to the end of the 1st millennium AD or beginning of the 2nd millennium AD (after 2 σ AD 895-1021) were identified in two units, and thick colluvium layers were identified dating to the end of the 15th century AD (Beta-332861 (below colluvium), 2 σ AD 1408-1452; Beta-366731 (below colluvium), 2 σ 1299-1413; Beta-372700, 2 σ AD 1498-1795). Given the ubiquity of charcoal in these colluvial deposits, they were likely the result of erosion following vegetation clearance on the slopes overlooking the coastline. The impact of climatic change, however, cannot be ruled out.

All this evidence indicates a dynamic landscape, particularly within the last 2,000 years. Progradation expanded the coastal plain. By the 13th century AD, the western coastline had stabilised enough where landforms created by progradation could be used. The next chapter examines the archaeology of the island's interior uplands to build upon this sequence of changing settlement and subsistence patterns.

Chapter 6: Archaeology of the Ofu Island Interior

A characteristic of Ofu is the limited area of low relief for settlement. Even the habitable places in the interior uplands require the construction of earthen modifications given the steepness of slope. It is the earthen modifications necessitated by slopes that make these landscapes attractive to archaeologists. Comparable to the island of Olosega (Quintus and Clark 2012), evidence of past activities in the interior of Ofu is abundant and, given the relative lack of historic land use in the detailed survey areas, well preserved.

This chapter presents the results of survey and excavation in the interior. These investigations were initiated to examine patterns of land use through space and time. Topics addressed in this chapter include the nature and function of archaeological remains, the spatial distribution of those remains, and the chronology of initial interior residential settlement and subsequent use. Given that this study is concerned with agricultural development, special attention is paid to identifying patterns of cultivation. This was largely accomplished by the study of agricultural infrastructure, but was also addressed through the analysis of vegetation patterns.

The first part of this chapter investigates the interior uplands at an island-wide scale using Lidar imagery and vegetation patterns. The second part of this chapter presents qualitative and quantitative information about feature types discovered within two detailed survey zones. The final part of this chapter presents the results of excavation and radiocarbon dating.

Modelling Feature Location and the Spatial Extent of Cultivation on Ofu

Two methods were utilised to establish the distribution of archaeological remains and the extent of cultivation strategies at the island scale. The first is a GIS procedure informed by the pedestrian survey that defines areas of high archaeological feature density using a Lidar dataset. The second is a correlation analysis that examines the relationship between defined areas of high feature density and the distribution of economic and secondary vegetation.

Mapping Island-Wide Feature Density

A GIS procedure, the specific methods of which can be found in Chapter 4, was used to define the boundaries of areas with high densities of archaeological features at the island-wide scale. To summarise the procedure, an iterative process was undertaken where the results of survey were compared with a high resolution slope map derived from Lidar. This indicated that the location of terraces mapped in the field were associated with areas of 0-10 degree slope in contrast with the surrounding area (Fig 6.1). Building on this pattern, a slope map of the entire island was classified and converted to highlight discrete areas with slope values of 0-10 degrees. The density of these features was then calculated to define boundaries of high feature density (HFD) zones.

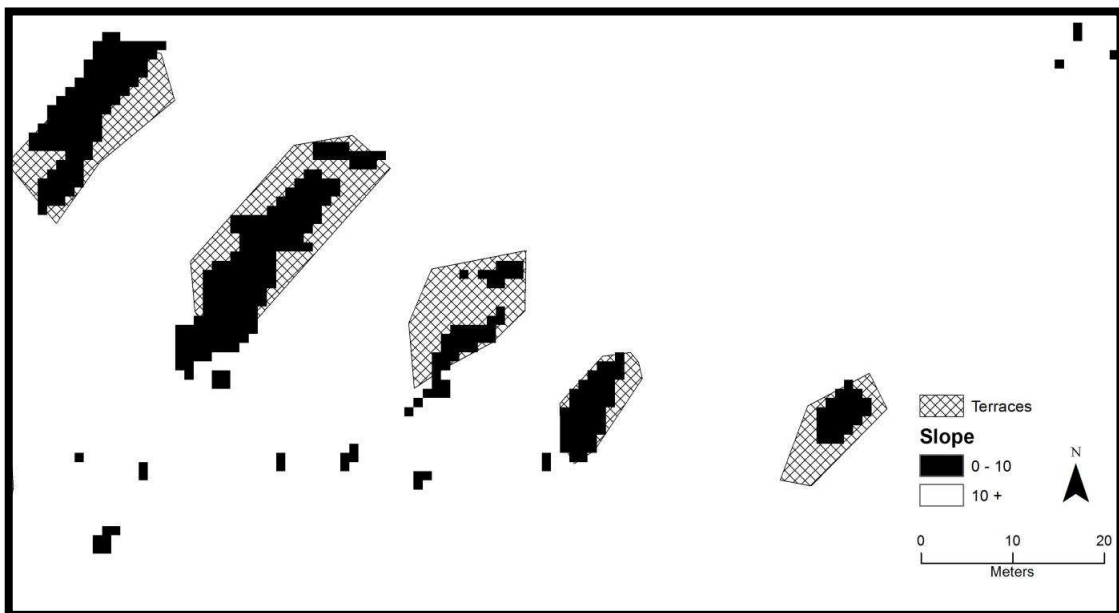


Figure 6.1 The association between 0-10 degree slope features and outline of archaeological terrace. Polygon outlines represent what was recorded during previous pedestrian survey while the black represents 0-10 degree slope

The application of this procedure identified several areas of potential high density archaeological remains (Fig. 6.2). Places highlighted on the ridgeline correspond to the known locations of star mounds, a group of depressions, and historic/modern infrastructure. Additionally, much of the ridgeline itself has a slope of less than 10 degrees, which results in some areas being falsely identified as archaeological sites. Outside of the ridgeline, the procedure identified four zones, three on the western slopes and one on the northern slopes. The HFD area on the northern slopes corresponds with a known, by the local population and

archaeologists, location of archaeological features referred to as A’ofa. Unfortunately, the Lidar dataset exhibits areas where bare earth returns were absent in parts of A’ofa, the result of cloud cover during Lidar data acquisition. Therefore, two boundaries were defined for this zone. The first boundary outlines the high density area as defined by the GIS procedure, and the second extends the boundary to include an adjacent area in which there was a lack of bare-earth returns in the Lidar dataset. This extended boundary is based on the extent of terracing identified during a small reconnaissance survey on the steep slopes on the western portion of the area, and it also includes a smaller HFD zone identified by the GIS procedure inland of the eastern third of the larger zone. The three areas identified on the western slopes also correspond to places of known terraces, one of which is examined here (Tufu).

Using these boundaries, a mean centre of each HFD zone was calculated in ArcGIS and used as a baseline for the locational analysis of detailed survey areas. The use of the mean centre as an analytical baseline is partially due to the importance of the centre: periphery distinction in Samoa (Mead 1969; Quintus and Clark 2012; Shore 1982, 1996), but, above all, it is a fixed point to help illustrate spatial patterns. The spatial patterning of archaeological features within Tufu and A’ofa are presented in this chapter.

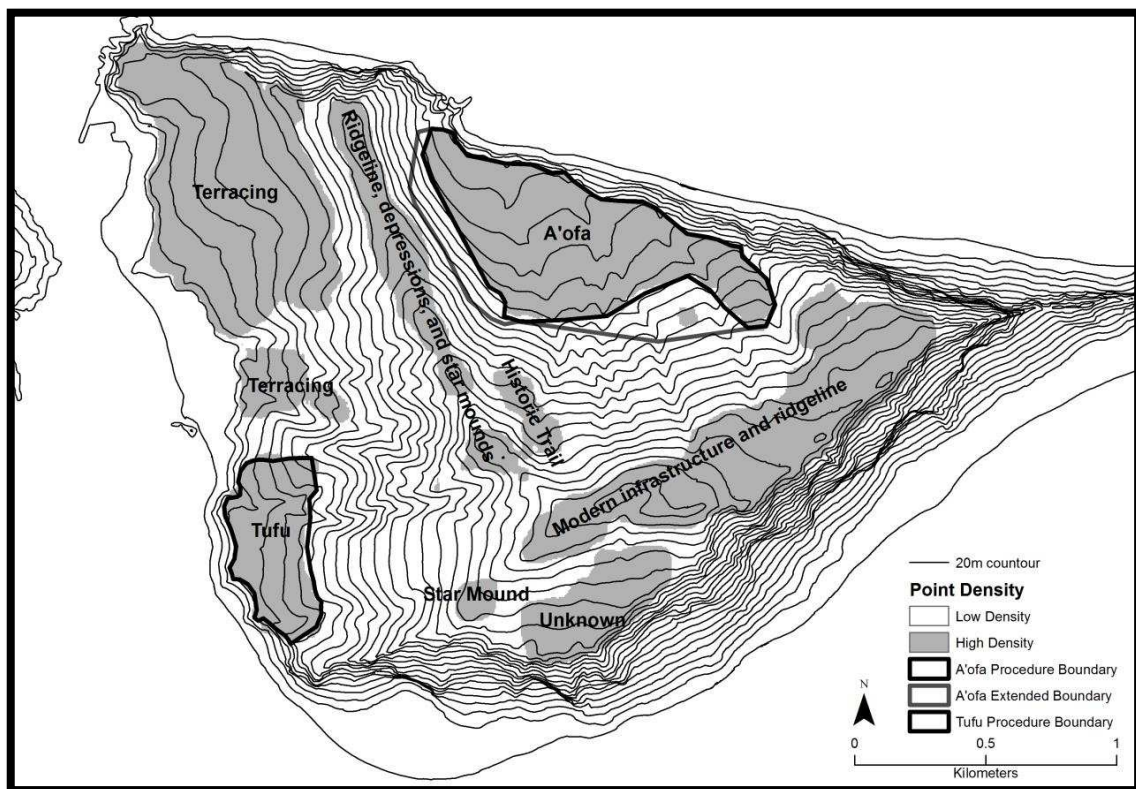


Figure 6.2 Areas of high density archaeological remains in the interior uplands of Ofu

Examination of Vegetation Patterning

Because cultivation inevitably impacts vegetation, the distribution of extant vegetation types can reflect the collective result of human land use over long time scales, perhaps highlighting activities associated with food production during prehistory. On Ofu, as discussed in Chapter 3, much of the extant vegetation is modified, either economic or secondary forests (boundaries defined by Liu and Fischer 2007). Economic forests, as the name implies, consist of economic tree crops, especially *Artocarpus altilis* (breadfruit) and *Cocos nucifera* (coconut), though *Aleurites moluccanus* (candlenut) and *Inocarpus fagifer* (Tahitian chestnut) were also identified in the area. Secondary forest is constituted by a number of plants, but on Ofu consists largely of *Hibiscus tiliaceus* (*fau*). The above defined HFD zones were compared to modern vegetation patterns, and their correlation was statistically assessed.

Economic forests are distributed in three discrete locations in the interior uplands (Table 6.1; Fig. 6.3), which spatially correlate with three areas of HFD. In the area designated as A'ofā, ~20 ha of economic forest are situated seaward of ~19 ha of secondary forest. Approximately ~23 ha and ~25 ha of economic forest are distributed near the area designated as Tufu and the far northern HFD zone on the western slopes. A collective total of ~89 ha of secondary forest is located inland of and between these two zones, with another ~6 ha of secondary forest located to the south of Tufu. Interestingly, variation is also apparent. In A'ofā, both economic and secondary forests are situated within boundaries of the HFD zone, while the Tufu HFD boundaries more clearly correlated with economic forest with almost no secondary forest situated within the boundaries. Neither economic or secondary vegetation types was found associated with HFD zones on the ridgelines, as primary cloud and rain forests (e.g., *Dysoxylum* spp., *Ficus* spp., *Reynoldsia pleiosperma*) are distributed across the rest of the island.

A pattern highlighting prehistoric activity zones may be inferred from the distribution of vegetation, even though variation exists. Significantly more economic forest is found within HFD zones than outside ($\chi^2 = 8.30$; $p = 0.015$), and the presence of these Polynesian introduced economic trees (e.g., breadfruit) on these slopes is clearly related to human activity. Secondary forest, meanwhile, is found within and outside HFD zones, but the general location of the vegetation type and zones of HFD correlate. Secondary forest is not the exclusive result of vegetation clearance for cultivation, but other explanations of the

vegetation patterns on Ofu are not as plausible. Natural fires are an extreme rarity. If a natural fire did occur, it would not spread given a lack of dry material to burn. Forest clearance for residential purposes could result in the growth of secondary forests, but this does not account for the total distribution observed as secondary forest is frequently located outside areas of archaeological remains (refer to Fig. 6.3), especially immediately inland. This pattern, of secondary vegetation situated immediately inland of economic forests is similar to a pattern of shifting cultivation inland of arboriculture zones; a pattern that is known ethnographically for Samoa and elsewhere in West Polynesia (Fox and Cumberland 1962; Kirch 1994:166-183), and archaeologically for Samoa and other places in the Pacific (Lincoln and Ladefoged 2014; Quintus 2012).

Table 6.1 Distribution of economic forests in reference to areas of high density archaeological remains

	Within	Outside	Total
Tufu	16	7	23
Ofu Village	24	1	25
A'ofa	19	1	20

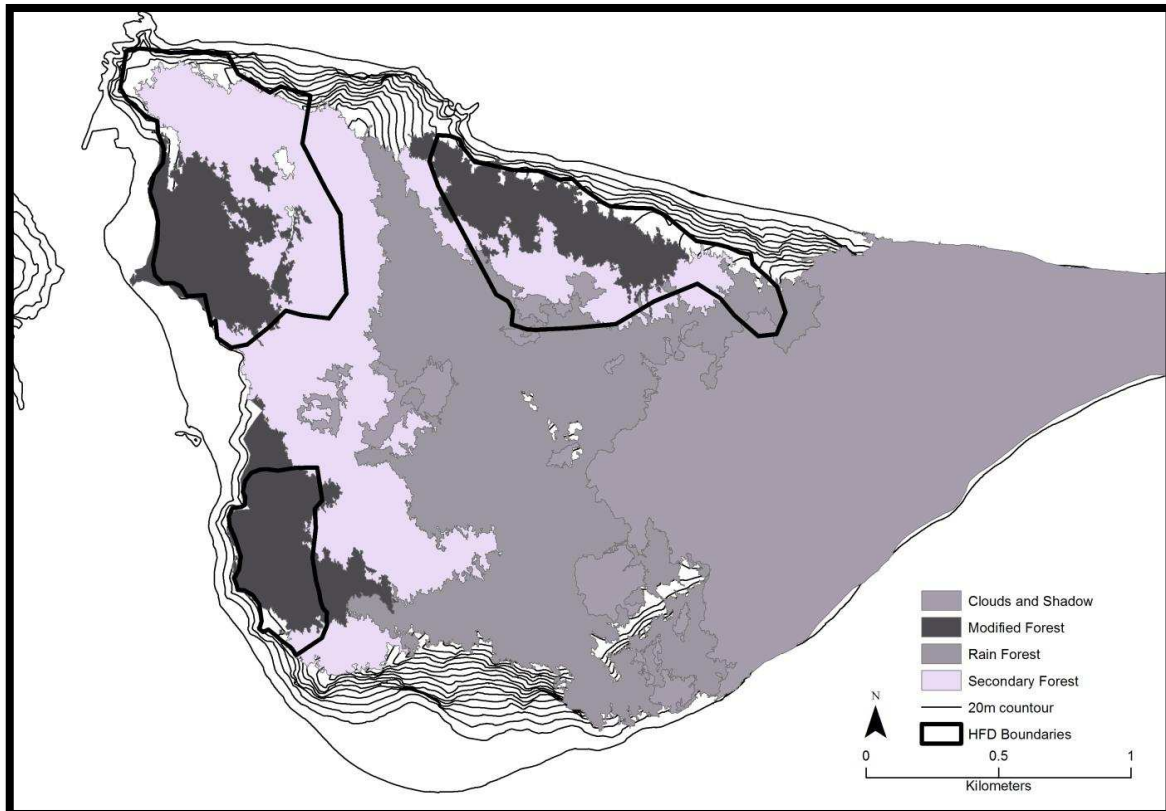


Figure 6.3 Vegetation map exhibiting the spatial extent of secondary and economic forests. These locations roughly correlate with HFD zones identified using the Lidar dataset

In order to understand the nature and formation of HFD zones, the results of surface and subsurface investigations in two interior upland areas, Tufu (AS-13-42) and A'ofa (AS-13-39), are presented in the rest of the chapter. These two quantitatively defined zones are used as analytical units for comparative purposes because of their value in organising data and highlighting locational patterns.

Feature Definitions

Features in both A'ofa and Tufu can be classified into similar classes (for definitions, refer to Table 4.2 in Chapter 4), based on *morphological* attributes. These classes were created prior to fieldwork and were based on features that had previously been recorded in Samoa (e.g., Clark and Herdrich 1993; Davidson 1974a; Holmer 1980; Hunt and Kirch 1988; Quintus and Clark 2012). The following is a short description of each feature class. Quantitative data (e.g., size, distribution, proportions, etc.), which are site specific, are subsequently discussed in reference to each sample area, but general interpretations of form are considered here. For ease of presentation, the discussion of feature types in this section is organised in the same way as the discussion of each HFD zone below.

Ditch-and-Parcel Complexes

Aggregate features with at least one ditch that surrounds an area of *sloping land* are classified as ditch-and-parcel complexes (Fig. 6.4). These features possessed two morphological elements, a ditch and a parcel. Ditches are defined as artificially constructed narrow channels situated below the level of the ground surface that are longer than they are wide. Ditches in the study areas are morphologically similar, constructed entirely of earth with a bund – presumably manufactured of fill dug out to construct the ditch – that defined the side and downslope boundaries. Variability of ditch depth and bund height exists as a result of slope.

In this feature class, the majority of the area encompassed by ditching remained sloping, and this area is referred to as the parcel. The downslope edge of most parcels have been purposeful cut away to create an earthen facing, and there is no ditch on the downslope side. This ensures that the ditch ends remain open to drain on the downslope side of the features. Earth removed to create the cut earthen facing appears to have been piled on the downslope edge of parcels, creating a narrow (~1-2 m) flat area. In the cases where the flattened area was wider than 5 m, it was classified as a terrace. Even in these scenarios, these

features were classified as ditch-and-parcel complexes, as opposed to ditched terraces, if a higher proportion of land encompassed by the ditch was sloping rather than flattened.

Two types of ditch-and-parcel complexes were identified on Ofu: networks and single branch features. Networks exhibit multiple ditch branches or segments connecting to create, in all but one circumstance, multiple parcels. In cases of networks, there was a main ditch from which smaller branches extend. Single branch features exhibit a single ditch branch that surrounds a parcel. Ditches of single branch features are often U-shaped, open on the downslope end of the feature.

Terraces

Terraces are defined as artificially flattened earthen structures with three free-standing sides or less. Each was constructed by a cut and fill technique, in which the back of the feature was cut out from the natural slope with the earth used to flatten the front (Fig. 6.5). Terraces displayed variable surface areas and surface remains. On the surfaces of most, evidence of past use was identified, either in the form of sub-rounded coral gravel or rounded to angular basalt gravel, referred to here as paving. Coral was transported from the coastline into the interior uplands, and the basalt could have been collected from the coast or interior. Angular basalt likely represents the latter case and, in fact, could be naturally occurring on some terraces. Paving usually does not cover the entire surface, but, especially when only angular basalt was found on the surface, this material was present in low densities (< 5 percent of surface). Surface visibility was influenced by the degree of vegetation cover on some terraces, and for this reason the simple presence or absence of coral and basalt was recorded, not an estimated portion of the terrace covered. Paving, coral in particular, was not commonly found off terraces other than in a few unique circumstances, and those terraces with more than five pieces of one or another, coral or basalt, were classified as paved. The only other surface remains identified on terraces was one low platform, 20-30 cm high, built atop one terrace, and two curbing alignments; one on the mentioned low platform and one on another terrace.

Circular Depression

Depressions are defined as circular areas situated below the land surface that are the result of human activity. This feature class is variable in both morphology and, presumably, function. The rims of depressions are at ground surface, none were identified with

unambiguous raised rims. However, rims are always more defined on the downslope side of features. Basalt and coral boulders (20-30 cm in length) were seen to line the edge of some depressions, though the distribution and density of this edging around each is variable. The presence of edging appears to be important and is an aspect of feature variation that likely has functional relevance. Of note, the determination of presence/absence for each was difficult in the Tufu HFD zone, as vegetation cover precluded close examination in some circumstances.

Ditched Terraces

A ditched terrace is an aggregate feature type defined as a terrace, with significant sub-rounded and flat plate coral and rounded waterworn basalt paving, which is ringed by a ditch (Fig. 6.6). Upright basalt slabs have also been identified on these features. The distinguishing attribute separating ditched terraces from regular terraces is the presence of the ditch that rings the terrace. This feature is differentiated from ditch-and-parcel complexes by the proportion of land inside the ditch that is modified or flattened. In the case of ditched terraces, a higher proportion (> 50 percent) of land ringed by the ditch is artificially flattened. Additionally, ditched terraces are completely ringed by a ditch, as opposed to being open on the downslope side. The ditch of ditched terraces is O-shaped instead of U-shaped. Additionally, the footprints of these features tend to be smaller relative to ditch-and-parcel complexes. Ditched terraces may be a unique characteristic of settlement systems in Manu'a, though features identified by Ishizuki (1974) on 'Upolu might represent these.

Central Open Spaces

The absence of archaeological remains across an area was also recorded when meeting a set of criteria. To be recorded, these spaces must have been devoid of structures, larger than needed for a single domestic unit (exceeding ~500 m²) and associated with multiple (three or more) large structures along their peripheries. Furthermore, these spaces were of particular interest if they were situated in the centre of HFD zones or directly seaward of the centre of the HFD zones and large terraces. These spaces may compare with the ethnographically and historically documented *malae*. That these features were present in prehistoric Samoa is supported by initial European descriptions of Samoan villages, which highlight the presence of a central village green (Davidson 1969:58, 62; Shore 1996:267). One such space recording ethnohistorically was 300 yards in diameter (Davidson 1969:62), but it is unclear whether this size was common or unique.

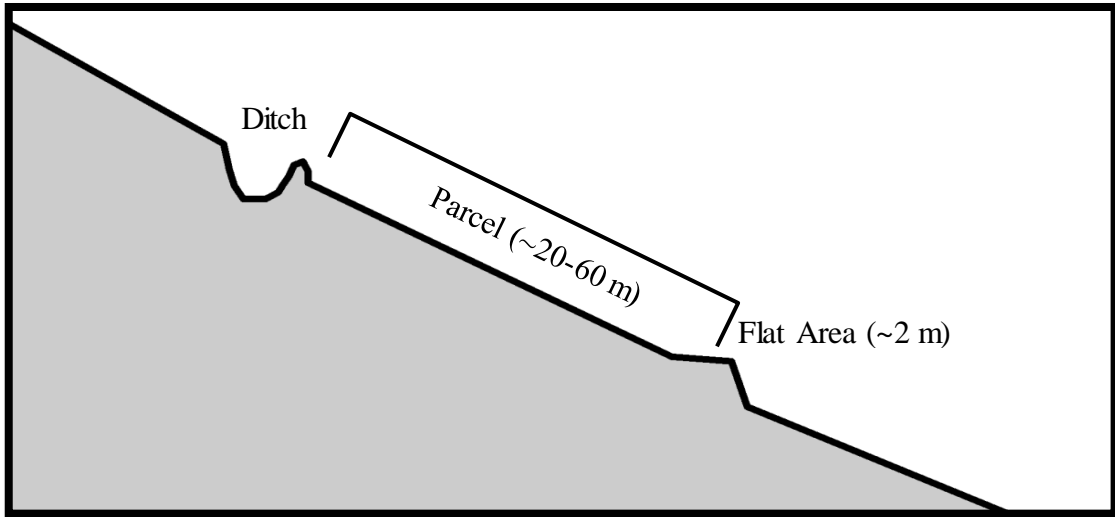


Figure 6.4 Schematic profile view of a ditch-and-parcel complex

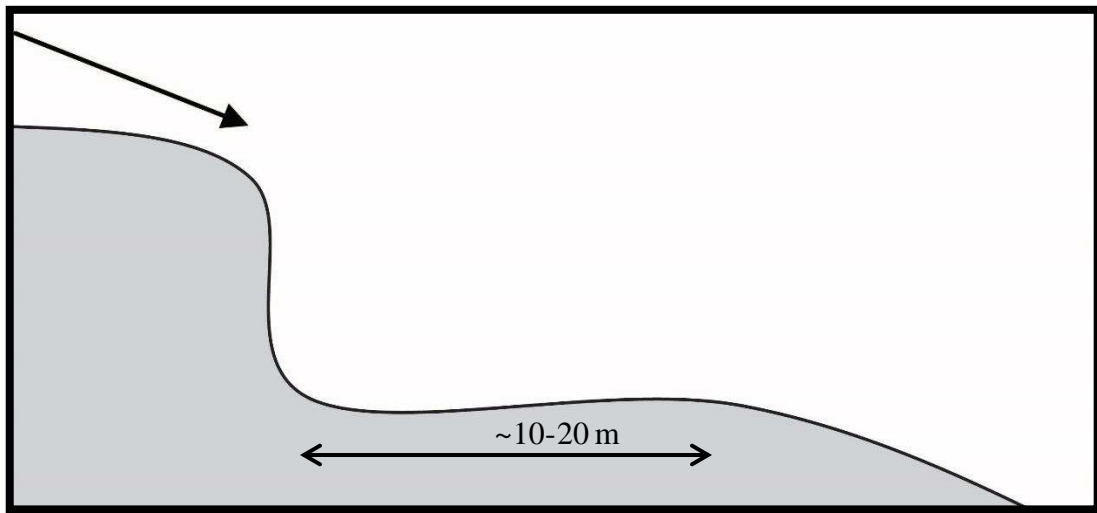


Figure 6.5 Schematic profile view of a terrace

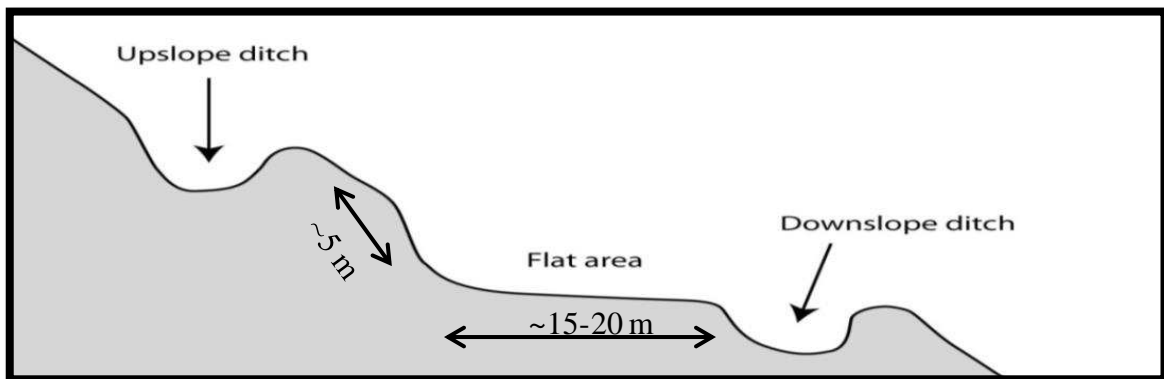


Figure 6.6 Schematic profile of a ditched terrace. Exaggerated ditches and back banks

The Archaeology of A'ofa (AS-13-39)

Archaeological remains in A'ofa, inland of the north coast of the island (Fig. 6.7), were first identified in the late 1990s by Jeffrey Clark and local village members, visited in 2010 and 2011 by the author and Jeffrey Clark, and surveyed in 2012 and 2013 as part of this study. Based on the results of the GIS procedure discussed above, archaeological features in the A'ofa HFD are expected to be distributed across an area of roughly 49 ha. Of that area, 15 ha were surveyed in detail with 10 m spaced transects, while the remaining area was visually examined using the Lidar dataset to gather additional distributional data.

Within the HFD zone, from 80-200 m above relative sea level, the slope ranges from ~10-40 degrees. The vegetation consists largely of either economic plants or secondary forest. Among the more common trees of breadfruit and coconut, additional economic trees of Tahitian Chestnut and Candlenut were noted. Secondary forest, which constitutes the majority of vegetation in slopes greater than 20 degrees, consists of a number of taxa but is dominated by *Hibiscus tiliaceus* (*fau*). Three streams cut across the survey area (see Fig. 6.8). All run intermittently, and no standing water was apparent in any during field work.

One hundred and four features were recorded during detailed pedestrian survey, in addition to several ditch-and-parcel complexes ($n = 18$, five networks and 13 single branch features). Below is a summary of the features identified. As mentioned previously, a mean centre was calculated in ArcGIS for each survey area defined by zone boundaries created using the GIS procedure. In A'ofa, two mean centres were calculated because of a lack of bare earth returns in some areas of the Lidar dataset. These mean centres are used analytically to examine and compare the form and spatial distribution of feature classes.

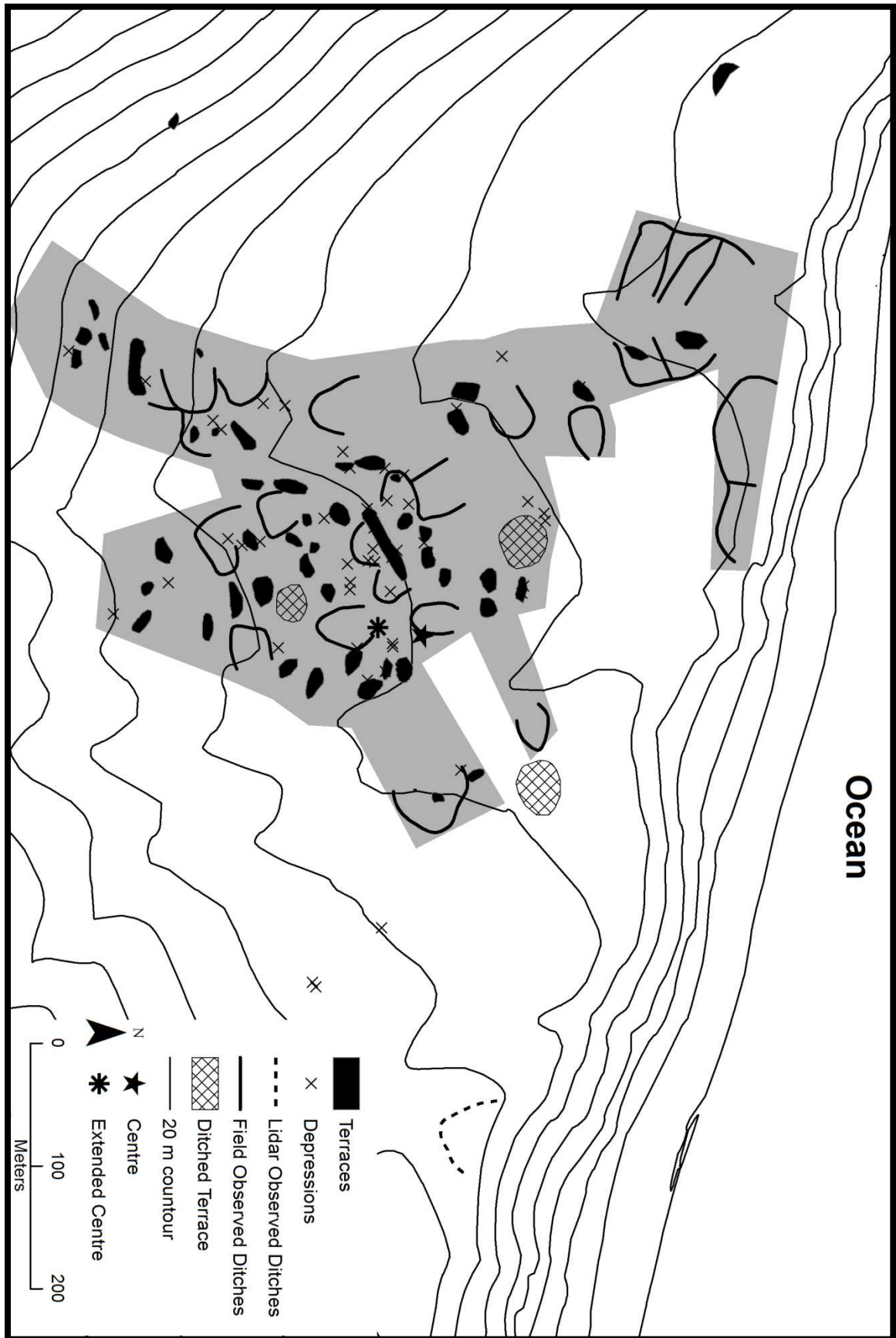


Figure 6.7 Distribution of archaeological remains in A'ofa. Shaded area is detailed survey area

Ditch-and-Parcel Complexes

Morphology. Eighteen ditch-and-parcel complexes were identified forming a total of 27 individual parcels (Fig. 6.8; Appendix 1). Ditch elements associated with these features have a total length of 2,182 m, and individual ditches range in length from 51 m (Parcel 13) to 347 m (all connected ditching associated with Parcels 24-27). The average length of ditches per complex is 114 m (s.d. =70 m), as measured when all segments of networks were measured as one ditch. Ditch elements associated with networks (mean = 204 m) are larger than those associated with single branch features (mean = 83 m) (t-stat = 3.16, p = 0.03, two tail assuming unequal variance). Of the ditch-and-parcel networks, two very large examples were documented, constituted by ditches with lengths of 212 m (Parcels 22 and 23) and 347 m (Parcels 24-27). Ditch width, measured from bund to bund, ranges from 3.2 to 6 m and averages ~4 m (Fig. 6.9, 6.10). The assessment of the original depth of each was difficult, given the probability of post-construction infilling and erosion, but the present depth of most is not significantly less or more than ~0.45 m. Rocks, coral, shell, and vegetation were found scattered within these ditches, but no formal paving or walling was identified. It is likely that this debris was swept into these features by way of rainfall run-off.

Slightly more parcels in A'ofa are formed by single branch features than by networks (14 of 27; 52 percent). The size of each parcel was measured in ArcGIS utilising the area measurement tool. As ditches that form the boundaries of parcels are present on only three sides, the fourth side was created by drawing a straight line from one ditch end to the other. Thus, these measurements should be thought as conservative estimates. Parcel size ranges considerably, from 173 m² to 3,063 m² with an average of 924 m² (s.d. = 565 m²) (Fig. 6.11). This range was divided at equal intervals of 300 m² to consider correlations with complex type (single branch feature or network) and enable comparison with the Tufu dataset. Three parcels measured under 399 m², six measured between 400 and 699 m², 11 measured between 700 and 999 m², and seven measured over 1,000 m² (Table 6.2). The largest parcels tend to be associated with networks (11 of 18 over 700 m²; 61 percent), and the proportion of single branch features within each size class decreases from the smallest to largest classes. The average size of parcels in single branch features is smaller in comparison to those in networks (731 m² and 1132 m²), though this difference is not statistically significant at the 0.05 alpha level (t-stat = -1.90; p = 0.07; two tail assuming unequal variance). The largest parcel, Parcel 23, is a clear outlier.

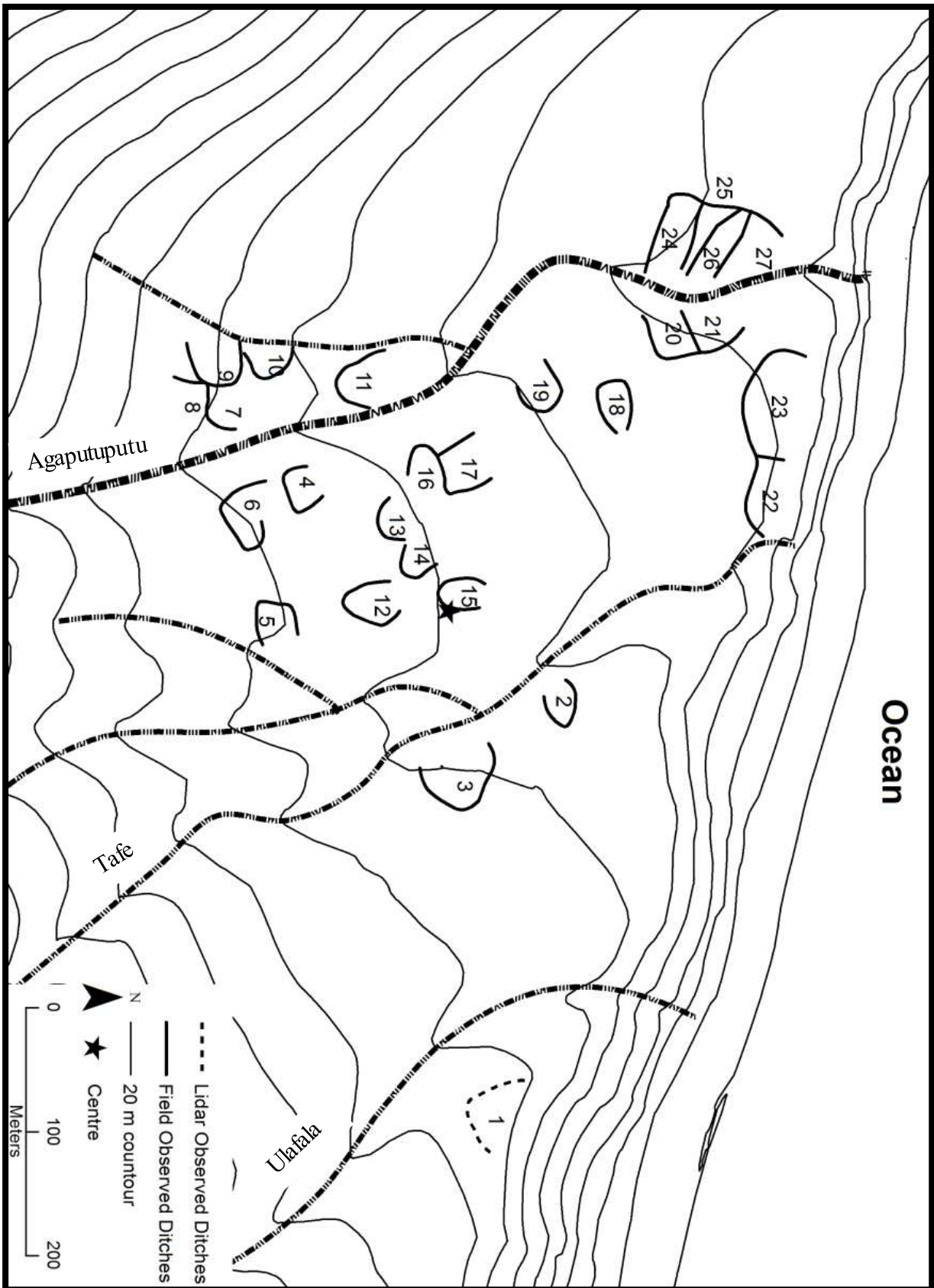


Figure 6.8 Distribution of ditching in A'ofa. Streams are marked with broken lines. Numbers correspond to individual parcels



Figure 6.9 Ditch, which is 4 m across, of Parcel 23 in A'ofa



Figure 6.10 Ditch associated with Parcel 9

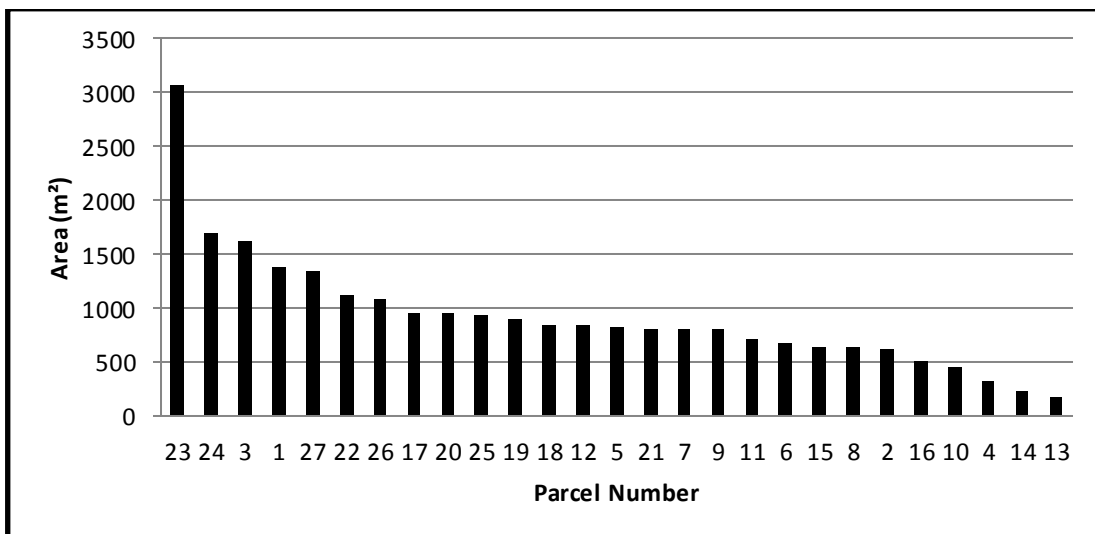


Figure 6.11 Size distribution of parcels in A'ofa

Table 6.2 Frequency of size of parcels and the relationship between size and complex type

Size Range	No.	No. Single Branch Features (proportion)	No. Networks (proportion)
100 m²-399 m²	3	3 (1.0)	0 (0)
400 m²-699 m²	6	3 (0.50)	3 (0.50)
700 m²-999 m²	11	5 (0.45)	6 (0.55)
1000 m²+	7	2 (0.29)	5 (0.71)

The modification of parcels, in the form of terracing or mounding, was limited; most consisted simply of sloping surfaces with a small flat area near the bottom created by the piling of excess dirt from ditch and earthen facing construction. On a few parcels, terraces were recorded, some of which clearly supported structures (Parcels 20 and 21), as indicated by the presence of dense sub-rounded coral and basalt paving. Even in these cases, though, the area of modified land is a small portion of the total land encompassed by the ditching (15 and 37 percent respectively). These associations are discussed at more length below.

Spatial Distribution. The majority of ditch-and-parcel complexes are located within 20 m of streams or cliff edges (23 of 27 parcels; 85 percent) (Fig. 6.8). Though other features that included ditch elements were noted near the centre of the HFD zone, they were classified as ditched terraces (see below). Of the five examples of ditch-and-parcel networks, three are located in seaward positions relative to other features in the HFD zones, one draining over the edge of the cliff that forms the northern boundary (Parcels 22 and 23), and the other two draining near the convergence point between Agaputuputu Stream and the cliff (Parcels 20, 21, 24, 25, 26, and 27). Ditch elements that constitute these three networks are the largest in A’ofa. Of the two smaller ditch-and-parcel networks, one (Parcels 16 and 17) is located near the centre of the HFD zone, just downslope of Feature 19 (the largest terrace identified, refer to Fig. 6.7). The other is located on the greatest slopes in which ditching was identified (Parcels 7, 8, and 9) (Fig. 6.12), between and connecting to two streams. Single branch features were found throughout A’ofa and are associated with other archaeological remains, particularly those in the centre of the HFD zone. Eight of 12 single branch features for which confident distributional data is available are within 10 m of terraces (67 percent). More specific details regarding the association of ditch-and-parcel complexes with other features are discussed in regard to the terrace feature class below.

Parcel size increases as the distance from the mean centre of the HFD unit increases ($n = 27$; $r = 0.49$; $R^2 = 0.24$; $p = 0.009$) (Fig. 6.13). In general, then, larger parcels are located near the borders of the HFD zone, and smaller parcels near the centre. To further check the validity of this pattern, the mean centre of the extended boundaries, which accounts for areas lacking bare earth returns in the Lidar data, was utilised in analysis. The pattern is more statistically significant using this variable ($n = 27$; $r = 0.55$; $R^2 = 0.30$; $p = 0.003$) (Fig. 6.14).

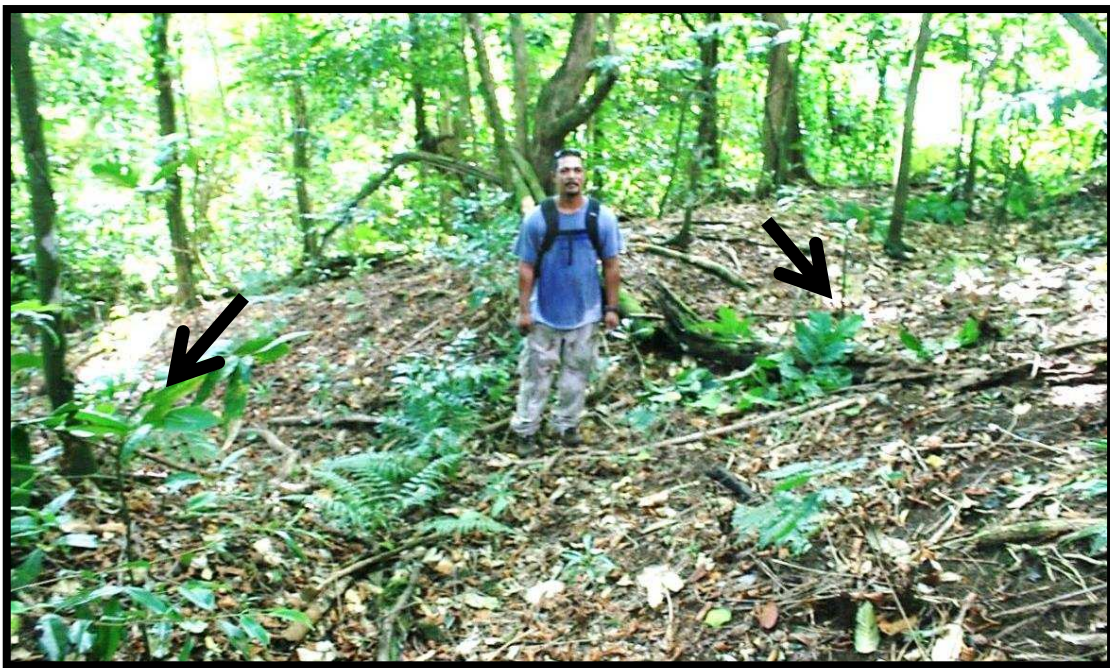


Figure 6.12 Connection point of ditch-and-parcel network (Parcels 7, 8, and 9). Arrows indicate the direction of slope off of the ditch bund

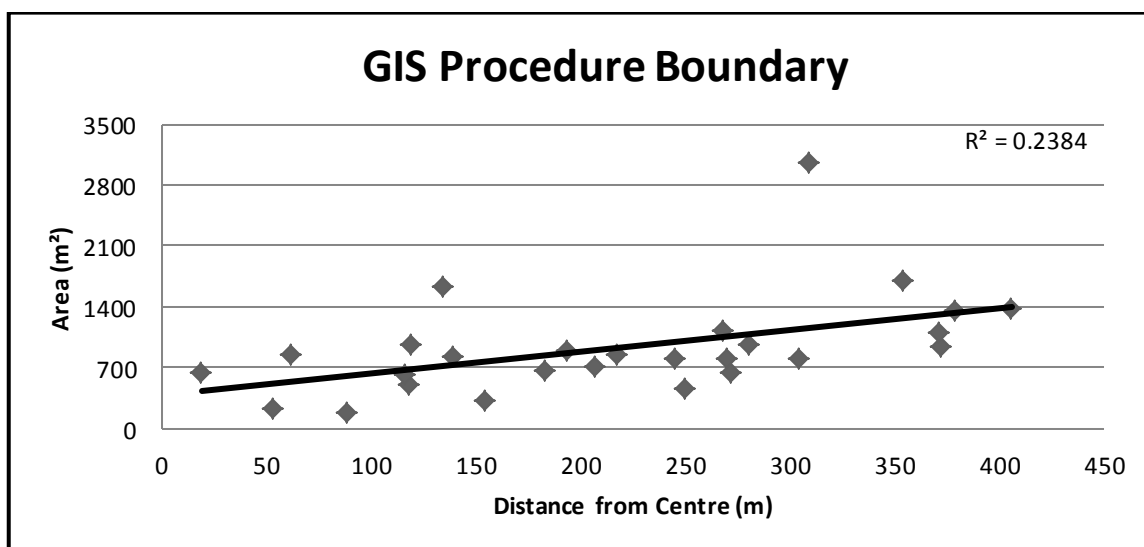


Figure 6.13 The relationship between parcel size and distance from centre (GIS boundaries)

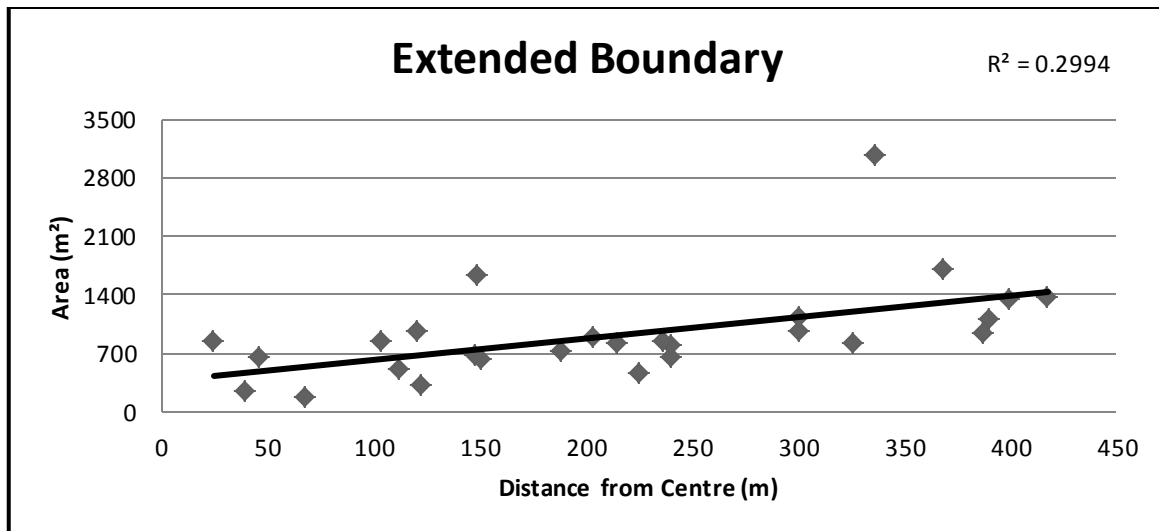


Figure 6.14 The relationship between parcel size and distance from mean centre (extended boundaries)

Terraces

Morphology. Fifty terraces were recorded in the A’ofa HFD zone (Fig. 6.15, Appendix 1), most as part of the detailed survey transect. Two additional terraces were recorded outside of this transect for analytical purposes. One was located on steep slopes and was excavated, presenting an opportunity to date features in this area (Feature 78). Another unique terrace, in terms of size and surface features, is included for comparative purposes (Feature 101).

All terraces in A’ofa exhibit an elongated oval shape, similar to others in the archipelago, suggestive of a similar construction method (Fig. 6.16). A combination of coral and basalt gravel (mixed paving) was most commonly found on terrace surfaces ($n = 35$) followed by just angular basalt ($n=13$). Two terraces possessed no discernible paving, but here vegetation was dense. The recorded lack of paving in the latter two might be related to post-depositional natural processes or dense surface cover. The size of terraces is variable, ranging in length from 7 to 65 m and in width from 4 to 14 m, likely a reflection of geographical characteristics (e.g., slope and elevation) and functional differences (see below). The average terrace size, of 18.8 m in length (s.d. = 10 m), 9 m in width (s.d. = 3 m), and 194 m² in area (s.d. = 129 m²), is similar to the average terrace size within Tufu (see below). These terraces were divided into equal sizes ranges, at intervals of 100 m², to discern the relationship between size, paving type, and general feature location. Of the total 50 terraces, 13 measure under 100 m², 16 measure between 101 and 200 m², 14 measure between 201 and 300 m², four measure between 301 and 400 m², and three measure over 400 m² (Fig. 6.17; Table 6.3).

Those with basalt paving were, based on a t-test of area, smaller ($n = 13$; mean area = 130 m^2) than those on which coral was located ($n = 35$; mean area = 222 m^2 ; $t\text{-stat} = -2.23$; $p = 0.036$; two-tail assuming unequal variance), but were otherwise morphologically similar. Of the terraces with a surface area below 100 m^2 , coral was not identified on 59 percent, compared with 36 percent of terraces with areas between $101\text{-}200 \text{ m}^2$. Coral was absent on only two of 21 terraces over 201 m^2 . Curbing alignments were identified, though rarely ($n = 2$). In one case, on a terrace with a surface over 400 m^2 , the curbing alignment is situated on an elevated platform atop the terrace (Feature 101; Fig. 6.18), and in the other, a terrace with a surface area under 100 m^2 , the alignment completely covers the terrace on which it was placed (Feature 8).

Spatial Distribution. When all terraces are taken into consideration, terrace size decreases as elevation increases ($n = 50$; $r = -0.31$; $R^2 = 0.096$; $p = 0.029$) (Fig. 6.19). However, when terraces recorded outside the detailed survey area are removed from analysis, the correlation between elevation and terrace size is not statistically significant, though still somewhat suggestive ($n = 48$; $r = -0.21$; $R^2 = 0.05$; $p = 0.14$). This could mean that a larger sample of terraces is needed to fully evaluate this pattern.

Ten of the 13 terraces on which coral was not identified but basalt was are situated in elevations higher than 130 metres above sea level (masl) (77 percent), the point where average slope exceeds ~ 15 degrees. Of the eight terraces exhibiting surface areas under 101 m^2 and no evidence of coral paving, six are located at least 140 masl (75 percent). Eighty-six percent of terraces on which coral was scattered are located below 130 masl (30 of 35). The two terraces that lack discernible paving were identified on slopes leading down to stream channels and were heavily vegetated. Generally, these findings indicate that large terraces with coral paving are located seaward of small terraces with no coral paving (Table 6.3).

Of the terraces with surface areas of over 400 m^2 , the largest is located in a central location (Feature 19), 40 m from the mean centre of the A'ofa HFD zone. Another (Feature 101) – the one in which a curbing alignment was situated on an elevated platform – is approximately centrally located between the western boundary of the settlement and Agaputupu Stream (175 m from the stream and 150 m from the west HFD unit boundary). The third (Feature 6) is in proximity to, 15 m away from, a ditch-and-parcel network.

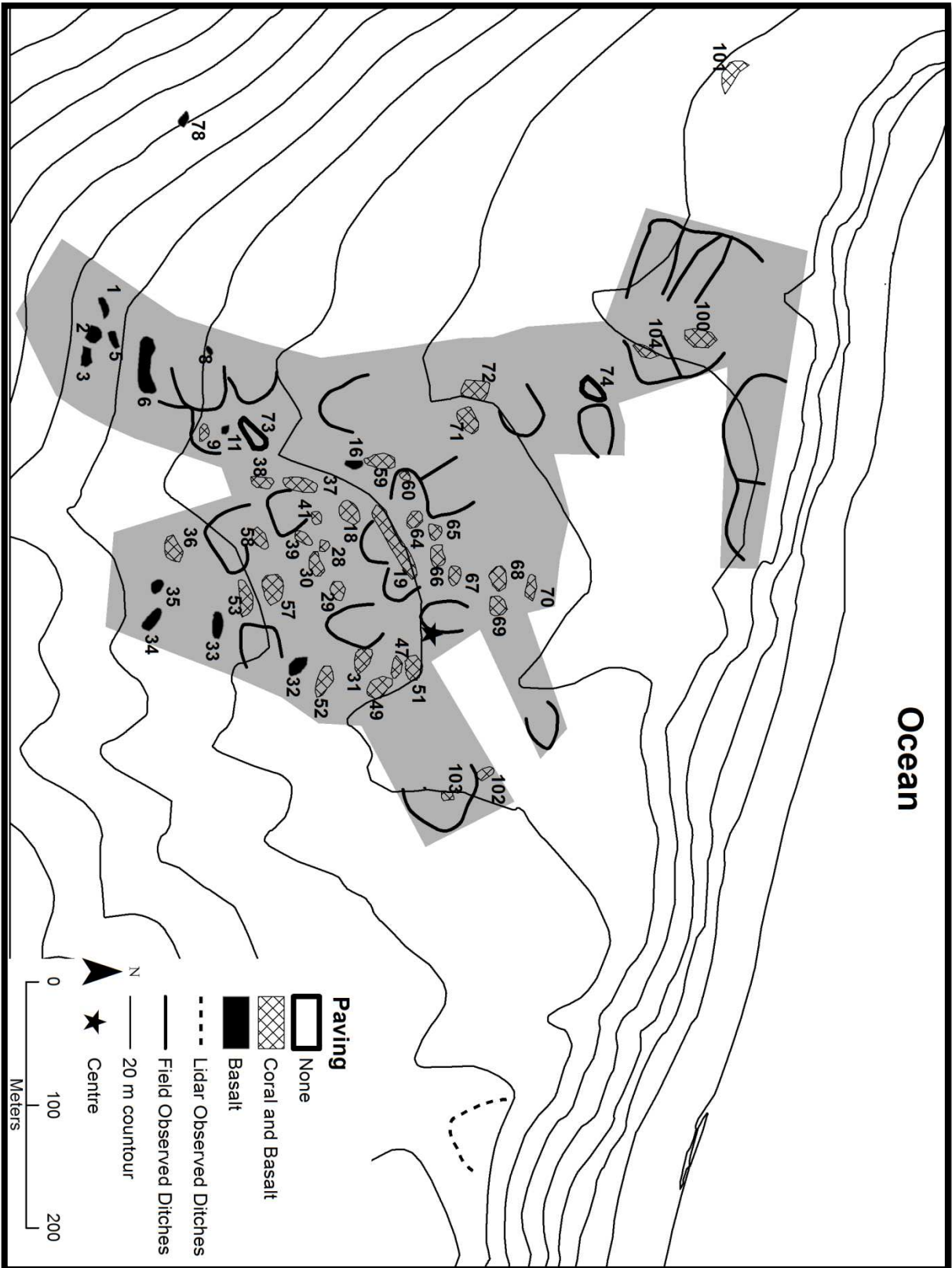


Figure 6.15 Distribution of terraces in reference to ditching in shaded detailed survey area. Labels are terrace feature numbers



Figure 6.16 Feature 1, a well-defined but small terrace in steep slopes

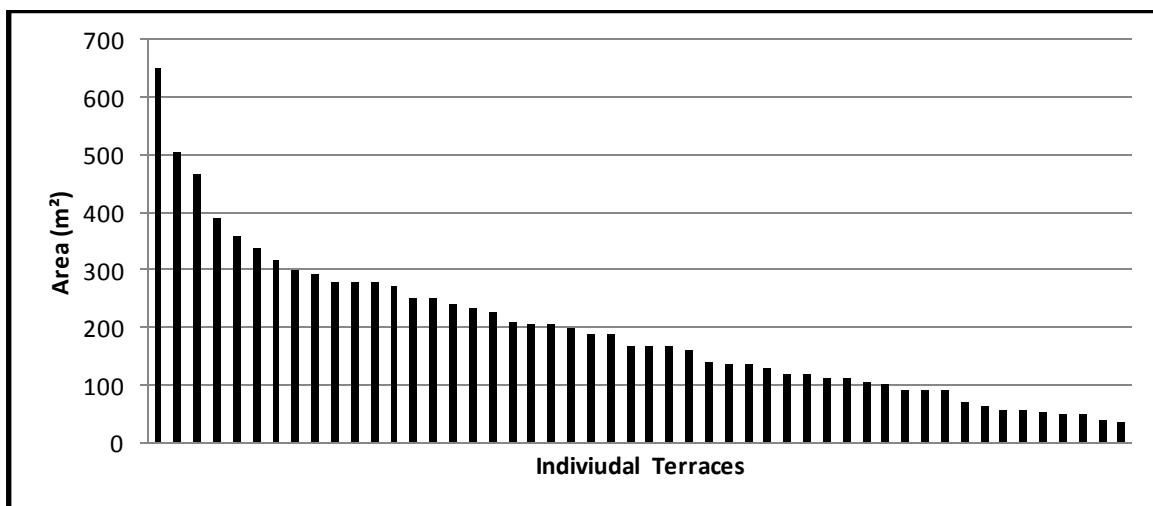


Figure 6.17 Size distribution of A'ofa terraces

Table 6.3 Frequency of each terrace size class and association with mixed paving

Size Range	No.	No. with Coral (proportion)	No. below 130 masl (proportion)
0-100m ²	13	5 (0.38)	4 (0.31)
101-200m ²	16	11 (0.69)	13 (0.81)
201-300 m ²	14	13 (0.93)	9 (0.69)
301-400 m ²	4	4 (1.0)	3 (0.75)
400 + m ²	3	2 (0.67)	2 (0.67)



Figure 6.18 Curb alignment of Feature 101

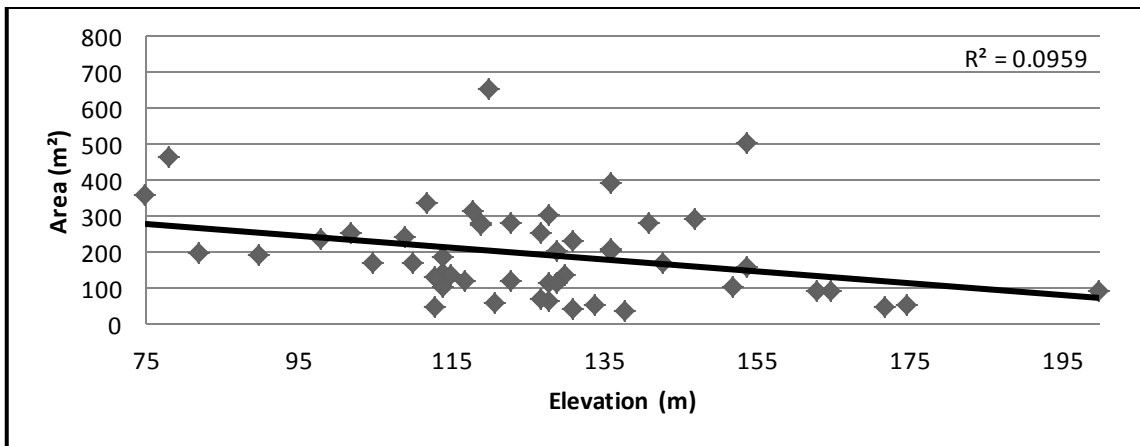


Figure 6.19 The relationship between terrace size and elevation plotted. Additionally, this analysis includes all terraces identified in the A'ofa HFD unit

Terraces also were found associated with other features. Sixteen terraces are within 10 m, but located outside the boundaries, of ditch-and-parcel complexes (16 of 50; 32 percent). Of these, nine are located within 5m: three downslope of ditching (Features 19, 37, and 74), four to the side (Features 31, 39, 59, and 102), and two to the upslope (Features 64, and 64). Six of these nine are associated with single branch features (67 percent), while the other three are in proximity to networks (33 percent). At least some coral was identified on the surface of all nine terraces. Though rare, terraces were also identified on parcels (n = 6; 12 percent of total). Four of these are quite small (Features 9, 11, 60, and 103), below average area (mean area = 49 m²), but two are either average or above average (Features 100 and 104, mean area = 279 m²). All but one of the terraces located on a parcel, Feature 103, are associated with ditch-and-parcel networks (83 percent).

Circular Depressions

Morphology. Circular depressions were more frequently identified than terraces in A'ofa (n = 52) (Appendix 1). The diameters of depressions range from 2 to 5.6 m with an average of 3.24 m (s.d. = .80 m) (Figs. 6.20, 6.21; Table 6.4). Depth is more uniform displaying a range from .16 to 1.03 m with an average of .40 m (s.d. = .19 m). Two morphological groups were identified, based on the presence or absence of basalt or coral boulders around the rim of the depression. More depressions lack this stone edging (n = 32; 62 percent), than possess it (n = 20; 38 percent) (Table 6.4). Even those possessing edging exhibit varying amounts, some with very little (3-4 stones), and basalt and coral boulders are located in different locations around the rim of each feature. No coral or basalt that was identified as edging was fire altered.

Three equal interval size classes based on feature diameter were created to examine the covariance of edging and size (depth was not utilised because of the influence of infilling). The first class ranges from 0 to 2.9 m (n = 21), the second from 3 to 3.9 m (n = 17), and the third greater from 4 m and above (n = 9). Dimensions for four depressions were not recorded and the dimensions of another were estimated given time constraints. Of the 21 that are less than 3 m in diameter, 12 have some degree of basalt or coral edge (57 percent), whereas only seven of the remaining 26 have an edge (27 percent) (Table 6.4). Based on a Chi-square test, there is some evidence to posit an association between depression diameter and the presence of basalt and coral edging, with those measuring less than 3 m more likely to possess such edging. However, this pattern is not statistically significant at the 0.05 alpha level ($\chi^2 = 4.6$; $p = .099$).



Figure 6.20 Stone edged depression (A'ofa Feature 81). Most depressions do not have this degree of edging

Table 6.4 Frequency of depression size classes and association with edging. Five features are not included in this analysis as their dimensions were estimated

	Size Range	No.	No. with Edge (proportion)
Small	2-2.9m	21	12 (0.57)
Medium	3-3.9m	17	5 (0.29)
Large	4m+	9	2 (0.22)

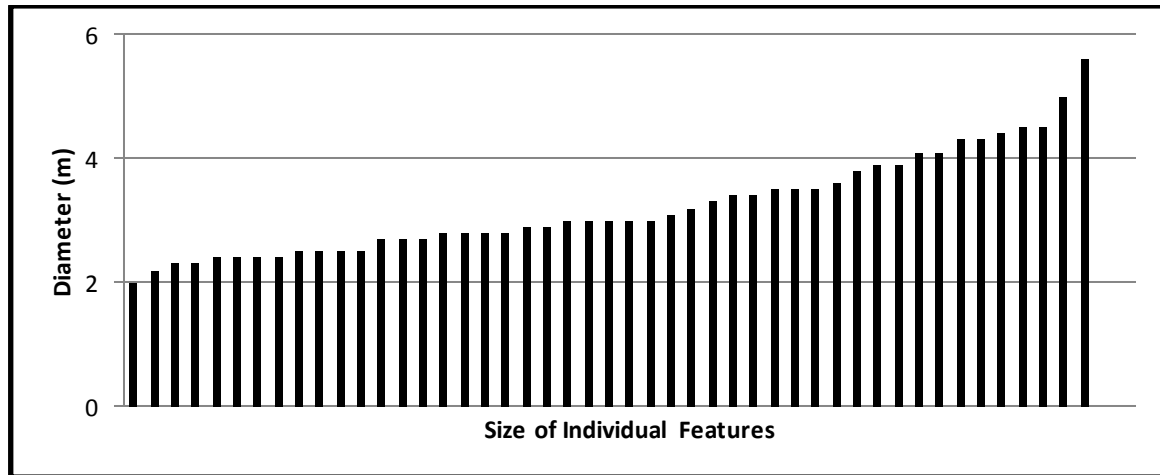


Figure 6.21 Size distribution of depressions in A'ofa

Spatial Distribution. Depressions were found throughout the detailed survey zone (Figs. 6.22, 6.23), and most are proximal to other features (90 percent). In terms of depressions for which accurate measurements were obtained, eight of the small edged examples are associated with terraces (66.6 percent): six atop a terrace (50 percent) and two within 10 m (16.6 percent). Two others are within 10 m of ditched terraces (16.6 percent) and the other two are within 10 m of ditch-and-parcel complexes (16.6 percent). One of the five medium edged depressions is located on a terrace (20 percent), three are within 10 m of a terrace (60 percent), and one is within 10 m of a ditch-and-parcel complex (20 percent). Of the two large edged depressions, one is located within 5 m of a ditched terrace and one is situated on a terrace. Six of the small non-edged depressions are situated on terraces (66.6 percent), while the rest are located within 10 m of terraces or ditch-and-parcel complexes (33.3 percent). Of the 12 medium non-edged depressions, three are located on terraces (25 percent), three are within 10 m of terraces (25 percent), one is located within 10 m of a ditch-and-parcel complex, one is located on a parcel, and one is at the end of a ditch branch. Three do not have a clear association with another feature (25 percent). Of the seven large depressions without

an edge, two are located at the end of ditch branches (28.5 percent), two within 10 m of a terrace (28.5 percent), and one atop a terrace (14 percent). Two are not associated with another feature (28.5 percent).

To summarise the detailed discussion above, depressions are more often associated with terraces than any other feature class, with 60 percent located on or within 10 m of terraces. However, edged depressions are more likely to be in proximity to terraces relative to non-edged depressions, 68 and 54 percent respectively. Of the three depressions associated with ditched terraces, all of them have an edge. Only non-edged depressions are located at the end of ditch branches ($n = 3$), and five of the non-edged depressions have no relationship with other features (5 of 28; 18 percent). The only depression situated on a parcel lacked an edge. There are more specific relationships based on size, and these relationships are examined in more detail below in relation to feature function.

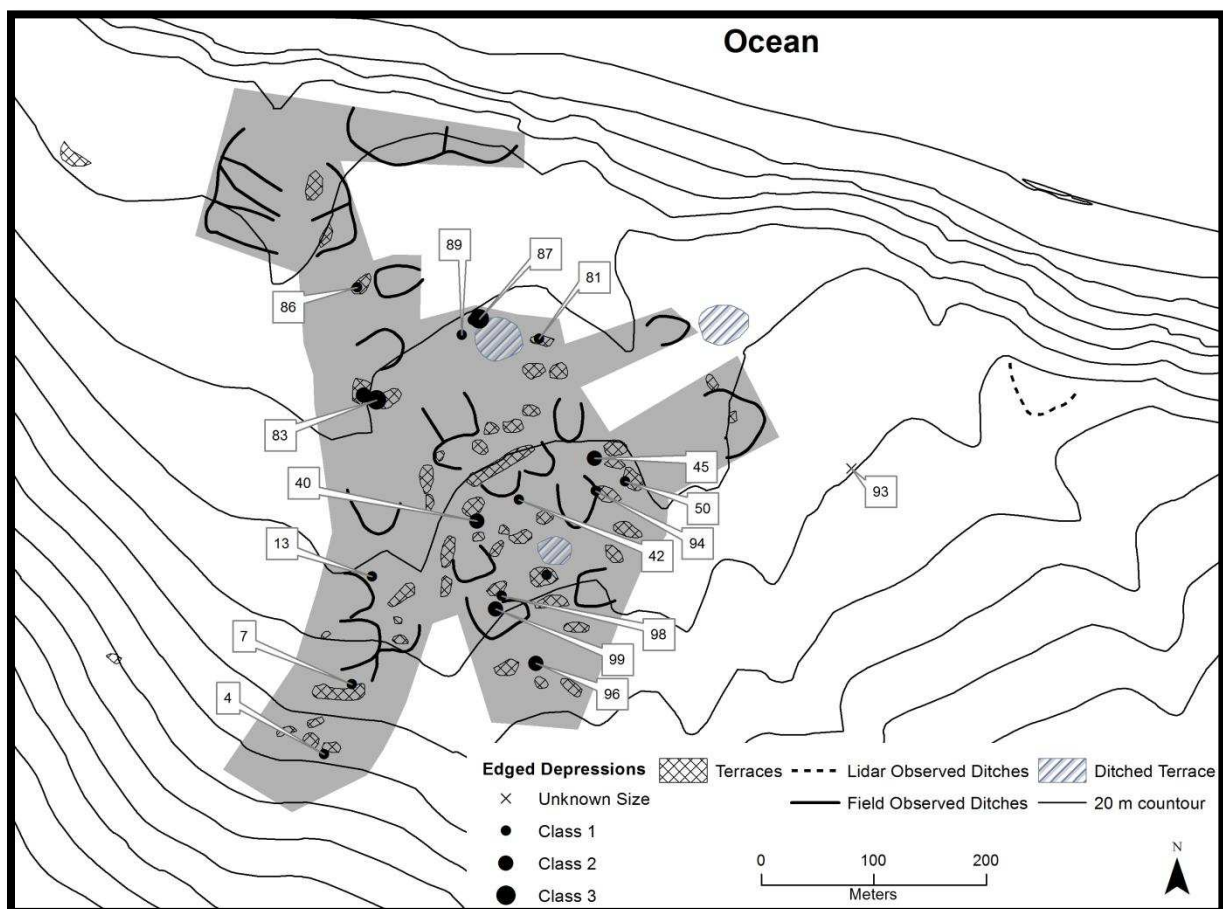


Figure 6.22 Distribution of edged depressions in A'ofa with reference to terrace distribution

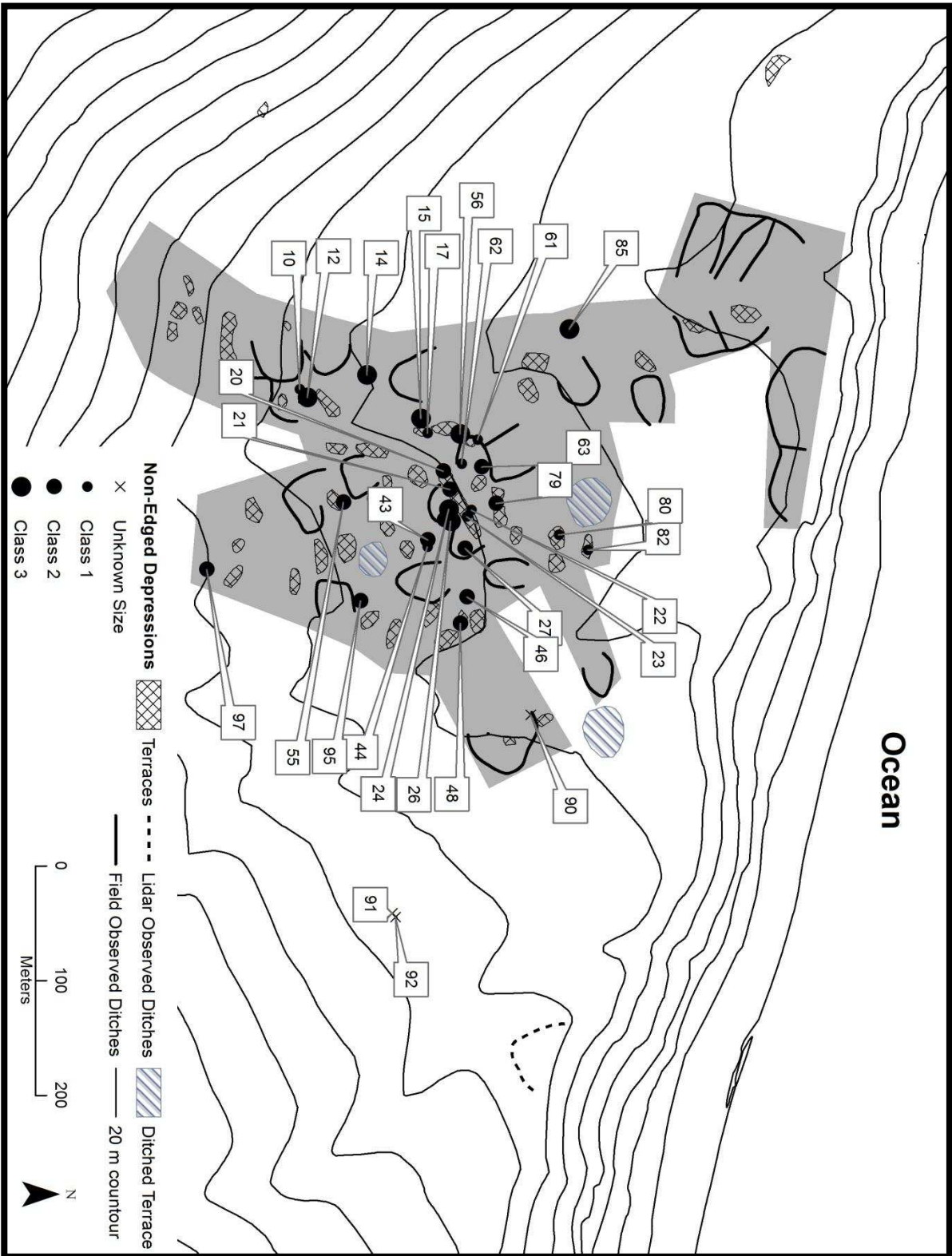


Figure 6.23 Distribution of non-edged depressions in A'ofa with reference to terrace distribution. Labels are depression feature numbers

Ditched Terraces

Two ditched terraces were confidently identified within the detailed survey area: Feature 75 measuring 23 m long and 30 m wide and Feature 77 measuring 39 m long and 41 m wide. A third, identified using the Lidar dataset, appears to be present to the east measuring 35 m long and 44 m wide (Fig. 6.24). The two confidently identified features, characterised by the presence of a terraced area completely surrounded by a ditch, are located near the centre of the A'ofa HFD zone. Each is 109 m from the mean centre. Feature 77, the northern most ditched terrace, is unique in the survey area in that it was paved only with coral, with no basalt observed on the surface. Three depressions are associated with the feature, situated within 10 m downslope. All have some degree of coral and basalt around their edges, but the size of each is variable: one is 2.2 m in diameter (Feature 89), another is 2.4 m (Feature 88), and the other 4.5 m (Feature 87).

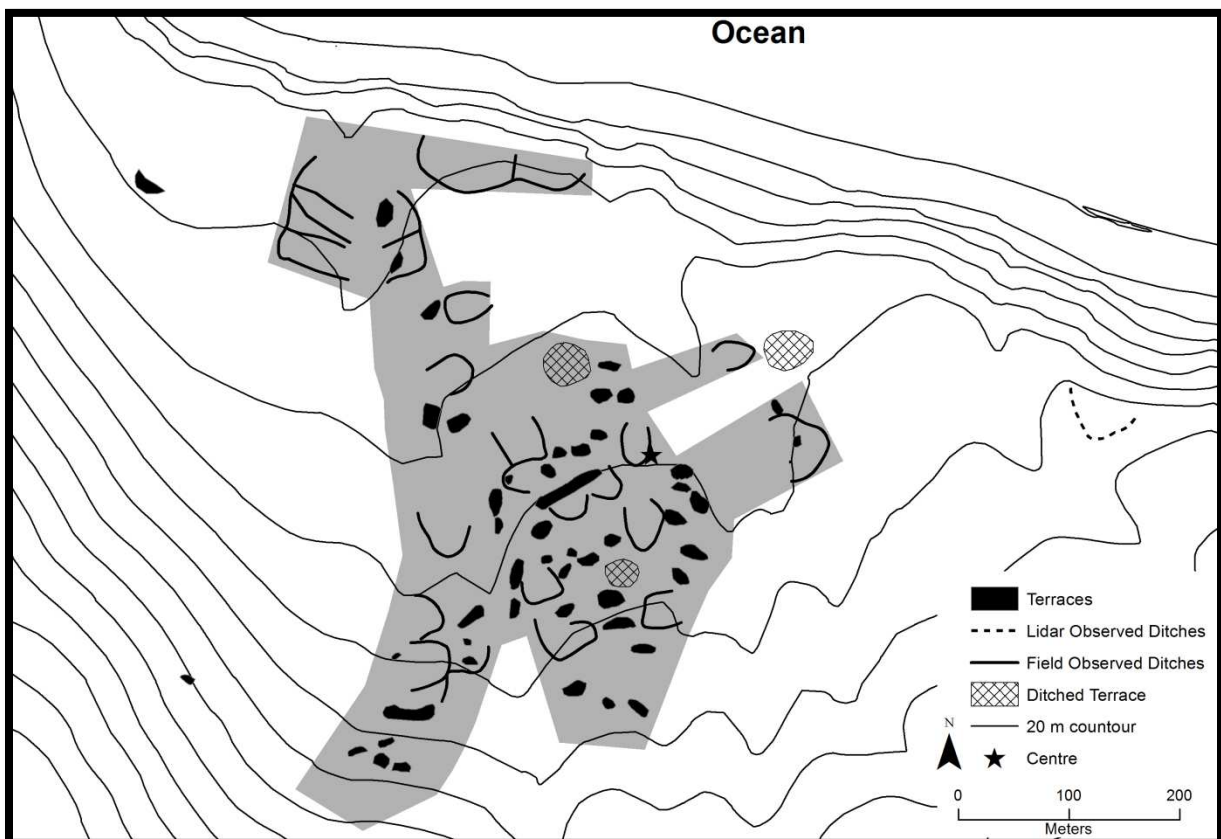


Figure 6.24 Location of ditched terraces in A'ofa. Shaded area is the detailed survey zone

Central Open Spaces

Central open spaces are identified by the absence of archaeological features in an otherwise inhabitable space (e.g., flat, close to other features), as well as the presence of surrounding structures. No areas within the detailed survey area of A'ofa meet this feature definition. This does not mean a central open space is not situated within the A'ofa HFD, though, as only limited survey was undertaken in areas seaward of the centre of the zone (directly inland of Parcels 22 and 23). Vegetation in this area is dense, which, because of time constraints, precluded reconnaissance survey in the area. No archaeological features were noted via visual inspection of the Lidar dataset.

Summary

All feature classes except for central open spaces were confidently identified in the A'ofa HFD zone. Ditch-and-parcel complexes were variable in morphology, classified as networks constituted by multiple connecting branches or single branch features. In terms of spatial patterning, single branch features are more often associated with terracing relative to networks, and the size of parcels is larger farther from the centre of the zone. The largest three ditch-and-parcel networks, in terms of the length of ditching, are located in seaward positions. Terraces were variable in terms of size and the presence of coral. Generally, terraces decrease in size as elevation increases. In a similar pattern, those terraces with coral are more likely to be found in lower elevations, and these are statistically larger than those that lack coral. Some terraces were associated with ditch-and-parcel complexes, most of which have coral on the surface. Two morphological variants of depressions were noted, based on the presence of basalt or coral distributed around the edge of the feature. Stone edged depressions were of varying size, but most are less than 3 m in diameter. In general, smaller depressions are more closely associated with terraces. Some large non-edged depressions are located at the ends of ditch branches, while others do not appear to be associated with other features. Finally, two ditched terraces were identified in the detailed survey area, with a third possible identified in Lidar. The two confidently identified ditched terraces are located near the centre of the A'ofa HFD zone, and one of these is the only feature found that exhibits only coral paving, as opposed to mixed paving.

The Archaeology of Tufu Stream (AS-13-42)

The Tufu HFD zone, inland of the southwest coast of the island, was identified in 2012 with further work undertaken in 2013. The zone is situated within a relatively flat area perched above the sea, with cliffs leading to the coastline on the west side. This flat area is bisected by Tufu Stream, the deepest drainage on the island, which leads from the coast to the ridgeline. Archaeological remains are scattered to the north and south of Tufu Stream over an area of 18 ha according to the Lidar-based density map (Fig. 6.25). Field work was more detailed to the south of the stream. The detailed survey area encompassed 10 ha of the total zone, while the remaining eight were analysed with Lidar imagery in ArcGIS. As a way to increase total coverage in the detailed survey zone, high confidence terraces, areas of 0-10 degree slope in contrast with the surrounding landscape, were identified and outlined using the Lidar dataset. Because surface modification could not be recorded for these features (e.g., presence or absence of coral and basalt), they, labelled with a prefix L, are not used in all analyses.

Within the HFD zone boundaries, ranging from 50 m to 200 m above relative sea level, slope ranges from ~10 to 30 degrees. Vegetation is variable, but largely consists of economical plants (coconut, breadfruit, *ti*, etc.) or secondary forest (largely *Hibiscus*). Historic land use is more pronounced in Tufu than in A'ofa. At the time of survey, taro gardens were situated on the slopes near the Tufu Stream channel, as well as near the cliffs on the west side of the zone. These gardens, because they have been cleared of vegetation, made it easier to identify and record prehistoric architectural features.

A total of 85 features were recorded², one being an interpreted central open space. Several ditch-and-parcel complexes were also identified, four networks and seven single branch features. Additional features, three possible ditch-and-parcel networks and nine high confidence terraces, were identified with the aid of Lidar. This section presents and analyses the results of that survey. Locational analysis utilised a mean centre of the Tufu HFD zone as a baseline. This was calculated in ArcGIS using boundaries based on the GIS procedure discussed at the beginning of this chapter (Fig. 6.2).

² There are 86 feature numbers as one feature, a depression originally labelled Feature 57, was removed from analyses as it was deemed to be natural.

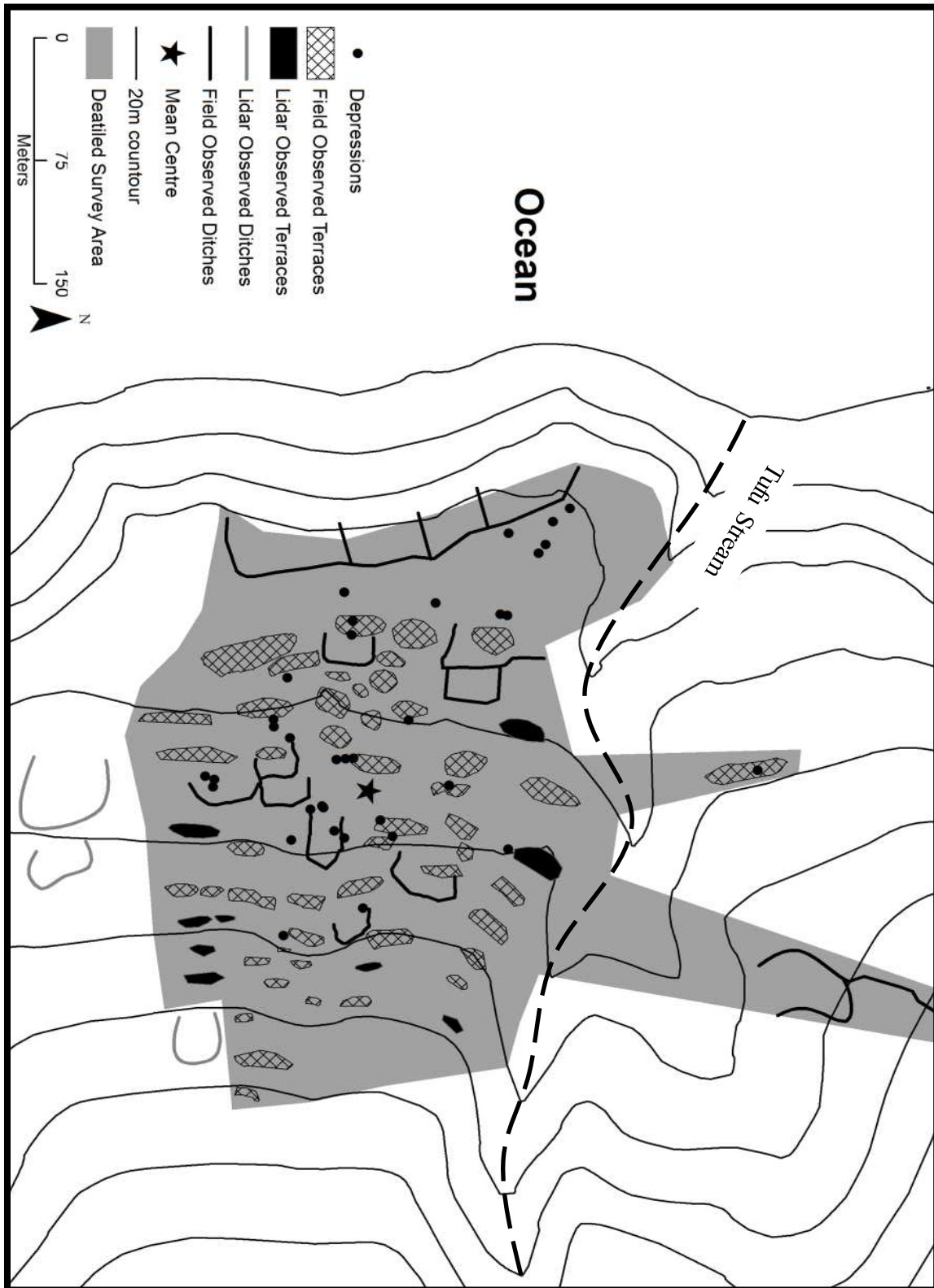


Figure 6.25 Distribution of archaeological features identified in the Tufu HFD zone

Ditch-and-Parcel Complexes

Morphology. In Tufu, 11 ditch-and-parcel complexes were identified among other archaeological features defining at least 17 individual parcels (Fig. 6.26) (Appendix 1). Most of these were visited and recorded in the field, but three were identified using the Lidar dataset. Only four single branch features were observed in the field. In sum, 1,339 m of ditching was identified in Tufu. Individual ditch elements range from 41 m (Parcel 9) to 330 m long (all ditching defining Parcels 14-17), with a mean length of 121 m (s.d. = 83 m). Based on a t-test, the difference between mean ditch length of A’ofa and Tufu is not significant ($t\text{-stat} = -0.23$; $p = 0.82$; two tailed assuming unequal variance). Also similar to A’ofa, ditch elements of networks (mean = 208 m) were larger than those that are part of single branch features (mean = 73 m) ($t\text{-stat} = 3.17$, $p = 0.04$; two tail assuming unequal variance). One network, although large (ditch length of 185 m), only forms one parcel with two distinct branches (Parcel 1). Another network is clearly an outlier in terms of total ditch length (Parcels 14-17; 330 m). Ditches average ~4 m in width, though their width ranges from 3 to 6 m (Fig 6.27). Depth was difficult to measure since many appeared infilled or eroded, but estimated depths range from 0.30-0.50 m.

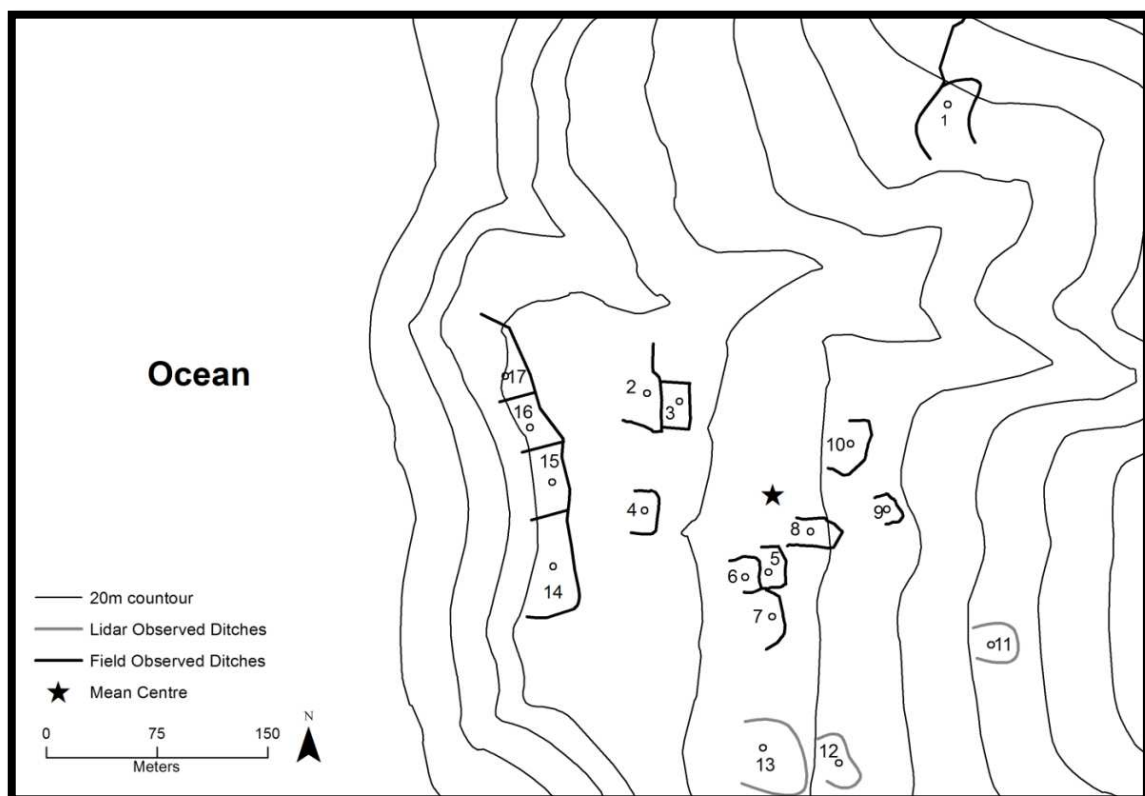


Figure 6.26 Distribution of ditch-and-parcel complexes in Tufu in relation to the mean centre of the HFD zone

Ten of the 17 parcels are part of ditch-and-parcel networks (59 percent). Parcel sizes were measured using the same methods as in A'ofa. Unfortunately, some areas of Parcels 14 and 16 could not be observed in the field given dense vegetation cover, and more ditch segments might exist that would decrease each parcel size. Though, no additional segments were visible using the Lidar dataset. Parcels range in size from 250 m² to 1,830 m², averaging 830 m² (s.d. = 493 m²). These measures do not differ significantly from A'ofa (t-stat = -0.46; p = 0.64; two tail assuming unequal variance). When features identified in Lidar are removed from consideration, there is no statistically significant difference (t-stat = -0.72; p = 0.47). The size range of these elements was divided into four equal classes (Table 6.5; Fig. 6.28): below 400 m² (n = 3), between 400 and 699 m² (n =4), between 700 and 1,000 m² (n =2), and greater than 1,000 m² (n = 5). Single branch features formed two of the three parcels measuring less than 400 m². Four of the seven parcels in the second class are part of single branch features as well, while the others are part of small networks. Two of the single branch features in this class were identified in Lidar. Of the two ditch-and-parcel complexes measuring between 700 and 999 m², both are part of a network. Four of the five parcels over 1,000 m² in area are part of networks, and the one that is not was identified using the Lidar dataset. Based on mean size, parcels that are part of networks are larger (940 m²) than those that are part of single branch features (673 m²), but, similar to A'ofa, this difference is not statistically significant (t-stat = -1.11; p = 0.28; two tail assuming unequal variance). However, when those features identified in Lidar are removed from analysis, these findings become significant (t-stat = 2.65; p = 0.02).



Figure 6.27 Ditch of Parcel 14

Table 6.5 Frequency of each ditch parcel size class with reference to ditch-and-parcel type

Range	No.	No. of Single Branch Features (proportion)	No. in Networks (proportion) (Not including Lidar)
100 m ² - 399 m ²	3	2 (0.67)	1 (0.33) (0.33)
400 m ² - 699 m ²	7	4* (0.57)	3 (0.43) (0.60)
700 m ² - 999 m ²	2	0 (0)	2 (1.0) (1.0)
1000 m ² +	5	1* (0.20)	4 (0.80) (1.0)

*Denotes that at least one of these features was identified on Lidar

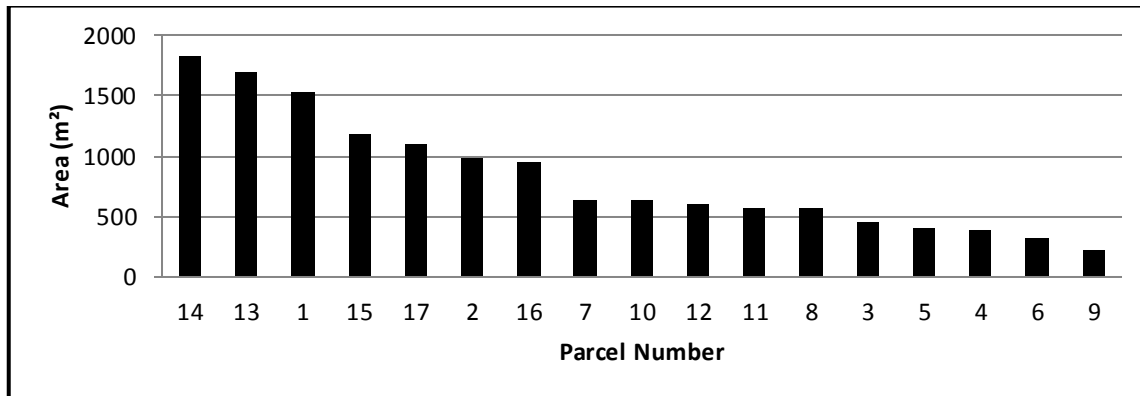


Figure 6.28 Size distribution of parcels in Tufu

Spatial Distribution. Unlike in A'ofa, only some ditch-and-parcel complexes in Tufu connected to streams or cliff edges (7 of 17; 41 percent). Most of these features were identified south of Tufu Stream, and only one network (Parcel 1 consisting of only two branches) was identified to the north (Fig 6.28). This ditch-and-parcel network, however, includes the second largest parcel in the site, and portions of this parcel are modified in the form of small terrace-like structures (not given feature numbers nor recorded in detail because of time constraints). Another large network (Parcels 14, 15, 16, and 17) is located on the zone's western periphery adjacent to a cliff. This feature is directly seaward of all terracing in Tufu, 175 m from the mean centre. Thus, it can be said that this network occupies a position seaward of the centre in the zone, buffered from terracing inland by a central open space (discussed below).

Statistically, based on correlations between parcel size and distance from mean centre, smaller parcels are situated nearer the centre of the high density zone than larger parcels ($n = 17$; $r = 0.67$; $R^2 = 0.45$; $p = 0.003$). When those ditches observed in Lidar, Parcels 12, 13, and 14, are removed from analysis, the pattern is even more statistically significant ($n = 14$; $r = 0.78$; $R^2 = 0.61$; $p = 0.0009$) (Fig. 6.29). All four of the field observed single branch features

are located within 75 m of the mean centre. These patterns are the same as those identified in A'ofa.

A number of terraces were associated with ditch-and-parcel complexes, including Features 17, 18, 32, 37, 47, and 80 and Parcels 2, 3, 4, 6, 7, 9, and 10. These are discussed at more length below, but some were of particular interest. The ditch-and-parcel complex that includes Parcels 2 and 3 is associated with a large terrace enclosed by one of the ditches (Feature 80). Furthermore, Parcel 3 possesses some attributes similar to those of ditched terraces, specifically some coral and basalt paving on the downslope edge of the parcel. However, sloping land of the parcel is proportionally greater than the small flattened area (94 percent is sloping). Therefore, this feature is classified as a ditch-and-parcel complex as defined in this study. The modification of other parcels was restricted to smaller than average terraces (Feature 47 in Parcel 6) and some depressions (e.g., Feature 52 in Parcel 8). Even within parcels that exhibit some modification, the majority of the space remains unmodified (see below for statistics).

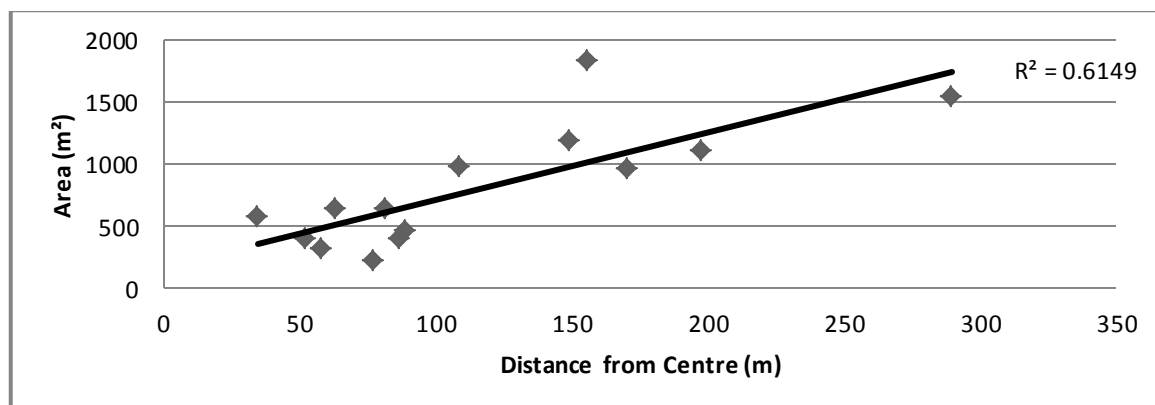


Figure 6.29 The relationship between parcel size and distance from centre. Field observed features only

Terraces

Morphology. Forty-nine terraces were identified and recorded during pedestrian survey in Tufu, with another nine outlined using the Lidar dataset (Fig. 6.30) (Appendix 1). Some terraces were point-plotted with a GPS in the field, while others were drawn utilising the area tool; a decision made based on the amount of vegetation and the estimated time it would take to clear said vegetation. Regardless of how they were plotted in the field, though, the same attributes were recorded. And, the spatial extent of point plotted terraces was outlined in ArcGIS with the aid of the Lidar dataset after fieldwork had been completed.



Figure 6.30 Distribution of terraces in Tufu in reference to ditching. Labels are the feature numbers of terraces

The Tufu terraces exhibited morphological attributes similar to those found in A’ofa. All are elongated oval shaped with steep back banks that define the feature. Those in steeper slopes, particularly near Tufu Stream, are better defined. The features range in length from 6 to 53 m and in width from 3 to 15 m, with averages of 20.0 m in length (s.d. = 7.8 m) and 10.2 m in width (s.d. = 3.5 m) (Fig. 6.31). The average area of Tufu terraces, which is 175 m² (s.d. = 134 m²), is not significantly different than that of terraces in A’ofa (t-stat = -0.73; p = 0.47; two tail assuming unequal variance). Some form of paving was found on nearly all features, basalt only on 15, a mixed paving (coral and basalt) on 33 (Fig. 6.32), and no paving on one. Curbing alignments were not identified on any.

There are correlations between terrace size, based on equal interval size classes, and presence of coral (Table 6.6). Those terraces on which coral was situated (n = 33, mean area = 215 m²) are statistically larger than those with basalt only (n = 15, mean area = 79 m²; t-stat = -4.97; p = 0.0001; two tail assuming unequal variance). Only five percent of terraces with surface areas over 201 m² lacked coral (1 of 19), and vegetation impeding inspection on that lone terrace that lack coral. In contrast, 50 percent of terraces under 200 m² lacked coral (15 of 30). Therefore, larger terraces are paved with coral more often than smaller features.

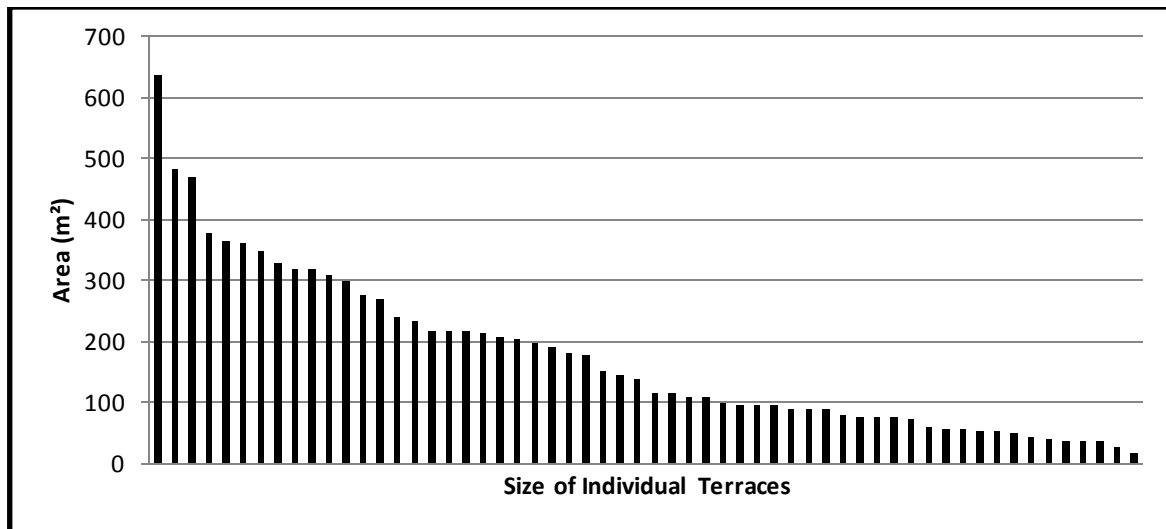


Figure 6.31 Size distribution of terrace in Tufu



Figure 6.32 Dense coral paving on Feature 31. Machete at the top of the photo is ~50 cm

Table 6.6 Frequency of terraces in each size class with reference to paving type and elevation

Size Range	No.	No. with Coral (proportion)	No. below 100 masl (proportion)
0 m ² - 100 m ²	21	10 (0.48)	6 (0.28)
101 m ² - 200 m ²	9	5 (0.56)	4 (0.44)
201 m ² - 300 m ²	10	9 (0.90)	6 (0.60)
301 m ² - 400 m ²	6	6 (1.0)	6 (1.0)
400 m ² +	3	3 (1.0)	3 (1.0)

Spatial Distribution. Terrace size decreases as elevation increases, based on correlations between terrace area and elevation ($n = 58$; $r = -0.51$; $R^2 = 0.26$; $p < 0.001$) (Fig. 6.33). In this sense, larger terraces are generally located more seaward of smaller terraces. However, exceptions do exist (e.g., Feature 58). When features identified with high confidence using the Lidar dataset are removed, this pattern is still very statistically significant ($n = 49$; $r = -0.48$; $R^2 = 0.23$; $p < 0.001$) (see also Table 6.6).

Additional patterns are evident when analysing the covariance between the paving type, location, and size of field observed terraces. All terraces with a surface area under 100 m^2 that lacked coral on the surface ($n = 11$) are located in elevations greater than 100 masl, where average slope is greater than ~ 15 degrees. Eight of these are located at least 120 masl. Seventy percent of terraces on which coral was identified are located below 100 masl (23 of 33). Two of the three largest terraces (Features 1 and 40) are two of the four most seaward terraces identified (based on linear distance from the seaward boundary). The other two seaward terraces, Feature 37 and 80, each have a surface area of over 300 m^2 . The third terrace with an area of over 400 m^2 (Feature 83) was identified north of Tufu Stream. The one terrace for which paving could not be discerned given the density of ground cover, Feature 72, is the closest feature to the mean centre of Tufu, within 10 m. This feature is larger than average, with a surface area of 300 m^2 . These general findings indicate that large terraces with coral are found more seaward of small terraces lacking coral (Table 6.6).

In some instances, terracing was found in association with ditch-and-parcel complexes; two terraces, Features 47 and 80, located on parcels (2 of 58; 3 percent). Both of these terraces are associated with networks and are paved with coral and basalt. Even so, similar to the situation in A'ofa, most of each parcel remains sloping (terracing representing 26 and 33 percent of total area respectively). Four features (17, 18, 32, 37) are located less than 10 m downslope from ditch-and-parcel complexes (4 of 52; 8 percent). Of these four, three are associated with single branch features. All of these features have a surface area over 100 m^2 , though coral was not found on two of the four.

Depressions are often found within 10-15 m of terraces, but only seven of these features are directly located on other features (on Features 37, 34, 66, 73, 76, 79, and 83). The only depression of that seven with edging was located on a terrace with coral and basalt paving. This number may be higher in reality given inconsistencies in how depressions were recorded and assigned feature numbers during initial survey (see below).

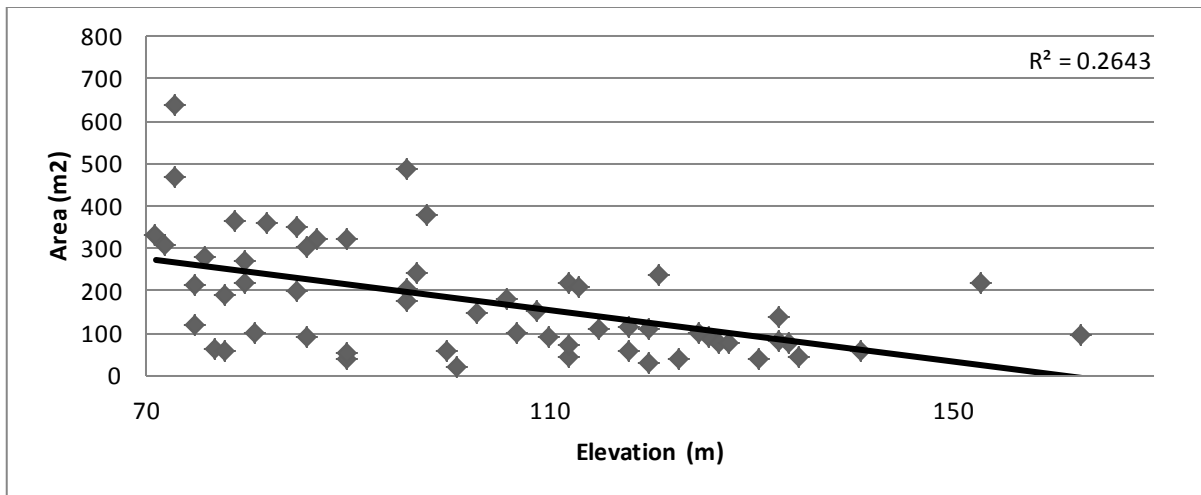


Figure 6.33 The relationship between terrace size and elevation, including terraces identified with the Lidar dataset

Circular Depressions

Morphology. Unfortunately, the documentation of depressions in Tufu was significantly limited by time constraints of field work, and only a subset of these features was recorded because of a preference for recording terraces and ditch-and-parcel complexes more thoroughly. The presence of basalt or coral was noted in field descriptions, but the recording of this attribute was not consistent and time constraints did not allow for resurvey. This bias limits what can be inferred about the nature of the feature class. Definitive statements regarding these features are problematic and this discussion should be thought of as preliminary.

Thirty-five circular depressions of two forms were identified within Tufu (Appendix 1). The dimensions of many depressions in Tufu had to be estimated in the field given time constraints. Based on both estimated and measured values, the diameter of depressions averaged 2.86 m (s.d. = 1 m) with an average depth of .48 m (s.d. = 0.31 m), ranging in diameter from 6 m to 1 m and depth from 1.36 m to 0.14 m. Of the 24 depressions for which dimensions were measured, 17 had a diameter of less than 3 m (71 percent), four had a diameter of between 3 and 4 m (16 percent), and three had a diameter of greater than 4 m (13percent) (Fig. 6.34; Table 6.7). Based on dimensions of measured features, depressions in Tufu are statistically smaller than those in A'ofa (t-stat = -2.54; p = 0.0144; two tail assuming unequal variance). However, when estimated sizes are included in the Tufu dataset, the size difference of depressions within each zone is not significant at 0.05 alpha level (t-stat = -1.75; p = 0.08; two tail assuming unequal variance).

Similar to A'ofa, two morphological forms were noted. The first of the two, which included just eight examples, is characterised by coral and basalt boulders that form an edge around the depression. Usually, this edging is not present on all sides of the feature, but, instead, is denser on one side than the others. The side with the densest edging is different on each. Of the six edged depression for which accurate dimensional measurements were obtained, four (Features 34, 50, 51, and 53) have a diameter of less than 3 m (4 of 17 in this size class; 23 percent). The other two edged depressions (Features 3 and 52) have diameters of 3 m and 4.3 m. Edged depressions account for two of the seven depressions in the two largest size classes (29 percent) (Table 6.7). The other type of depression exhibit no apparent edging (n = 27). These depressions were at times difficult to identify as anthropogenic, and it is possible that some of the smaller ones are natural. Nevertheless, some were quite large, particularly Features 69, 71, and 82, and are clearly anthropogenic (Fig. 6.35).

Spatial Distribution. The small sample size and the uneven identification of depressions severely restrict what can be said about the spatial distribution of these features (Fig. 6.36, 6.37). Sixteen depressions were found in direct association with other feature classes (46 percent). Seven are located on terraces, six on parcels, and another three at the downslope termination point of ditches. Most others are situated within 10-20 m of associated features, and nine depressions were found in the gap between the most seaward ditching and the most seaward terracing, the only archaeological features in that location. Three of these depressions had an edge and the remaining six did not. Half of all recorded edged depressions are located in proximity to Parcel 8, though this is a reflection of sample bias and not human behaviour. Only one of seven depressions located on terrace has an edge (14 percent), though, again, this may relate to sample bias.

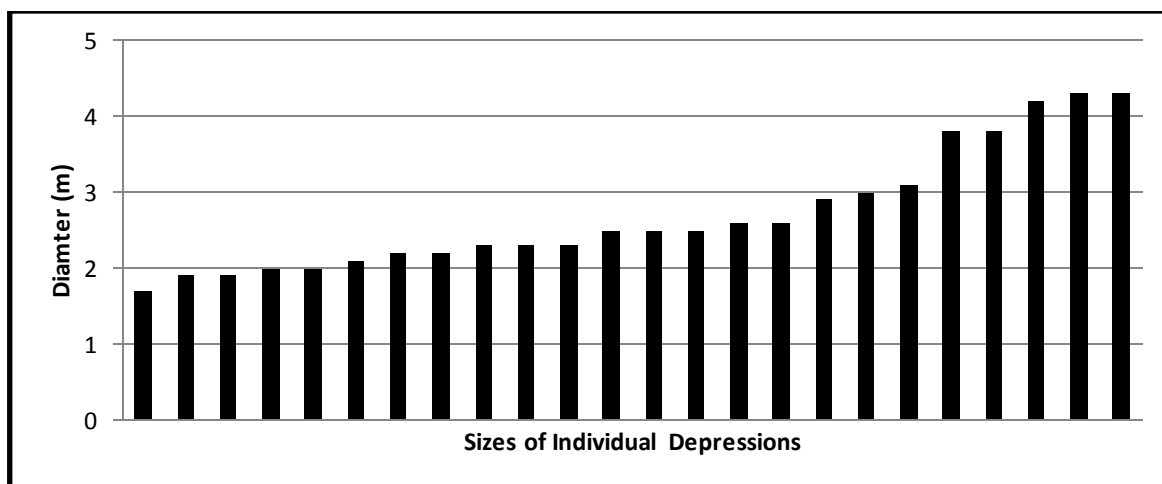


Figure 6.34 Size distribution of measured depressions in Tufu

Table 6.7 Frequency of size classes and their relationship with stone edging. These should be viewed with caution as this is only a subset of depressions in the area

	Size Range	No.	No. with Edge (proportion)
Small	2-2.9m	17	4 (0.24)
Medium	3-3.9m	4	1 (0.25)
Large	4m+	3	1 (0.33)



Figure 6.35 Feature 52 dug into the bottom of Parcel 8. Note the otherwise sloping ground around the depression

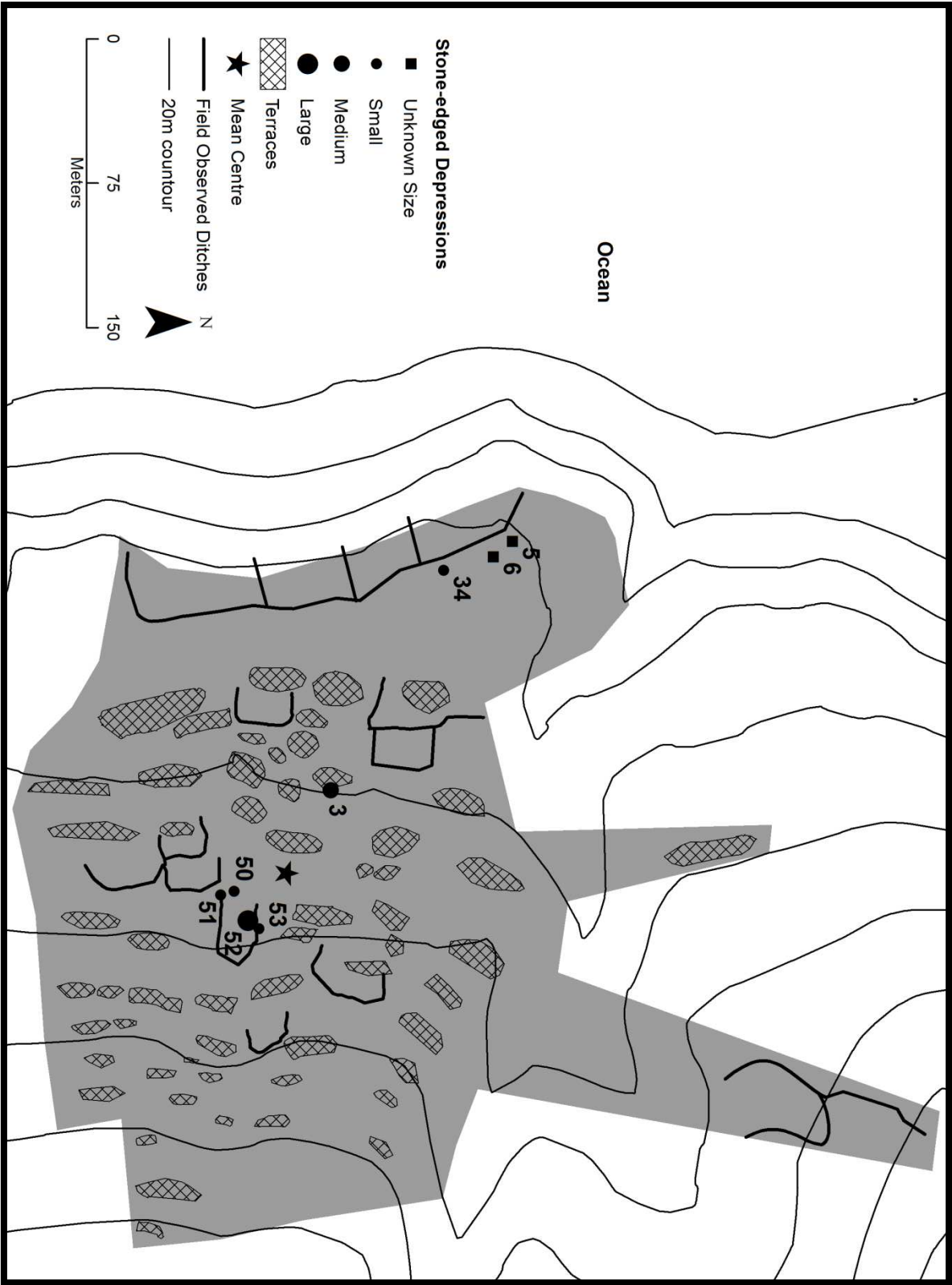


Figure 6.36 Distribution of edged depressions of Tufu in reference to terraces. Depressions in which dimensions were estimated are not included

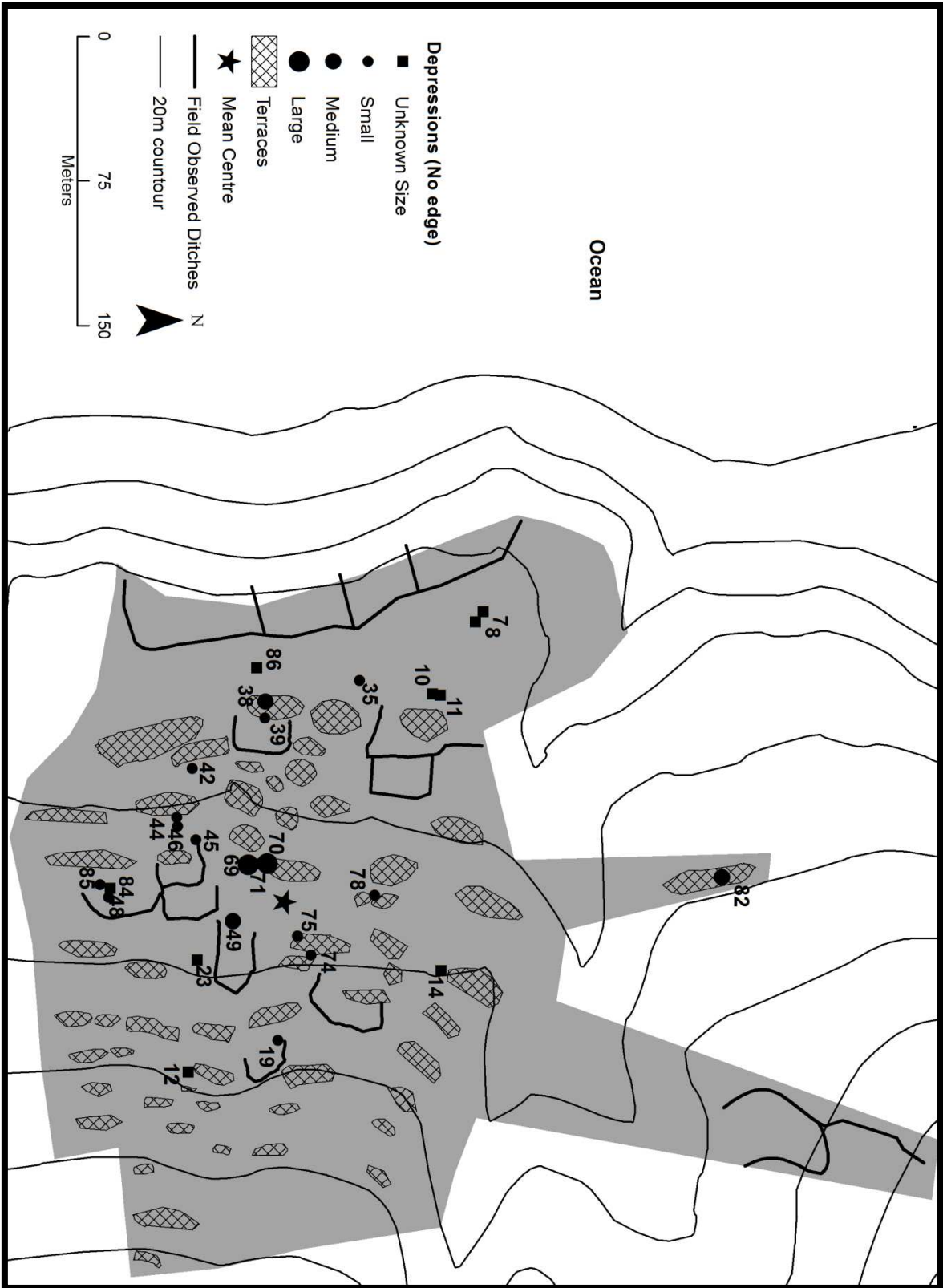


Figure 6.37 Distribution of non-edged depressions in Tufu in reference to terraces. Depressions in which dimensions were estimated are not included

Ditched Terraces

The only feature with some attributes of a ditched terrace is Parcel 3. The feature exhibits an artificially flattened surface at the front of the parcel onto which is scattered coral and basalt gravel (downslope side). Like other parcels in Tufu and A'ofa, and unlike ditched terraces, the majority of the parcel remains sloping (94 percent). Because of this, the feature is classified as an element of a ditch-and-parcel complex.

Central Open Space

A central space was identified in a seaward central position near the cliffs that form the western boundary of the HFD zone (recorded as Feature 4) (Fig. 6.38). Located within an area devoid of terraces, coral gravel and a few depressions were found dispersed across the surface. Such unterraced land is unusual given the optimal characteristics of the location, in terms of slope and accessibility of the coast. The largest and visually most prominent ditch-and-parcel network is located seaward of this area, and the possible central space creates a buffer between the network and the seaward most terracing. These terraces, situated parallel to the central open space, are larger than average (see below) with coral and basalt paving. The size of the zone ranges, but is roughly 30 wide and 180 m long (5400 m² area).

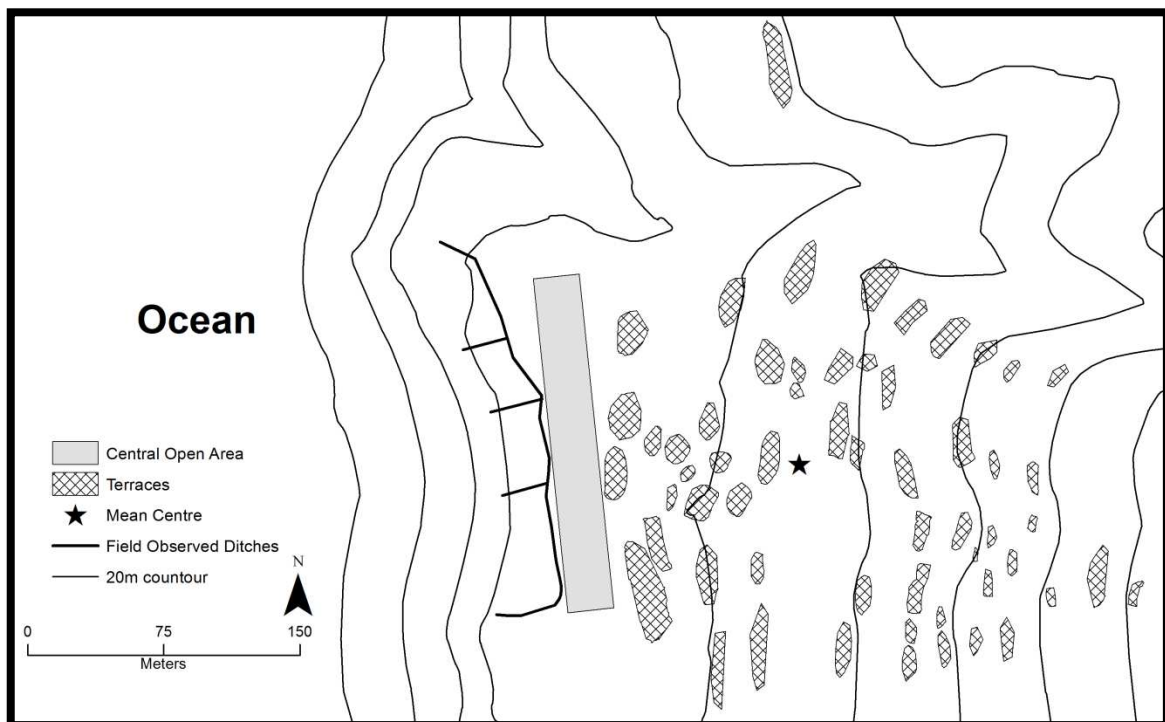


Figure 6.38 Central open space in Tufu

Summary

All feature classes except for ditched terraces were positively identified in Tufu. The spatial patterning of each feature class is similar to those in A'ofa, and feature variability between the two zones is not significantly different. Two ditch-and-parcel complex variants can be distinguished, those constituted by multiple branches (networks) and those that are single branch features. Parcel size generally decreases with increased distance from the centre of the zone. All field observed single branch features are within 75 m of the centre. Terraces decrease in size as elevation increases, with four of the largest terraces located in a central seaward position. Additionally, terraces lacking coral on their surfaces are generally located inland of those possessing coral. A central open space is situated in the zone between the seaward most terracing and a prominent ditch-and-parcel complex network. Depressions in Tufu were not consistently recorded making inferences about their nature problematic. Nevertheless, like A'ofa, two forms were identified, those with and without basalt or coral edging.

Feature Analysis and Functional Interpretation

In this section, features from A'ofa and Tufu are examined as one dataset in order to present some functional interpretations. General patterns of morphology in each zone were identified and discussed above, but combining both datasets allows for a more confident evaluation of these findings based on a larger sample size. In the case of depressions, however, only the A'ofa dataset is considered because of uncertainties associated with the Tufu dataset. The arguments regarding function are based on performance modelling and empirical observation. In each case, interpretations presented are compared to similar features that have been identified on other islands of the archipelago.

Ditch-and-Parcel Complexes

Aggregate features that include ditches and other elements have been identified throughout the archipelago (e.g., Clark 1989; Clark and Herdrich 1988, 1993; Davidson 1974a,b,c; Quintus 2012). Ditch features and groups of features that include ditches have been interpreted as defensive features (e.g., Clark and Herdrich 1993:163), paths (e.g., Davidson 1974a:239; Quintus and Clark 2012:283), or agricultural protection or drainage devices (e.g., Davidson 1974a:239, c:157; Ishizuki 1974:49; Quintus 2012:136).

If ditches were used as paths on Ofu, they would be unlikely to define parcels. Additionally, the general ditch size and downslope bunds would not be necessary if employed as such. If used as defensive features, ditches would be more linear, stretching the length of the seaward portion of each HFD zone to provide protection. Instead, the spatial distribution of parcels defined by ditches provides little defense for any feature, residential or non-residential, in A'ofa or Tufu. Therefore, the internal complexity (Fig. 6.39) and spatial distribution of ditch-and-parcel complexes on Ofu excludes their primary use as paths or defensive features.

To gather more evidence relating to function, hydrological modelling was conducted on ditching associated with Parcels 7, 8, and 9 utilising ArcGIS hydrological tools and the Manning Equation described in Chapter 4 (whereas $k = 1 \text{ m}^{1/3}/\text{s}$, $n = 0.024$, $A = 1.26 \text{ m}^2$, $P = 4.23 \text{ m}$, $R = A/P = 0.30 \text{ m}$, and $S = 0.22$) (Fig. 6.40).

$$Q = \frac{k}{n} AR^{2/3} \sqrt{S}$$

Estimated volumetric flow rates (Q), a measure of discharge capacity, indicate that ditches could transport as much as 11 m^3 of water per second (roughly 10,000 litres of water per second). These results illustrate the capacity of these ditches to drain water. As a heuristic comparison, Table 6.8 presents the peak discharge amounts of 11 streams on the island of Tutuila (Wong 1996; average discharge is significantly lower). Most of these streams act as drainage points for large watersheds, which is not the case of ditch-and-parcel complexes on Ofu. Even so, the drainage capacity of the scanned complex on Ofu is greater than or roughly equal to four of the 11 streams for which peak drainage capacity was calculated (36 percent). This indicates that the drainage efficiency of these anthropogenic ditches was on par with natural drainages, and they could effectively transport water under peak drainage conditions.

By feature definition, parcels are not flattened, terraced, or paved (Fig 6.39 illustrates the sloping nature of typical parcels, which have a minimum slope of ~15 degrees). Even when portions of the parcel are modified in some way, terraced or flattened land constitutes a minimal proportion of the parcel, in every instance less than 40 percent of the parcel area. When terraces were identified downslope of ditch-and-parcel complexes, the extent of the ditching did not fully encompass the terracing, an example being Feature 19 in A'ofa and Features 18 and 32 in Tufu. Rather, if it was not for depressions on the end of some ditch branches, water would be transported onto terrace surfaces. If these features defined

households, multiple feature classes would likely be represented *within each* ditch-and-parcel complex. Additionally, ditch-and-parcel complexes were not associated with all terraces, especially the networks of ditching in seaward positions (e.g., Parcels 14-17 in Tufu and Parcels 23-27 in A’ofa). These attributes imply that their primary function was not as residential features, nor was it to define household groups.

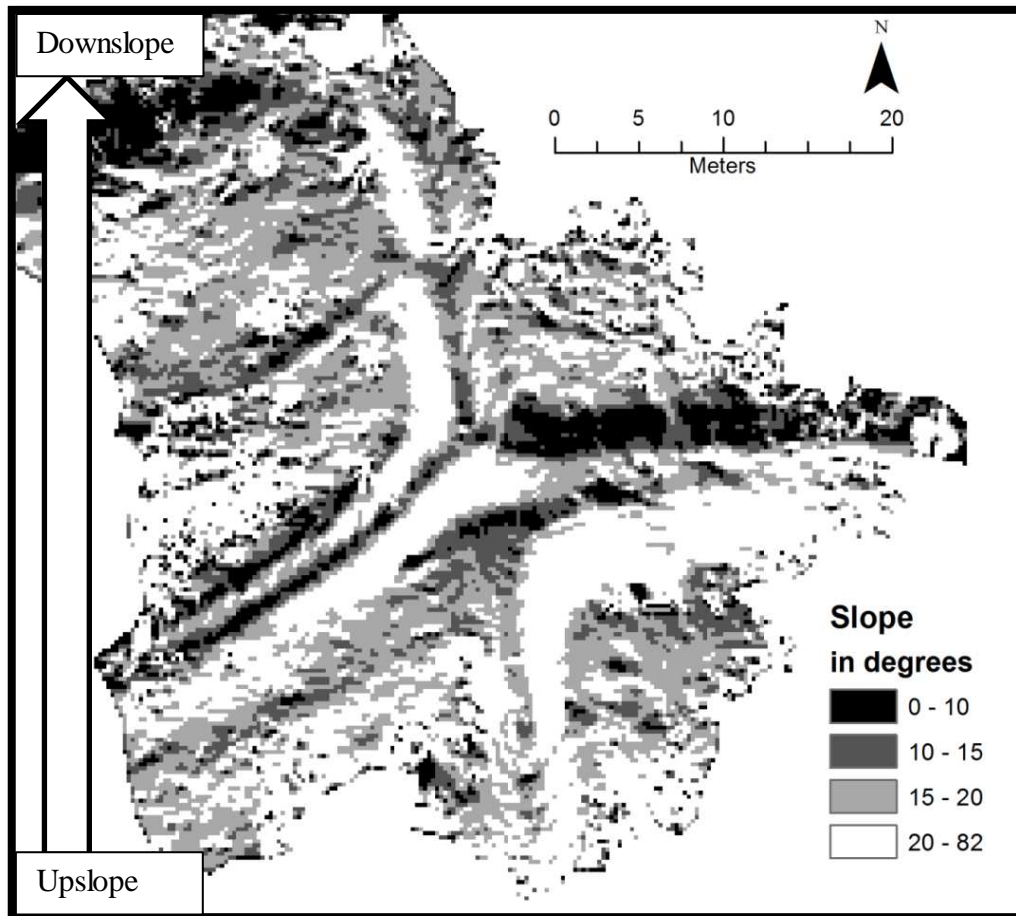


Figure 6.39 Slope map of ditch-and-parcel complex Parcels 7, 8, and 9

Given the above evidence, I propose that ditch-and-parcel complexes were water control features where parcels served as cultivation plots. Cultivation is one of few activities that could be undertaken on such sloping ground and would necessitate the construction of ditches. Ditches are oriented or are curved downslope, some widening with decreased elevation, a shape which is conducive to allowing slope and gravity to transport water around parcels. All open ditch ends terminate at lower elevations than the top of ditches, downslope of parcels, from which many drain into stream courses or off cliffs (68 percent) or, perhaps, into depressions. Ditch bunds do not include any opening, which precludes the transference

of water into parcels. Therefore, the ditches and parcels that are part of this feature type acted as drainage not irrigation features. Assuming drainage of excess water, these ditches were most likely utilised to protect herbaceous cultigens and soils on parcels from excess run-off. The cross-slope ditch components of each complex situated upslope probably decreased run-off to the extent that soil erosion was reduced on parcels. Potentially, this could increase the long-term, decadal or longer, productivity of cultivated spaces.

These features probably also served additional functions. Given the size of ditching (~4m wide and ~.50 m deep), they would likely have the ability to trap debris flows or landslides moving downslope. Boulders, several quite large (over a 1m in diameter), were found in many ditch elements during survey, while upslope sections of some ditch-and-parcel complexes were observed to be completely infilled by post-use sedimentation. These might not have demarcated entire households, but ditch-and-parcel complexes created permanent plot boundaries. This configuration could be managed more effectively than unmarked shifting cultivation plots, a situation argued for permanent boundaries in Hawai'i (Allen 2004:219) and Anuta (Yen 1973). Given the very modest evidence of the presence of a possible post mold or root or tuber cast in profile of one ditch bund (A'ofa Parcel 3), it is possible that fences were built or crops were planted atop ditch bunds. This latter practice is one that still occurs today on ditch bunds built along streams on the coastal flats to protect crops from flooding.

Finally, there appears to be differences in the labour invested to construct different types of ditch-and-parcel complexes. When the datasets from Tufu and A'ofa are combined, the mean length of ditches that form networks (205 m; n = 9) is statistically greater than those that form single features (79 m; n = 21) (t-stat = 4.74; p = 0.001; two tail assuming unequal variance), with no overlap between lengths (Fig. 6.41). Using this data, the average volume of dirt removed to construct these earthen modifications was 410 m³ for each network and 159 m³ for each single branch feature, with volume calculated as L x W x D, assuming an average ditch width of 4 m and depth of 0.50 m. For the largest ditch-and-parcel networks in Tufu and A'ofa, approximately 660 m³ and 694 m³ of earth was moved. These findings imply that the construction of different types of ditch-and-parcel complexes required different levels of effort.

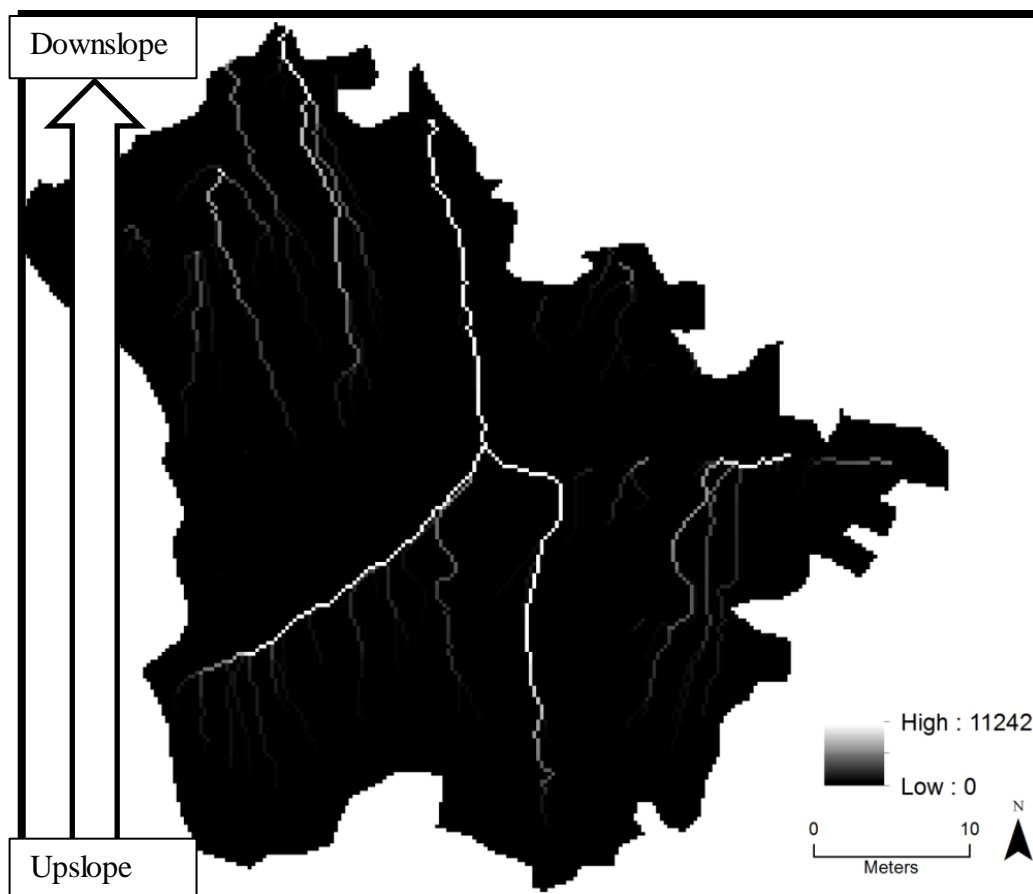


Figure 6.40 Flow accumulation model based on a TLS derived DEM of the ditch-and-parcel complex constituted by Parcels 7, 8, and 9. White indicates increasing flow accumulation

Table 6.8 Peak discharge of 11 streams on Tutuila (data from Wong 1996), and modelled archaeological ditch

Number	Name	Maximum Discharge (m ³ /s)
9442	Papa Stream	46.4
9120	Pago Stream (Afono)	38.2
9310	Atauloma Stream	23.1
9060	Vaitolu Stream	22.7
9315	Asili Stream	18.0
9480	Afuelo Stream	15.1
9205	Aasu Stream	14.1
9335	Leafu Stream (Leone)	11.3
This Study	Parcels 7, 8, 9	11.0
9175	Leele Stream	11.0
9600	Alega Stream	6.6
9639	Leafu Stream (Auasi)	6.6

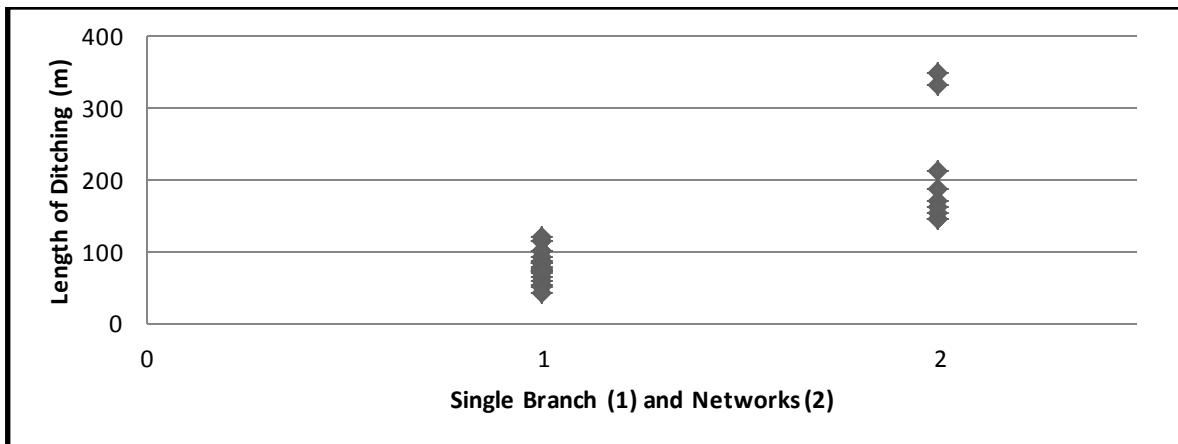


Figure 6.41 Total length of ditches of each single ditch (1; n = 21) or individual network (2; n = 9).

Terraces

The primary functional distinction in the terrace feature class is between those that served residential functions and those that did not. Residential terraces formed a primary living floor, on which one or more structures for everyday domestic activity could be erected. Non-residential terraces did not form a primary living floor and probably never supported large, permanent structures. Certain domestic activities likely occurred on these latter features, such as eating or limited cooking, but they are hypothesised to have been used more ephemerally. The identification of residential terracing is partially based on the presence of sub-rounded coral paving indicative of a house floor, a variable proposed by others for terraces in Manu'a (Clark et al. 2012:8; Quintus and Clark 2012). This variable is supplemented by considering feature size. Specifically, a simple two-variable paradigmatic classification scheme was defined by studying the intersection of the five size classes of terrace surface area with the presence/absence of coral, creating 10 classes (Table 6.9). These classes were compared to terrace location to further assess functional and spatial differences (above or below a threshold based on the approximate location where average slope exceeds ~15 degrees; 100 masl in Tufu and 130 masl in A'ofa). Functional interpretations are presented based on these results. The following functional assessments are generalisations about each class as a whole. The majority of features within each class probably share the function, but a definitive functional assignment cannot be made for each feature individually.

Features within Classes 1N (n = 19), 1C (n = 15), and 2N (n = 9) are all relatively small (all under 200 m² in surface area), and those in Class 1N and 2N lack coral on their surfaces. Features within these classes were identified at higher elevations more frequently

than features in other classes (Table 6.3, 6.6, 6.9). One hundred percent of Class 1N terraces are found in the high elevations of each HFD zone (>100 masl, Tufu; >130 masl, A'ofa; point where average slope exceeds ~15 degrees), and the majority of Class 2N terraces are as well (5 of 9; 56 percent). The lack of coral implies the absence of a floor, and their small size precludes the construction of permanent domestic structures. These attributes of Class 1N and 2N terraces are consistent with a non-residential function. This evidence is consistent with the proposition that non-domestic activities occurred in high elevations and steep slopes. Features in Class 1C, especially those located on parcels (e.g., A'ofa Feature 103) or in high elevations (e.g., Tufu Feature 61), might have been non-residential as well, as their location implies close association with areas of cultivation. However, at least some appear to have been used for more permanent residential activities (e.g., A'ofa Feature 8).

The specific function of non-residential terraces remains unclear, but they could have been used in multiple ways. On other islands of the archipelago, these have been interpreted as field shelters for those cultivating slopes (cf. modern bush huts) based on size, lack of paving, and spatial distribution (Clark 1989:139; Clark and Herdrich 1993:168; Quintus and Clark 2012:291), defensive structures based on location (Best 1993; Best et al. 1989; Clark and Herdrich 1993:164), and cultivation plots based on size, location, and lack of paving (Cochrane et al. 2004; Quintus 2012). None of the current examples on Ofu lend a defensive advantage. The differentiation of terraces used as cultivation plots and those utilised as temporary field shelters is more ambiguous, especially with a modest excavation sample ($n = 2$; see below). If used as cultivation plots, multiple burn layers or evidence of churning would be expected. Such evidence was not identified in either unit excavated into Class 1N terraces (A'ofa XU-9 and 10). Furthermore, the spatial distribution of these features is not consistent with a terraced cultivation *system*, which is expected to be clustered in a staircase-like pattern. Only 12 percent of the area above 100 masl is terraced in the Tufu detailed survey zone (3,340 m² of 26,650 m²), hinting that terraces, if cultivated, were part of a fallow cycle that included the surrounding slopes. The conservative and tentative interpretation is that many features in these classes were used as temporary rest areas or field shelters for people cultivating the slopes. Cultivation is a strenuous activity even in flat slopes. Locations in high elevations denote steep slope, which makes cultivation more difficult. Particularly when performing activities indirectly related to cultivation, such as food preparation/eating or simply resting, a flat area is useful. These are a ubiquitous characteristic of the modern Ofu agricultural landscape, even when gardens are close to villages.

Table 6.9 A paradigmatic classification of terraces on Ofu

Class	Definition (Size Class; P/A Coral)	A'ofa Number	Tufu Number	Prop. of Size Range	No. and Prop. above 130 masl in A'ofa	No. and Prop. above 100 masl in Tufu	Functional Classification
1N	0-100 m ² , No Coral	8	11	0.56	8 (1.0)	11 (1.0)	Non-residential
1C	0-100 m ² , Coral	5	10	0.44	1 (0.2)	4 (0.40)	Mixed?
2N	101-200 m ² , No Coral	5	4	0.36	2 (0.4)	3 (0.75)	Mixed?
2C	101-200 m ² , Coral	11	5	0.64	1 (0.09)	2 (0.4)	Mixed?
3N	201-300 m ² , No Coral	1	1	0.08	1 (1.0)	0 (0)	Residential
3C	201-300 m ² , Coral	13	9	0.92	4 (0.31)	4 (0.44)	Residential
4N	301-400 m ² , No Coral	0	0	0	NA	NA	Residential
4C	301-400 m ² , Coral	4	6	1.0	1 (0.25)	0 (0)	Residential
5N	401 m ² +, No Coral	1	0	0.17	1 (1.0)	NA	Residential
5C	401 m ² +, Coral	2	3	0.83	0 (0)	0 (0)	Residential

Coral paved terraces with a surface areas of over 100 m² are interpreted as residential features, given the coral indicative of a floor and the substantial size of the features suggesting the past presence of structures (Classes 2C (n = 16), 3N (n = 2), 3C (n = 22), 4C (n = 10), 5N (n = 1), and 5C (n = 5); no terraces meet the criteria of Class 4N; Table 6.9). Coral was absent on only three terraces with surface areas over 200 m² (5 percent), and only 23 percent of coral paved terraces over 100 m² are located in the high elevations of Tufu and A'ofa (12 of 53). This latter evidence is consistent with low elevations being associated with residential activities. Class 2C (n = 16) terraces, especially the larger examples, were likely residential, given their location in low elevations and the presence of coral paving (e.g., A'ofa Feature 66, 70, 104; Tufu Feature 36 and 66), but a non-residential function of some of the smaller examples in the higher elevations cannot be ruled out. The three terraces with surface areas over 200 m² that lack coral paving also might have served non-residential functions. Excavation must be used to examine the function of these.

Further functional differentiation of residential terracing is possible in some circumstances. Surface area and height are often the most critical attributes in reference to status (Holmer 1980), while size, spatial layout, and paving have been utilised by archaeologists to differentiate between sleeping structures, guest houses, and cooking houses in Samoa (e.g., Davidson 1969; Holmer 1980; Quintus and Clark 2012). Future research, specifically excavation, is needed to define areas of cooking and sleeping activities, but some preliminary interpretations can be proposed relating to potential status architecture based on size and location.

In Tufu, the four seaward-most terraces are some of the largest in the project area (Features 1, 37, 40, and 80). With a collective average area of 435 m², they are double the average size of other terraces with mixed coral and basalt paving. Even with this small sample size, this difference is statistically significant (t-stat = -3.12; p = 0.05). On each, coral paving is dense, indicating their clear association with residential activities, and smaller residential terraces are located immediately inland. In A'ofa, Feature 19 is a large structure with a dense paving of coral and basalt (650 m²). This feature is near the mean centre of the A'ofa HFD zone, within ~40 m, which is very close when considering the entire HFD unit spans an area of ~49 ha. Another terrace in A'ofa, Feature 101, is unique in terms of size (465 m²) and surface modification. When the group of terraces west of Agaputuputu Stream

are taken as a unit, this terrace is centrally located based on linear distance from the western boundary and the stream (measurements presented above).

Important features were often positioned seaward and near the centre of settlement units according to ethnographic and archaeological evidence from elsewhere in the archipelago (Davidson 1969; Quintus and Clark 2012; Shore 1982, 1996). In these descriptions, status is equated with a central or seaward location, and, as such, these locations are the most likely place to identify status architecture. Alternatively, structures built in these spaces could be communal or family (*aiga*) based, akin to *fale tele* (guest or meeting houses), which were situated directly behind the *malae* in modern and historic times (Davidson 1969:63-65). In relation to the archaeological record, *fale tele* and status architecture are hypothesised to be distinguishable from each other and from other residential terraces by their general size as well as their spatial location (Clark and Herdrich 1993:152; Davidson 1969, 1974a; Holmer 1980). The four large terraces in Tufu and two large terraces in A'ofa do indicate that some of these patterns exist in both zones, but variation is present. In Tufu, the four large terraces are both the seaward-most terraces and centrally located. In A'ofa, the large terraces are centrally located, but not the seaward-most terraces. Still, the size and spatial distribution of the four terraces in Tufu and the two terraces in A'ofa are consistent with a functional interpretation as status or communal architecture. Variation could reflect different manifestations of spatial organization (see below).

Circular Depressions

Depressions are found throughout the archipelago and have been assigned multiple functions. Depressions/pits identified on the western islands of the groups, 'Upolu and Savai'i in particular, have been interpreted as *umu ti*, water storage devices, barrow pits, cooking pits (*umu*), and food storage pits (*masi*) (Davidson 1974a:236-238; Holmer 1980). Similar functional interpretations have been proposed for depressions discovered on Tutuila and Olosega (Clark 1996; Quintus 2011:95-98). *Umu ti* have been distinguished from more common ovens by the presence of a raised earthen rim, their large size, and the degree of heat alteration to soil and cooking stones (Carson 2002; Davidson 1974a; Holmer 1980), often identified by Samoan informants as such. The identification of storage pits has been more tenuous, though the presence of stone around the rim of the pit might signify such a function. In Anuta, Yen (1973:122) recognised storage pits by a layer of stones that compressed the contents of the feature, and in Samoa, modern (Cox 1980:182) and ethnohistoric examples

(Kramer 1902-03, Vol. II:179; Ragone 1991:208-209; Turner 1984:193) were covered in stone. Archaeological examples in Samoa are found associated with stone boulders, either lining or edging the feature (Hunt 1993:26; Kirch and Hunt 1993a:70-71). To assess the function of depressions on Ofu, a simple two-variable paradigmatic classification scheme was defined by intersection of depression diameter and the presence/absence of a stone edge, highlighting six classes (Table 6.10).

The variability of depressions identified on Ofu indicates that multiple functional types are present. Only evidence from A'ofa is considered in this discussion given the lack of precise data from Tufu. Most of the basalt and coral edged depressions are small, less than 3 m in diameter (12 of 19; 63 percent) (Table 6.4; 6.10), and are generally associated with residential terraces, either located on or within 10 m (8 of 12 small stones edged depressions). No fire alteration was observed to any of the basalt or coral boulders associated with these depressions, which is evidence that these stones were not used for cooking activity. Furthermore, the use of coral, an inferior heating stone, would be deleterious to *ti* cooking, which needs constant high heat (Carson 2002:342). Based on this evidence, many of these stone edged depressions might have functioned as storage devices. Stone edged depressions associated with features other than terraces, specifically three near a ditched terrace in A'ofa, might have been communal storage devices, based on the fact that ditched terraces may represent ritual or ceremonial functions (Quintus and Clark 2012). This does not preclude the use of depressions without an edge as storage device, Class 1N and 2N especially, but there is no empirical evidence indicating such a function.

To further explore function, the volume of edged depression was calculated as the volume of a cone, $V = \pi r^2 h / 3$. Though calculating volume as a cone does result in an underestimation of total capacity, it is justified as most depressions had a tapered profile. Furthermore, infilling has resulted in the measurement of shallower depths than what was present during prehistory, and these calculations should be thought of as very conservative. The total storage capacity calculated for the 19 edged depressions in A'ofa is 21.07 m³ (Fig. 6.42). The volume of individual depressions ranges from 0.21 to 5.75 m³, averaging 1.17 m³ (s.d. = 1.24 m³). The largest depression, Feature 83 located atop a residential terrace, is a statistical outlier (*z*-score = 3.70). The second largest depression (Feature 87) is located within 5 m of a ditched terrace. In all cases, the measured volume of stone edged depressions is far less than any recorded volume of *umu ti* in Samoa (Carson 2002:351).

Table 6.10 A paradigmatic classification of depressions on Ofu. Relationships with other features based only on the A'ofa dataset

Class	Definition (Size Class; P/A Edge)	No. (A'ofa)	No. (Tufu)	Proportion of Class	On Terraces A'ofa Only (Proportion)	At Ditch End A'ofa Only (Proportion)	Associated w/ Ditched Terraces (Proportion)	Possible Functions
1N	2.0-2.9 m; No Edge	9	13	0.58	6 (0.67)	0 (0)	0 (0)	Refuse Disposal Masi Pits
1E	2.0-2.9 m; Edge	12	4	0.42	6 (0.50)	0 (0)	2 (0.17)	Masi Pits Ovens
2N	3.0-3.9 m; No Edge	12	3	0.71	3 (0.25)	1 (0.08)	0 (0)	Refuse Disposal Masi Pits
2E	3.0-3.9 m; Edge	5	1	0.29	1 (0.20)	0 (0)	0 (0)	Masi Pits Ovens
3N	4.0 m+; No Edge	7	2	0.75	1 (0.15)	2 (0.29)	0 (0)	Sumps Refuse Disposal Water Storage
3E	4.0 m+; Edge	2	1	0.25	1 (0.50)	0 (0)	1 (0.50)	Masi Pits Ovens

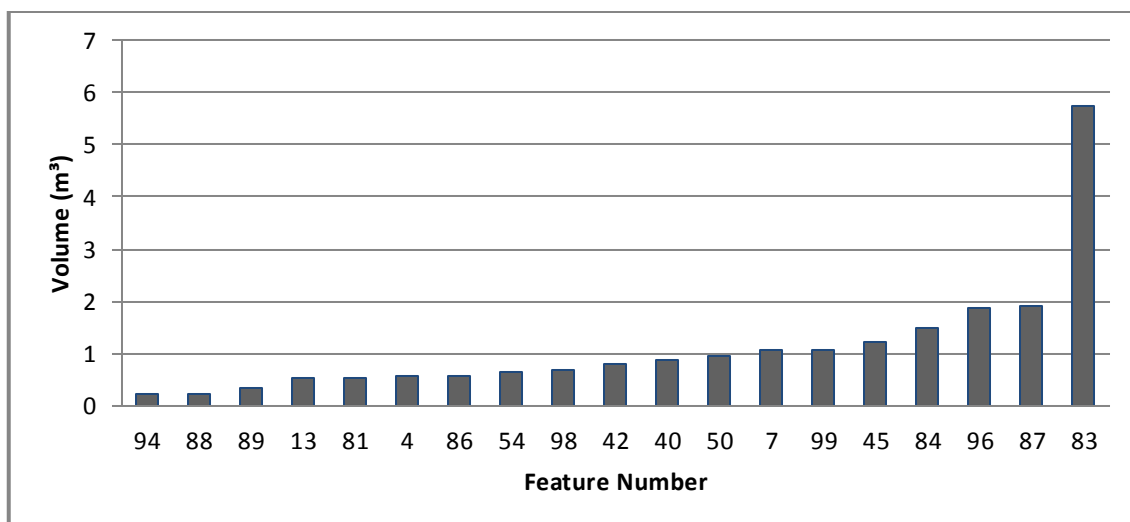


Figure 6.42 Estimated volume of stone edged depressions in A'ofa

However, the one coral and basalt edged depression excavated (Feature 98, XU-8; see below) apparently was utilised for an alternative function as well. Fire-cracked rock, charcoal, and evidence of intense burning were identified just below the surface of the feature, though the stone around the edge of the feature was not fire altered. These findings do not preclude its use as a storage device, but it does suggest that stone edged depressions had more complex use-lives, or some simply were ovens. Alternatively, the presence of unburned candlenut shell within this fire feature might imply that this activity occurred relatively recently, and it may be that this activity is not a reflection of the purpose for initial construction. This example demonstrates the difficulty interpreting the function of depressions, which have likely served several functions since they were constructed.

Depressions without edging are even more difficult to interpret (Classes 1N, 2N, 3N). Some of these features are located near the end of a ditch branch (e.g., A'ofa Feature 26, 62, and 90), and, as discussed above, water likely moved through ditches associated with ditch-and-parcel complexes. Given this, water probably drained into the depressions situated at the end of these ditches. These depressions could have been employed as sumps to gather drained water and sediment, the depressions used to protect structures downslope of ditching (e.g., residential terracing). If this interpretation is accurate, it hints that terracing located downslope of ditching was built later than the ditches. When the terraces were built, it became necessary to construct depressions to protect them from water and sediment draining from the ditches. Alternatively, these depressions could have been used to collect and store water. No permanent streams flow in the interior of Ofu, and no permanent water sources, other than wells on the coast, are available on the island (though there are reports that a

spring exists in the interior uplands, see also Clark 1980:46; Kikuchi 1963:74). One potential way to differentiate these functional possibilities is the identification of some sort of lining, clay or banana leaves, which would have reduced the permeability of the feature. Lining would be needed to collect and store water, but would be detrimental to the function of sumps.

The only non-edged depression that was excavated yielded a thick layer of marine fauna, which included shell, fishbone, and sea urchin spine (A'ofa XU-3; see below). The depression may have originally been utilised for another function, but it was also used as a refuse pit at the end of its use-life. Some depressions may have functioned in a similar way, principally those in proximity to residential terraces. Others, particularly those located on terraces, are likely associated with cooking activities.

Ditched Terraces

A small number of ditched terraces were identified on Ofu. Quintus and Clark (2012) have argued that ditched terraces served a ritual/ceremonial function based on the presence of coral gravel and flat coral paving, the presence of other, more unique, structural remains (i.e., upright stones), and their bounded nature (by shallow ditching). Three features meet these criteria, all in A'ofa, but no further evidence was obtained relating to their function.

Central Open Spaces

One area in Tufu meets the criteria of a central space as defined at the beginning of the chapter. No structures that represented domestic activity were identified across an area that was otherwise habitable, though a few depressions were noted. The area devoid of structural features is much larger than needed by a single domestic unit, extending over a space of ~5400 m². Finally, the space is bordered by multiple structures, four large residential terraces running parallel upslope and a large ditch-and-parcel network downslope. This configuration is comparable to 19th and 20th century AD examples of *malae*. In ethnographic descriptions, *malae* are open village greens within settlements (e.g., Mead 1969:49; Shore 1982:48-51). These can either be the most seaward features in the settlement or can be located in a central space; in both instances the *malae* is surrounded by other features. The most prominent residential features, specifically the communal or status architecture, are *always* situated adjacent to this space (Shore 1996).

Changes in the function of central open spaces have likely occurred since the end of the prehistoric period, making direct functional equivocation between archaeological and historic examples suspect. However, some functions were probably shared signalled by similar morphologies and spatial distributions. According to ethnohistoric and ethnographic sources, the *malae* was the focal point of villages, the locus of communal activity (e.g., Mead 1969; Pritchard 1866; Shore 1982:48-51; Stair 1983). That this archaeological example is situated in a central location seaward of four large terraces, one of which was the largest recorded in Tufu, hints that the space was a focal point of communal activity as well.

Synchronic Inland Archeological Feature Patterning

The archaeological landscapes of the interior uplands of Ofu are cumulative built environments or palimpsests of past activities. What is documented on the surface might never have been utilised contemporaneously, or was not used contemporaneously until immediately prior to abandonment. The palimpsest effect presents some interpretive difficulties without a robust chronology or relative dating technique. Since this is lacking for Ofu, though some dates were obtained on select features in each zone (see below), assumptions must be made regarding the importance of the observed spatial patterning of features. This section discusses the synchronic patterning of archaeological remains on Ofu.

Within each detailed survey area, the same major feature classes were identified: depressions, ditch-and-parcel complexes, and terraces. The nature of each feature class was similar across the island. The difference of average parcel size and ditch length and parcel size of ditch-and-parcel complexes was not statistically significant between A'ofa and Tufu. In both, positions directly seaward of the mean centre are occupied by ditch-and-parcel networks, the largest such features in each zone, and larger parcels are situated farther from the mean centre of each zone. The dataset of terraces in each zone are also markedly similar (Fig. 6.43). Terrace size increases as elevation decreases in both A'ofa and Tufu, and coral was more likely to be found in low elevations. These findings indicate that, as a *generalisation*, residential terraces (Classes 2C, 3C, 3N, 4C, 5N, 5C) are situated seaward of non-residential terraces (Classes 1N, 1C, 2N). In Tufu, four large terraces, one being the largest recorded, are the most-seaward of terraces and are immediately inland of a large area devoid of structural remains (central open space). These terraces occupy a position seaward of the mean centre in the Tufu zone. In A'ofa, one large terrace is located near the mean centre of the unit and another is located between a stream and the western boundary. Finally,

in both units, a zone of economic forest is located seaward of a zone or zones of secondary forest. These similarities hint that Tufu and A'ofa are part of separate settlement units or *nu'u*.

Ethnographic and early historic descriptions of Samoan settlement units emphasised two interacting spatial dichotomies: centre: periphery and sea: land (Shore 1982). Both of these can be thought of as graded relationships, not strict binaries (Shore 1996:270). In Shore's (1996:270) words, the center: periphery relationship, "defines a symbolic space in terms of a central viewpoint that looks out at a world defined by a gradually diminishing gradient of dignity and order". The centre and sea are associated with status and rank (Shore 1982:80, Fig. 5.1). The bush, on the periphery and inland of the occupation, is trouble and away from the control of society (Shore 1996:270); the realm of the *aitu* (spirits) (Shore 1982:49). Different structures are associated with different areas of the village, areas which augment the perception of, and give meaning to, those structures. The *malae*, given its location in the centre or directly seaward of the centre of the village, is considered communal, the focus of group activity and the focal point of the settlement (Shore 1982:48-51). The *fale tele* are situated directly inland from the *malae*, and serve as the meeting places of the *fono* and reception areas for honored guests (Davidson 1969:63-65). Sleeping houses, cooking houses, and gardens are located to the inland periphery of settlements. These spatial patterns, Shore (1996:267-268) has contended, extend into the prehistoric period based on the initial European descriptions of Samoan villages, and Kirch and Hunt (1993b:18) have argued that the ubiquity of the seaward: inland distinction in Polynesia is evidence of its antiquity.

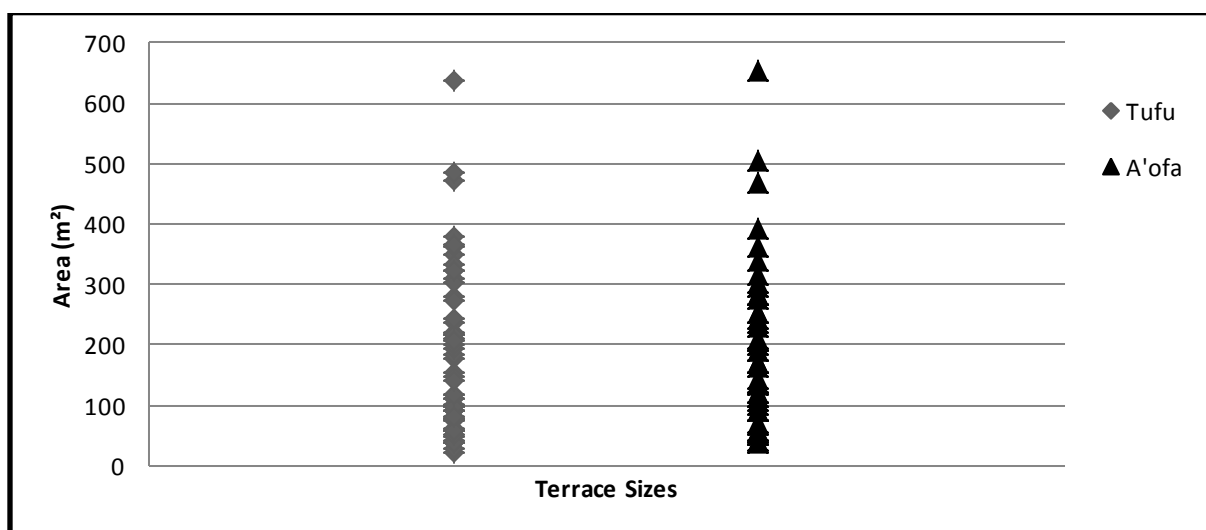


Figure 6.43 A comparison of terraces size between Tufu and A'ofa

The spatial distribution of archaeological features in Tufu and A'ofa is consistent with the above spatial concepts. In both areas, non-residential terraces are generally situated inland of the residential terraces. The seaward-most features in each zone are large ditch-and-parcel complexes, a position that perhaps reflects social importance. The distribution of vegetation in each area marks a spatial dichotomy in that economic vegetation is situated seaward of secondary forests, potentially reflecting the division of activity zones.

However, differences are apparent. In Tufu, the four seaward-most terraces are statistically larger than other residential terraces in Tufu, and they are situated directly seaward of the centre of the HFD zone. These terraces are buffered from the large seaward ditch-and-parcel network by a central open space. The spatial location of these terraces is evidence of their social prominence. In A'ofa, the largest terraces are not the most-seaward, but they are approximately centrally located within the A'ofa HFD zone. This distribution, too, is evidence of the social prominence of these terraces, but does reflect different uses of space. These differences indicate that the formation of each zone was a variable process, perhaps influenced by the interaction of different perceptual concepts of space, but also by environmental and other cultural factors. What is also apparent in both zones is the mutability of general activity areas. Ditch-and-parcel complexes, which likely functioned as cultivation spaces, are distributed amongst residential features. That variability does exist in the distribution of different activities signifies the difference between ideal and realised spatial patterning.

Modest evidence also hints at smaller scale feature groupings as well, though these are much more uncertain and require additional fieldwork to confirm. Depressions were often identified in the vicinity, or on the surface of, terraces. Using the A'ofa dataset, eight of the 12 Class 1E depressions are located on or within 10 m of terraces. Of the eight terraces on which edged depressions are located, six are paved with a mix of coral and basalt. Only one of these terraces was a Class 1N terrace. Additionally, in some cases, ditching was associated with residential terraces. Of the 13 field observed single branch ditch-and-parcel complexes in A'ofa, eight are located within 10 m of a residential terrace, and distributional data was not sufficient to evaluate this claim for another. In Tufu, of the four single branch field observed ditches, terraces are situated within 10 m downslope of three; all but Parcel 8. However, coral was not found on two of these terraces. Nevertheless, the grouping of depressions, terraces,

and, in some circumstances, ditch-and-parcel complexes may represent households. Data available to explicitly identify these social units is not yet available.

While spatial patterns have been proposed in the synchronic archaeological landscape, these probably were not present when the interior uplands were initially used for residential activities. To begin to address the formation of these patterns, trench excavation was conducted. Specifically, these excavations were targeted to address questions relating to the chronology of interior settlement, the chronology of individual feature classes, and the chronological relationships between feature classes and between HFD zones.

Excavation of Interior Features (Tufu and A'ofa)

A combined total of 18 0.5x0.5 m test units were opened in the interior uplands of Ofu (Tables 6.11, 6.12), ten units within A'ofa (Fig. 6.44) and eight within Tufu (Fig. 6.45). Of these, nine were into ditch elements of ditch-and-parcel complexes, seven into terraces, and two into depressions. All were excavated utilising pick and shovel, with troweling restricted to cleaning walls and floors. Testing was targeted to examine sections of features unlikely to yield artefacts but likely to yield charcoal that could date feature construction or landscape use prior to feature construction. Excavation was also meant to gather stratigraphic information and geomorphological histories that would aid in interpreting feature function (see few references to excavated examples above), but this was difficult because of the paucity of stratigraphic changes observed during excavation. No sediment was screened, given a goal of dating feature construction, the characteristics of the soil, which were wet clays, time constraints that would not allow the processing of soils, and difficulties in transporting screening equipment to these interior zones. Units were terminated below the point at which particulate charcoal was no longer present in the matrix.

Below is a short discussion of each unit. In cases where stratigraphic changes were observed, a short description is provided, which draws attention to how such changes were defined. Most layer boundaries were diffuse, based on the presence of a higher frequency of charcoal than other areas of the deposit. Charcoal for dating was taken from these dense concentrations of flecking, or from the transition between stratigraphic units when those were identified in profile.

Table 6.11 Summary of test units dug in A'ofa

Unit	Depth (cmbs)	Presence and Nature of Matrix Change	Contents	Dated?
XU-1	60	Stratigraphic change, layer of particulate charcoal	Charcoal	Yes
XU-2	60	Uncertain	Charcoal, basalt retaining wall	No
XU-3	100	Layer of marine fauna	Charcoal, marine fauna	Yes
XU-4	30	None	Charcoal, angular basalt, basalt flake	No
XU-5	80	Increased compaction toward bottom?	Charcoal	Yes
XU-6	90	Increased compaction toward bottom?	Charcoal	Yes
XU-7	50	Stratigraphic change, layer of particulate charcoal	Charcoal, angular basalt, coral	Yes
XU-8	50	None	Combustion feature, angular basalt, charcoal	No
XU-9	60	Stratigraphic change, layer of particulate charcoal	Charcoal, basalt retaining wall	Yes
XU-10	60	Uncertain	Charcoal, basalt retaining wall?	Yes

Table 6.12 Summary of test units dug in Tufu

Unit	Depth (cmbs)	Presence and Nature of Matrix Change	Contents	Dated?
XU-1	60	Layer of particulate charcoal	Charcoal, angular basalt at bottom	Yes
XU-2	55	Layer of particulate charcoal?	Charcoal, angular basalt at bottom	No
XU-3	50	None	Charcoal, angular basalt	No
XU-4	60	Layer of particulate charcoal	Charcoal	Yes
XU-5	60	Stratigraphic change?, layer of particulate charcoal	Charcoal	Yes
XU-6	60	Changing frequency of basalt, layer of particulate charcoal	Charcoal, angular basalt, coral	Yes
XU-7	80	C-horizon?	Charcoal, angular basalt, coral	No
XU-8	60	More compact below basalt retaining wall	Charcoal, basalt retaining wall?	No

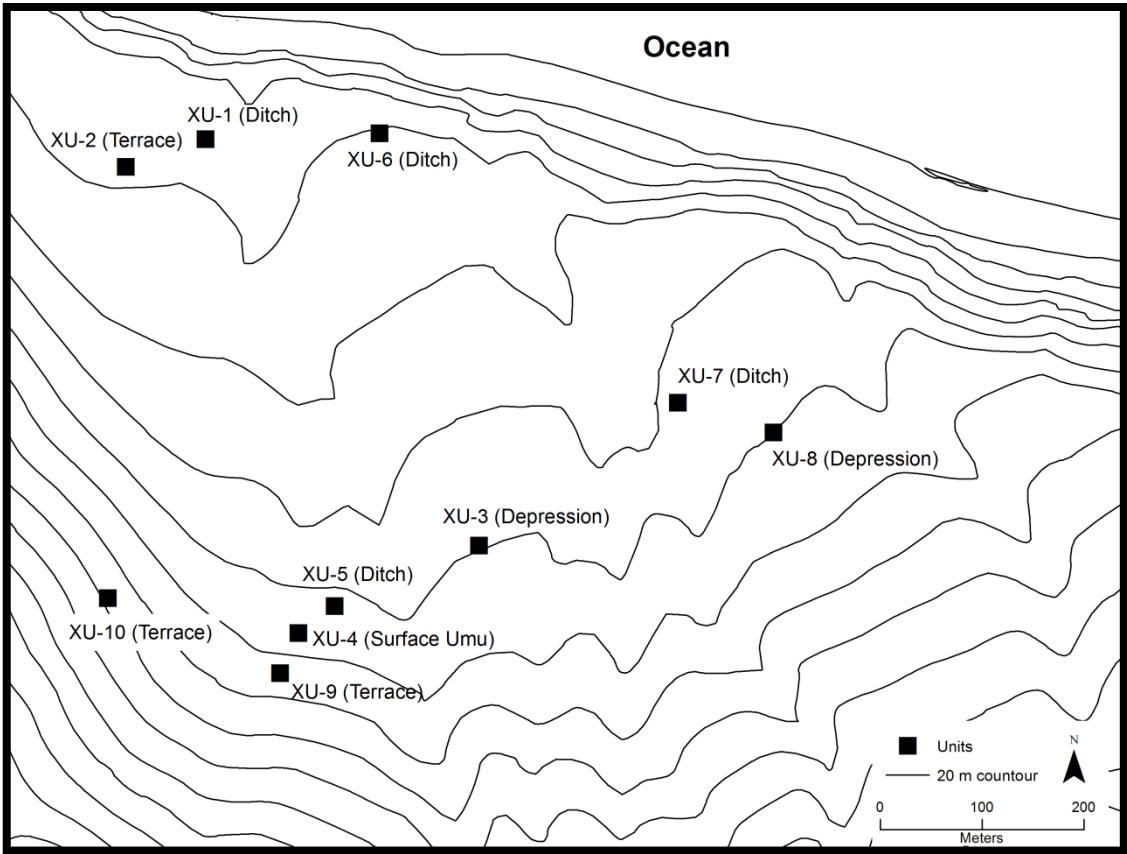


Figure 6.44 Distribution of excavation units in A'ofa

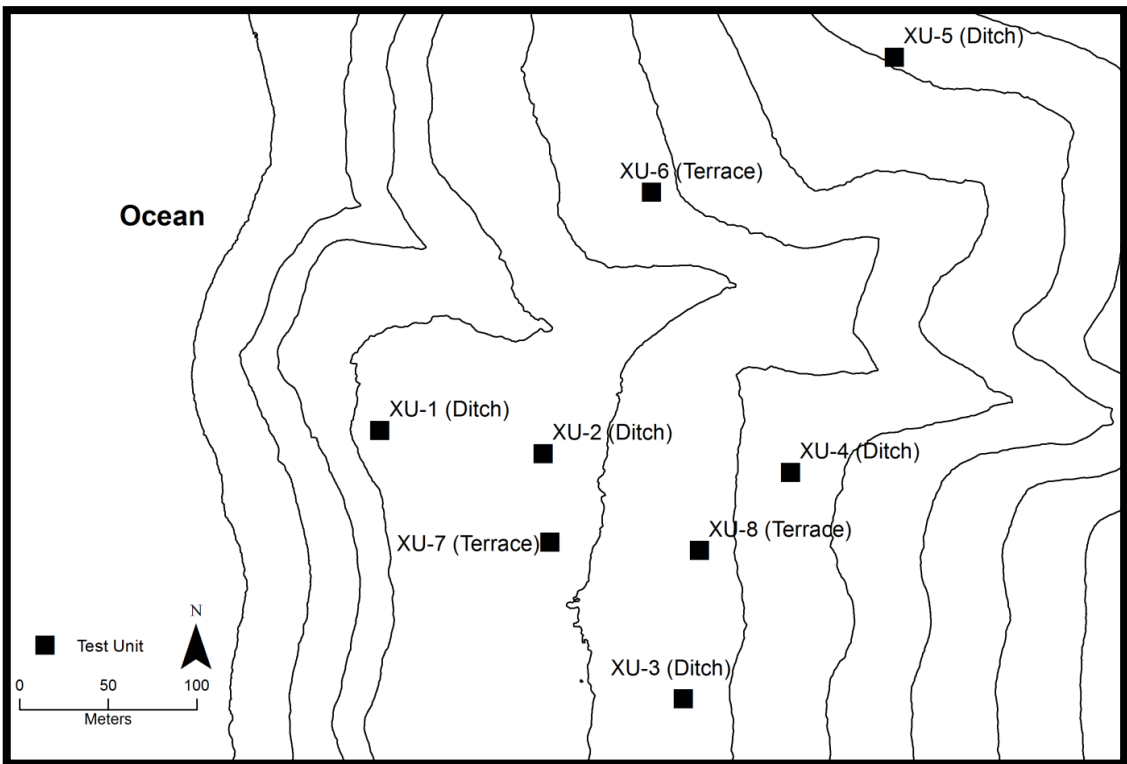


Figure 6.45 Distribution of excavation units in Tufu stream

A'ofa

XU-1 was a 60 cm deep unit located in a bund of a ditch-and-parcel network (Parcel 27). Charcoal was identified at all depths in excavation, though only collected below 10 cmbs. A stratigraphic change, perhaps marking the lower boundary of fill to create the ditch bund, was identified ~40 cmbs (Fig. 6.46), characterised by larger clastics, including decomposing basalts. Multiple charcoal samples were collected from this layer interface and one sample was dated (Beta-366724, AD 1690-1924).

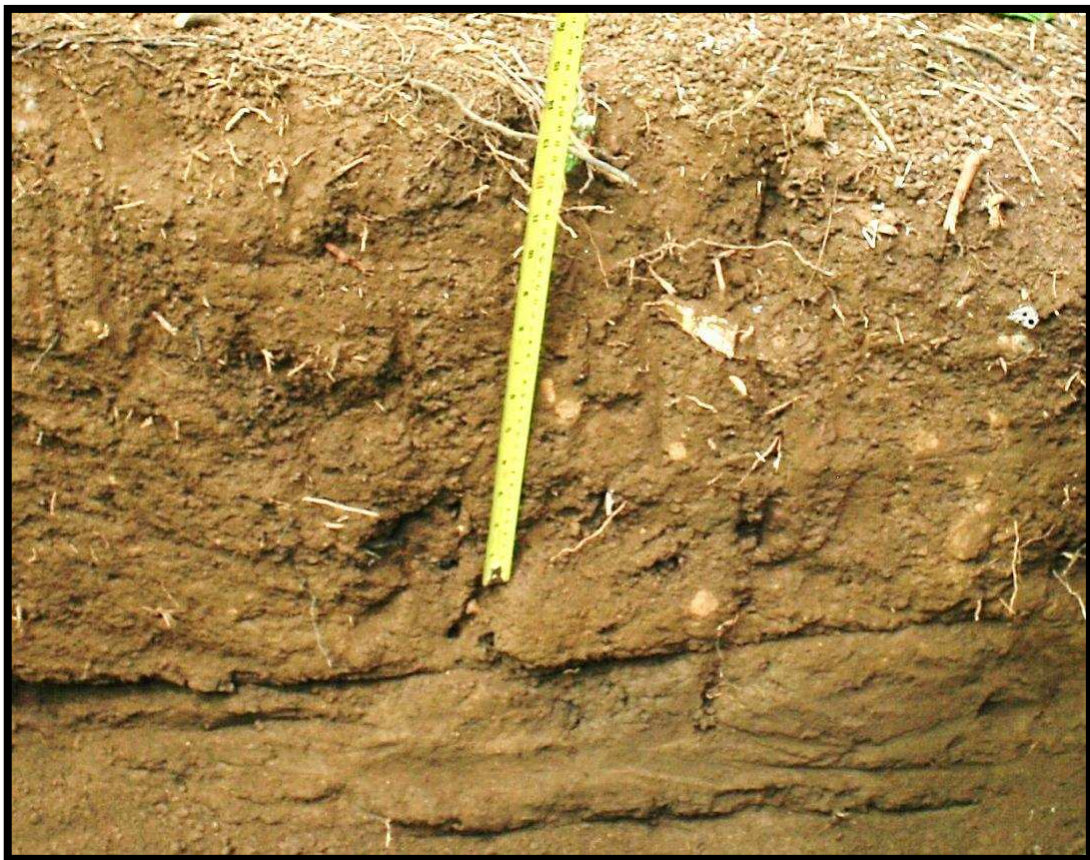


Figure 6.46 Excavation trench profile of XU-1. A slight Stratigraphic change was noted near the bottom of the measuring tape, which itself marks the point at which charcoal was collected for dating

XU-2 was an excavation unit dug into a terrace with dense coral paving located in the western third of the A'ofa HFD zone (defined as Terrace 74 in 2012, not revisited in 2013). Charcoal was identified throughout the excavation, but only collected from around a one course high retaining wall at the front of the terrace (Fig. 6.47). Charcoal for dating was identified beneath and abutting the inside edge of this retaining wall. No charcoal was dated from this feature.



Figure 6.47 Retaining wall that was excavated as part of XU-2

XU-3 was a unit dug into a large depression located near the centre of the HFD zone (Class 3N; Feature 76), within 10 m of two large terraces with coral and basalt paving. A 50 cm thick layer of shell (consisting of *Turbo*, *Cellana*, *Trochus*, and *Tridacna*), fish bone, and sea urchin spine was encountered at 40 cmbs of the depression (Fig. 6.48). No lensing was present within the deposit, suggesting that the material was discarded over a short period. Charcoal samples, as well as two small *Tridacna*, were collected from the top and bottom of the layer for dating. One charcoal sample, from the bottom of this layer, was dated (Beta-372702, AD1652-1917).

XU-4 was an excavation of a possible surface *umu* (oven), consisting of what appeared to be multiple fire cracked stones in a heap, on a terrace with no visible coral on the surface (Class 5N; Feature 6). Little charcoal was noted, and it appears that instead of an oven, the small pile of stone and soil was a natural feature. Nevertheless, some charcoal was collected near the bottom of the pile and a basalt flake was discovered and collected. No charcoal was dated from this feature.



Figure 6.48 Marine fauna in XU-3

XU-5 was an excavation unit dug into a ditch bund of a ditch-and-parcel network inland of the centre of the A'ofa HFD zone (Parcel 9). This complex was the southernmost ditch-and-parcel complex identified in the zone, and is located on the steepest slopes of any of these features. In the excavation, charcoal was first identified at 19 cmbs, with a higher concentration present around 40 cmbs. This concentration dissipated around 70 cmbs, at which point charcoal was very rare or absent. One charcoal sample was dated from this context (Beta-372703, AD1695-1919).

XU-6 was an excavation unit dug into the upslope ditch bund of a ditch-and-parcel network located near the cliff edge at the northern extent of A'ofa (Parcel 23). Charcoal was identified throughout the bund, increasing in density around 40-50 cmbs, at which time the surrounding matrix became more solidified. Datable material was noted and collected as deep as 80 cmbs, though. The one sample dated came from inside the ditch, not from the bund, and returned a modern age.

XU-7 was an excavation of the upslope bund of a ditch-and-parcel single branch feature (Parcel 3), which was located east of Tafe Stream. The matrix of the bund was looser than in previously discussed ditch-and-parcel complexes, with the inclusion of small pockets of coral. A small feature was identified in profile, which might be a post mold or, possibly, a

root cast of a large tuber or a banana trunk (Fig. 6.49). A stratigraphic transition was noted at the base, with a large chunk of coral near the northern side of the west (downslope) wall. Charcoal was collected from the interface of this transition and was dated (Beta-354139, AD 1024-1155), though some charcoal and a coral slab were identified below this transition as well.

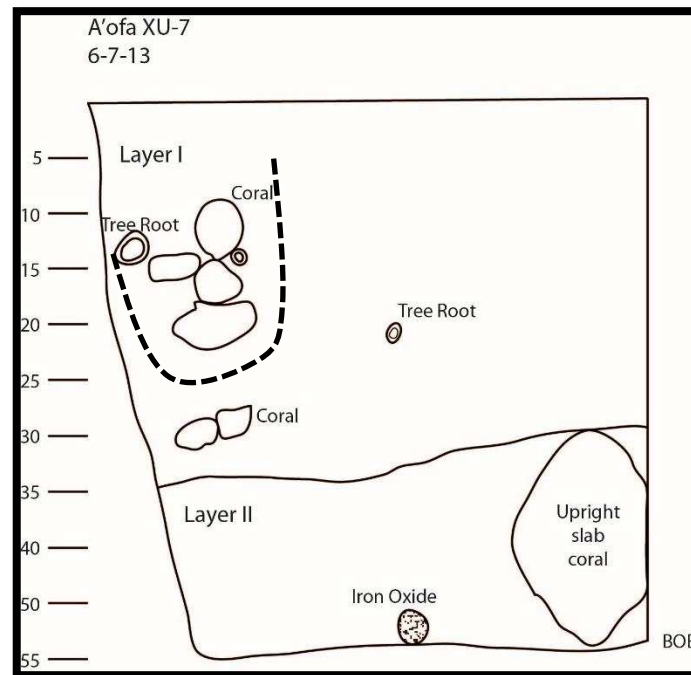


Figure 6.49 Western wall profile of XU-6. The dotted line outlines a possible post mold or root cast

XU-8 was an excavation of a basalt and coral edged depression located near the eastern boundary of the A’ofa HFD zone (Class 2E; Feature 93). Soon after excavation had commenced unburned candlenut shells were encountered, in addition to a small burn feature at the centre of the depression. This feature included significant amounts of charcoal, but also continued to yield unburnt candlenut shell. Oxidised and ashy soil was identified at the bottom of the feature, and, from there, charcoal was collected. No charcoal was dated from this feature.

XU-9 was an excavation of a terrace (Class 1N; Feature 2) located above the high elevation threshold of A’ofa (130 masl). After a possible retaining wall had been located, excavation commenced to collect charcoal from the base of the stone on the inside edge of the wall, which was accomplished. Additional charcoal was collected from a band (or faint layer) of charcoal ~40-50 cmbs situated below the retaining wall. At this point, the matrix became

more compact and a possible stratigraphic change was encountered (Fig. 6.50). One sample from this band of charcoal was dated (Beta-359272, AD 1224-1298).

XU-10 was an excavation unit dug into a small terrace in the steep slopes and high elevations of A'ofa immediately downslope of a historic trail/road (Class 1N; Feature 78). Excavation was undertaken around a possible shallow retaining wall at the front of the feature. Charcoal was not identified in the unit until 32 cmbs. The soil became lighter and more compact ~39 cmbs, at which point charcoal was identified in, and collected from, a band, or faint layer, similar to that identified in XU-9 (Fig. 6.51). A sample from this band was dated (Beta-359273, AD 1408-1452). Charcoal became rare to absent below ~45 cmbs.

Tufu

XU-1 was a unit dug into a ditch bund of a ditch-and-parcel network located near the western cliff edge of Tufu (Parcel 17). Charcoal was identified throughout the bund, with a particular high density between 35 and 45 cmbs (Fig. 6.52). Most charcoal samples were taken from this area and one was dated (Beta-366726, AD1498-1795). No stratigraphic changes could be identified, though, and no matrix changes (e.g., compaction, texture, and colour) were noted other than the possible faint layer of charcoal flecking mentioned above.

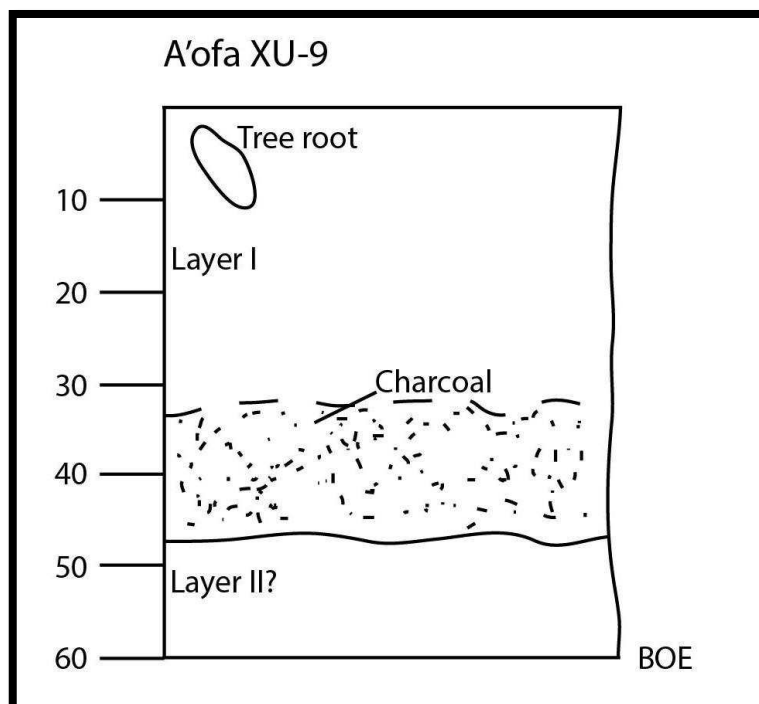


Figure 6.50 Profile of the south (inland) wall of A'ofa XU-9 (depths at cmbs). This profile is representative of most excavation units dug. Solid line is a stratigraphic change

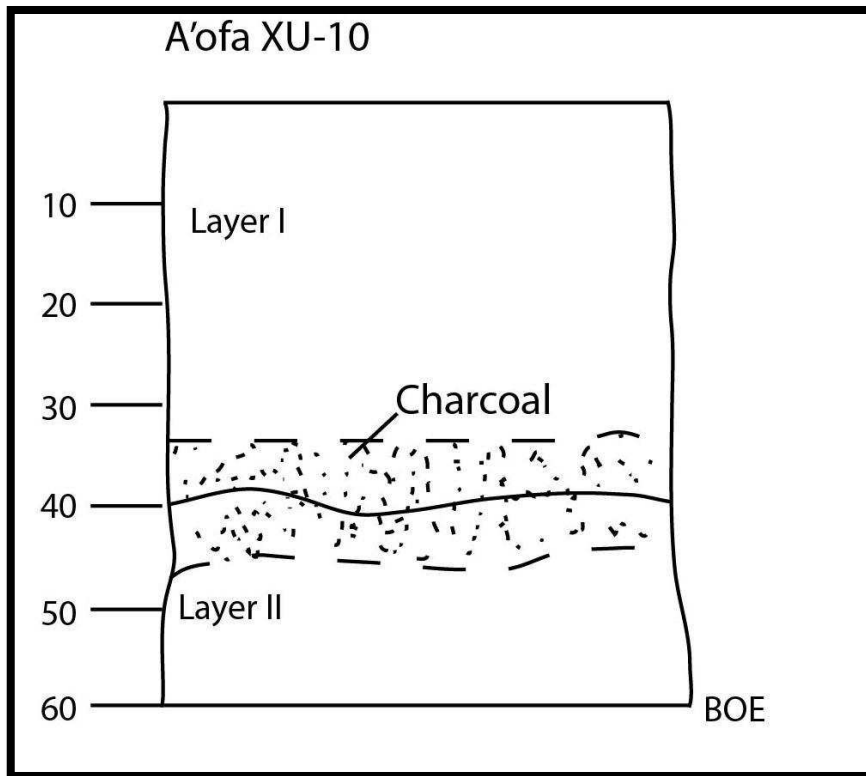


Figure 6.51 Profile of the south (inland) wall of A'ofa XU-10 (depths at cmbs). Solid line is a stratigraphic change

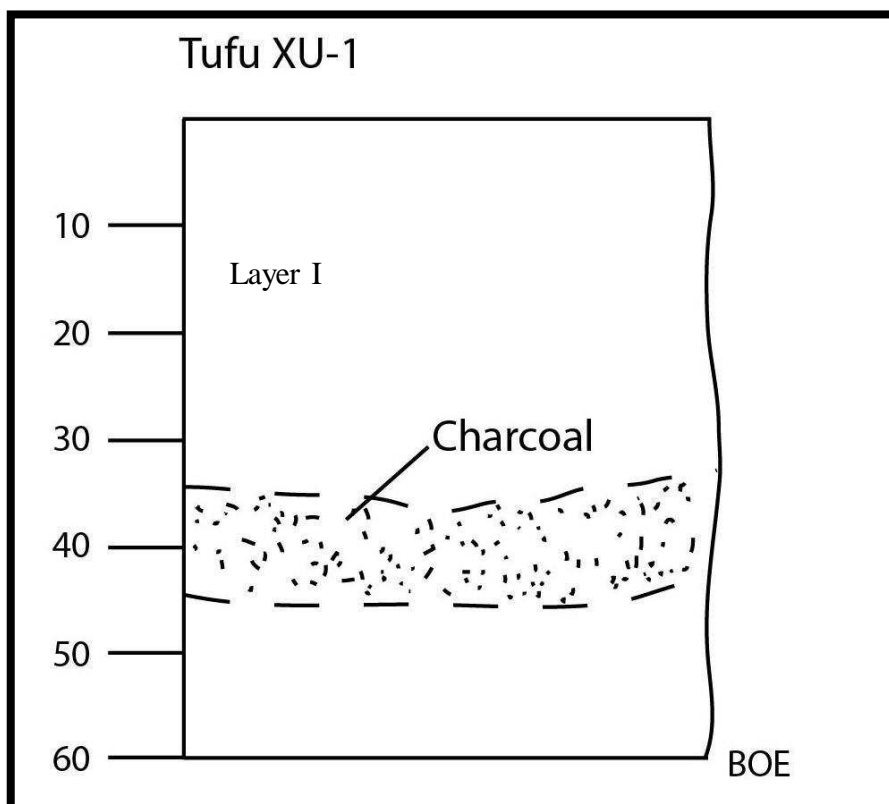


Figure 6.52 Profile of the south (seaward) wall of Tufu XU-1 (depths at cmbs). Note the presence of a layer of charcoal, which may mark a stratigraphic change. This profile is broadly representative of those with no clear stratigraphic change but with a possible band or layer of charcoal

XU-2 was an excavation unit dug into the upslope ditch bund of a ditch-and-parcel network located near the southern slopes leading to the Tufu stream channel (Parcel 2). Similar to XU-1, no stratigraphic divisions could be discerned, except for an apparent higher concentration of charcoal flecking. This one was identified at ~45-50 cmbs, from which samples were taken. No charcoal was dated from this feature.

XU-3 was a unit excavated into the upslope ditch bund of a ditch-and-parcel network located at the southern end of the detailed survey area (Parcel 7). The bund matrix was compact from the beginning of excavation, with angular basalt cobbles noted throughout the unit. Charcoal was rare, though it became more common as the unit was dug deeper until the termination of the excavation at ~50 cmbs. Charcoal was collected from throughout the bund, but, unfortunately, no layers or lenses of high charcoal density were identified. This ditch bund, in general, appeared to be lower than others, and it is possible that the top of the bund had eroded away. No charcoal samples from this feature were dated.

XU-4 was an excavation of a side bund of a ditch-and-parcel single branch feature located near the upslope boundary of the Tufu HFD zone (Parcel 10). Excavation was conducted through the side bund as the upslope ditch was partially infilled or the bund was partially eroded. Given the location of the unit near the corner of the parcel, an area in which ditches were generally deeper in other features as well, this excavated bund was higher than others trenched. Charcoal was identified throughout the bund, particularly below 35 cmbs, but a clear burn layer was identified near the base of excavation at ~60 cmbs, from which samples were collected and dated (Beta-361291, AD 1042-1222) (Fig. 6.53).

XU-5 was an excavation of the upslope corner bund of a ditch-and-parcel network (Parcel 1) located near the northeastern periphery of the Tufu HFD zone. A possible stratigraphic change was encountered ~30-40 cmbs, and the interface between these layers exhibited charcoal flecking. This flecking was collected and dated (Beta-359275, AD 1412-1468). Additional samples were taken from between 30 and 50 cmbs. The nature of the layer change is difficult to gauge; though, it appears to mark the extent of fill used to construct the feature given the presence of decomposing basalts and a more compact matrix.

XU-6 was a unit dug at the front of a large coral and basalt paved terrace located on the northern side of Tufu Stream adjacent to a large depression (Class 5C; Feature 83). Only a modest amount of datable material was noted until 35 cmbs, at which point a pocket, not a layer, of sub-rounded coral gravel and charcoal was identified. Multiple pockets of coral

gravel were identified elsewhere in the matrix as well. The densest concentration of charcoal flecking was identified at ~55 cmbs, from which charcoal was collected. A stratigraphic change was difficult to identify and no retaining wall was uncovered. Given the presence of decomposing basalts in the first 20-30 cmbs, the top 30 cmbs might have been fill brought in from elsewhere. The concentration of charcoal flecking, around 55 cmbs, may signify a stratigraphic interface (Fig. 6.54). However, charcoal of a short-lived or economic species was not identified from this specific context, and only one sample, from 36 cmbs, was dated (Beta-366727, AD 1039-1210).

XU-7 was a unit excavated into a terrace located to the south of Tufu Stream (Class 2C; Feature 4). Charcoal was identified from near the ground surface, continued to be found until termination of the unit at 80 cmbs, but was very low in density near the bottom of the unit. Pockets of degraded coral were identified in profile, though more was noted near the top than the bottom (likely brought down from ground surface as a result of bioturbation). Decomposing basalts were uncovered near the termination of the unit, and the project geologist (Dr. Stephanie Day) suggested that the floor of the unit could represent the top of a C-Horizon. Charcoal was collected from the transition between the first layer and the possible C-Horizon. No charcoal samples from this feature were dated.

XU-8 was a unit dug into a coral and basalt paved terrace located less than 20 m from the mean centre of Tufu (Class 3C; Feature 76). A possible retaining wall, consisting of three boulders, two of which were stacked, was chosen to be excavated. After mapping, each rock was removed, and the ground beneath was examined for charcoal. Charcoal was rare, rarer than in any of the other features excavated. Thus, unfortunately, only small pieces of charcoal could be collected from the base of the retaining wall, or the bottom of the rock, which is not enough to provide a radiocarbon date.



Figure 6.53 Charcoal staining on the floor of XU-4 (Beta-361291, see below). Width of unit is 50 cm

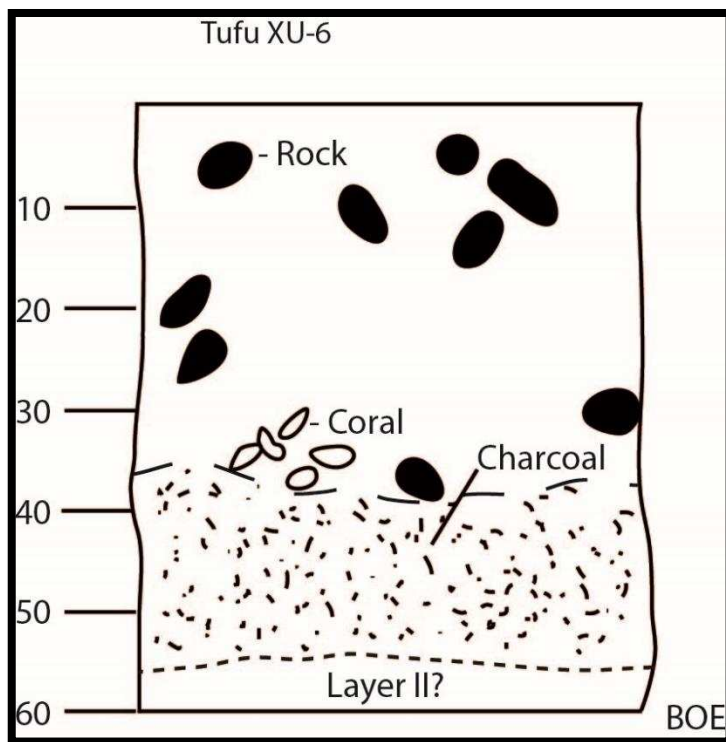


Figure 6.54 Profile of the north (inland) wall of Tufu XU-6 (depth in cmbs)

Summary

Even though clear stratigraphic differences were, unfortunately, rarely identified, datable material was retrieved in most excavations (chronological results presented below). Furthermore, excavation also informed on the construction sequences of some features and the geomorphological changes that occurred after they were abandoned. Excavation of terraces seems to confirm that they were constructed utilising a cut and fill technique, with some displaying remnants of retaining walls or basalt facing. Evidence of multiple phases of construction or maintenance was *not* identified, but it is likely that structures *on* the terraces were replaced over time and the coral identified in some of the excavations might be evidence repeated reconstruction episodes. Excavation of ditch-and-parcel complexes suggests that the ditch bunds were built-up by the spoil burrowed to construct the ditch. The varying size of ditch bunds, and the varying depths at which charcoal was found, implies that some post-construction erosion and infilling has occurred, at least on the upslope side of the features. Evidence of feature maintenance or remodelling was absent in excavated examples, but this of course does not mean the practice did not occur. Similar to ditches, the excavation of depressions yielded evidence that demonstrates substantial post-use infilling.

Charcoal Identification and Chronology

Seven ditches, three terraces, and one depression were dated to examine the chronology of interior land use and the construction of different feature classes. Of those features, seven were from A'ofa and four were from Tufu (Fig. 6.55, 6.56, 6.57, 6.58; Table 6.13). Charcoal was identified by Dr. Jennifer Huebert (U of Auckland) to isolate short-lived taxa to minimise the inbuilt age in each sample. As was the case in dating coastal deposits, however, short-lived materials were not always found. In these cases, economic plants were dated. All conventional radiocarbon determinations were calibrated in OxCal v. 4.2 (Ramsey 2013) using the northern hemisphere IntCal 13 atmospheric curve (Reimer et al. 2013).

The dating of earthen modifications is difficult, as middle range arguments must be made to ensure that radiocarbon determinations are dating the archaeological event of interest (Ladefoged and Graves 2008). As such, a contextual approach is necessary. Dates presented in this section were all of charcoal taken from areas of features unlikely to yield artefacts, but likely to yield organic material that could date some activity associated with feature construction or activities that occurred prior to feature construction. This section describes

each sample and presents a contextually-informed interpretation of the radiocarbon determination (summarised in Table 6.13).

Ditch-and-Parcel Complexes

Beta-366724 (A'ofa XU-1, *Myristica* sp.) 70 ± 30 (2σ AD 1690-1924)

This was a determination on an intact branch of *Myristica* wood recovered *in situ* at 30 cmbs in A'ofa XU-1. *Myristica* is a medium sized tree that can live for a few decades (J. Huebert pers comm.). So, while inbuilt age is possible, it is modest. Even though the date range extends into the historic period, there is no evidence that ditch-and-parcel complexes were in use at that time, and ditches were not noted by late 19th or early 20th century ethnographers (Buck 1930; Kramer 1902-03; Mead 1969). In fact, the Wilkes expedition stated that few people inhabited Ofu when they arrived in the 1840s (Wilkes 1852:157). Based on this restriction, the sample likely dates an event that occurred between AD 1690 and AD 1840. The event dated, given the presence of an entire branch and associated charcoal flecking, is interpreted to be vegetation burning-off. Therefore, this date provides a maximum age for the construction of the feature.

Beta-372703 (A'ofa XU-5, *Myristica* sp.) 30 ± 30 (2σ AD 1695-1919)

This determination was a single piece of *Myristica* wood recovered *in situ* at 70 cmbs in A'ofa XU-5. Given the nature of the calibration curve, this determination had multiple intercepts, creating a large range, though it can be tightened employing the same restrictions as mentioned above. Given these restrictions, the range of the determination, AD 1695 and AD 1840, provides a maximum age of feature was construction.

Beta-366725 (A'ofa XU-6, *Aleurites moluccanus* shell) Modern Carbon

This determination dated a single piece of charred candlenut endocarp collected at 40 cmbs of a ditch, not *in situ* from a ditch bund, in A'ofa XU-6. It is possible that the candlenut sample dislodged during excavation, and was collected far removed from its original context. Perhaps more likely, this charcoal may have washed into the ditch recently, since this sample did not come from within the bund but within the ditch itself, and was only ~10 cm below the surface of the ditch (~40 cm below the surface of the bund). This determination dates neither construction nor use of the feature. This date is removed from further discussion because it is unlikely to stem from activity associated with the use of this feature.

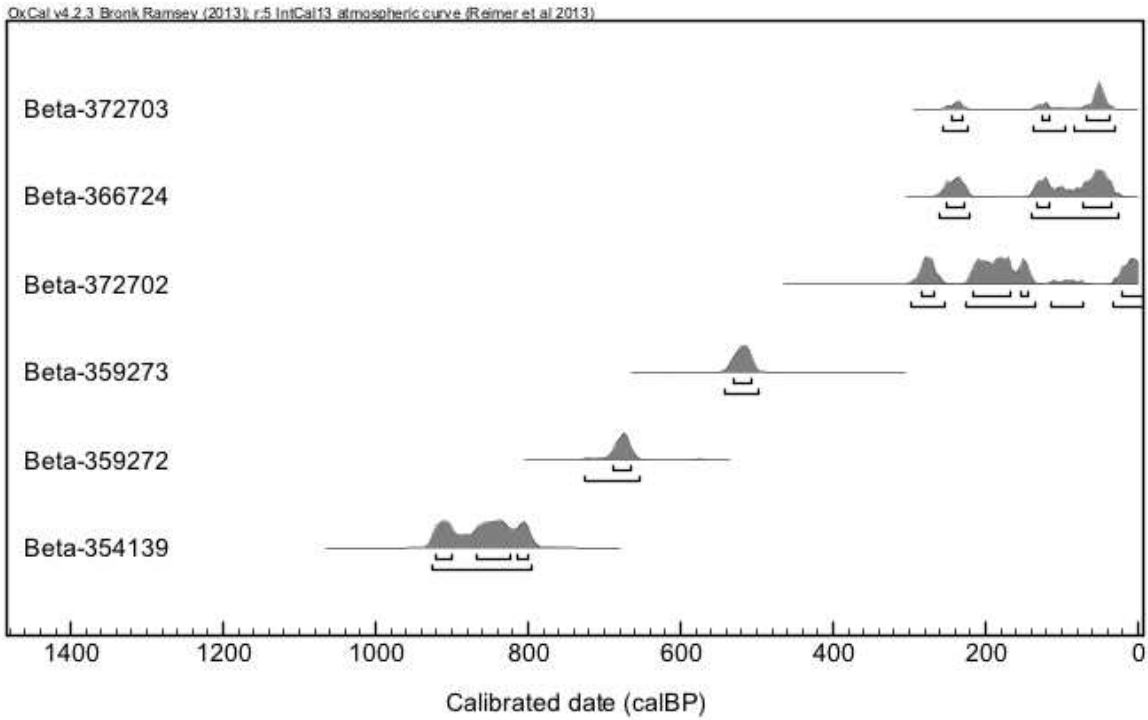


Figure 6.55 Calibration results of date determinations from A'ofa

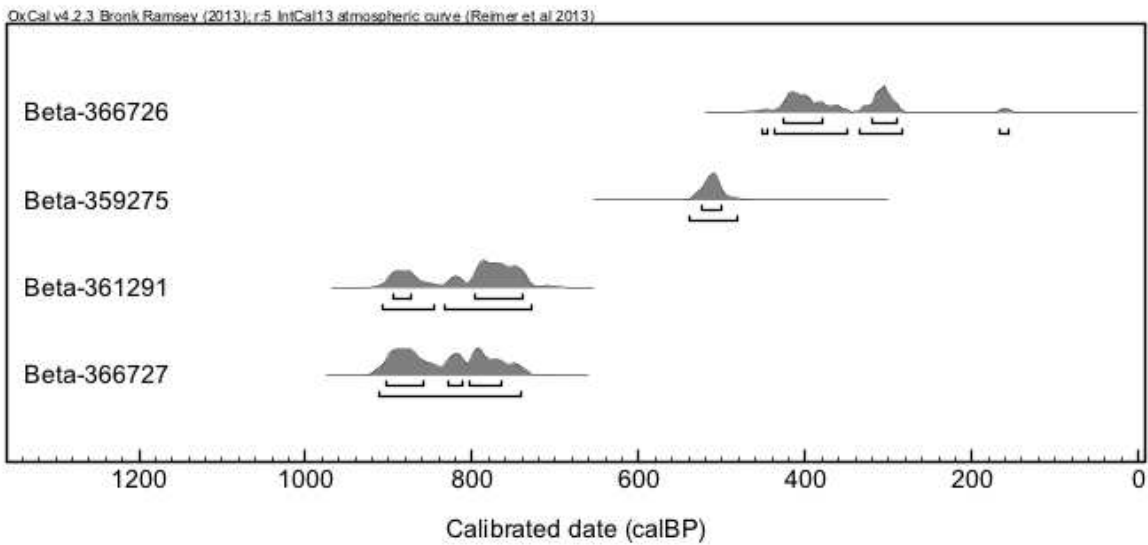


Figure 6.56 Calibration results of date determinations from Tufu

Table 6.13 Radiocarbon dates from the interior of Ofu Island

Sample Number	Area	Unit	Feature Type	Depth	Material	$\delta^{13}C$	Conventional Date	Calendar Date (2 σ)
Beta-366724	A'ofa	XU-1	Ditch-and-Parcel	30 cmbs	<i>Myristica</i> sp.	-26.4	70±30	AD 1690-1924
Beta-372702	A'ofa	XU-3	Depression	90 cmbs	<i>Artocarpus altilis</i> wood	-23.5	180±30	AD 1652-1917
Beta-372703	A'ofa	XU-5	Ditch-and-parcel	70 cmbs	<i>Myristica</i> sp.	-26.1	30±30	AD 1695-1919
Beta-366725	A'ofa	XU-6	Ditch-and-parcel	40 cmbs	<i>Aleurites moluccanus</i> shell	-24.8	Modern	Modern
Beta-354139	A'ofa	XU-7	Ditch-and-parcel	49 cmbs	<i>Allophylus</i> sp.	-26.9	950±30	AD 1024-1155
Beta-359272	A'ofa	XU-9	Terrace	48 cmbs	<i>Cocos nucifera</i> endocarp	-24.2	730±30	AD 1224-1298
Beta-359273	A'ofa	XU-10	Terrace	36 cmbs	<i>Hibiscus tiliaceus</i>	-26.2	480±30	AD 1408-1452
Beta-366726	Tufu	XU-1	Ditch-and-parcel	40 cmbs	<i>Cocos nucifera</i> endocarp	-22.7	280±30	AD 1498-1795
Beta-361291	Tufu	XU-4	Ditch-and-parcel	60 cmbs	Organic Material (from wood)	-28.0	880±30	AD 1042-1222
Beta-359275	Tufu	XU-5	Ditch-and-parcel	40 cmbs	Short Diameter wood	-28.0	460±30	AD 1412-1468
Beta-366727	Tufu	XU-6	Terrace	36 cmbs	<i>Artocarpus altilis</i> wood	-25.2	900±30	AD 1039-1210

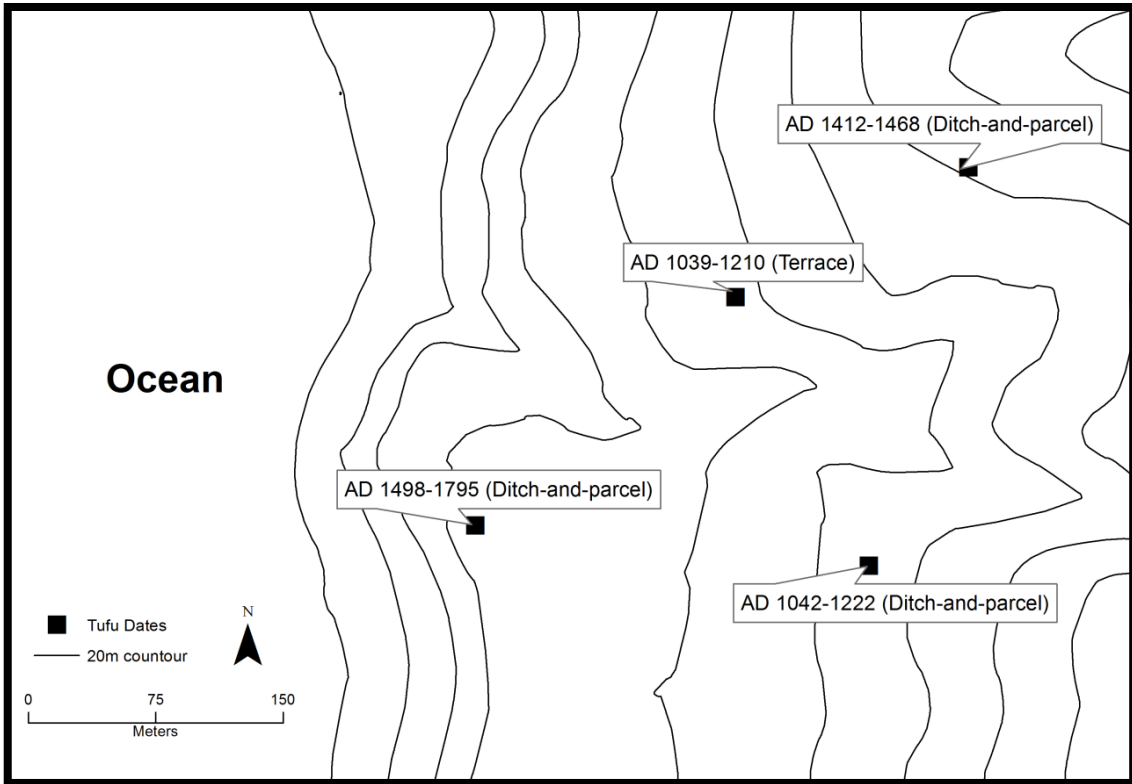


Figure 6.57 Dated features in Tufu plotted on a 20 m contour map

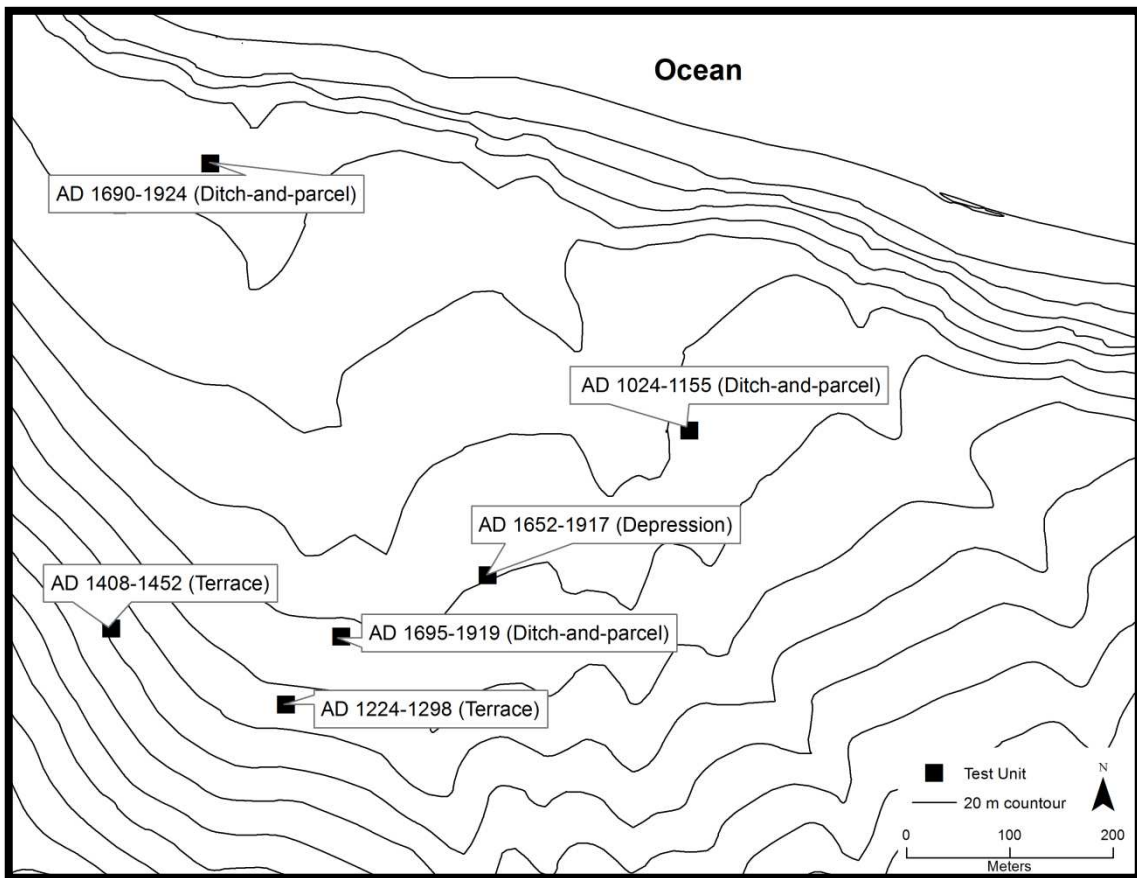


Figure 6.58 Distribution of dated features in A'ofa on a 20 m contour map. Date ranges are 2σ

Beta-354139 (A'ofa XU-7, *Allophylus* sp.) 950±30 (2σ AD 1024-1155)

This was a single piece of wood charcoal collected at 49 cmbs in A'ofa XU-7, along a soil transition interpreted as the interface between an old land surface and the built-up bund from ditch-and-parcel construction. *Allophylus* is a medium-lived species (J. Huebert per comm.), living as much as a couple decades. Therefore, the sample might have modest inbuilt age. Given that the charcoal was taken *in situ*, close to the interface between two stratigraphic layers that could mark the extent of fill used to construct the ditch bund, the date provides a maximum age for the feature.

Beta-366726 (Tufu XU-1, *Cocos nucifera* endocarp) 280±30 (2σ AD 1498-1795)

This was a single piece of coconut endocarp collected *in situ* within the ditch bund of the largest ditch-and-parcel complex in Tufu, at ~40 cmbs in Tufu XU-1. Coconut endocarp is a short-lived material with minimal inbuilt age. No soil boundaries could be identified within the ditch bund, but a definable layer of charcoal flecking was noted, from which this sample was taken. The layer of charcoal flecking is interpreted to stem from a vegetation burn-off prior to feature construction. Therefore, this sample is interpreted as a maximum date for the construction of this ditch-and-parcel complex.

Beta-361291 (Tufu XU-4, degraded organic material from plant charcoal) 880±30 (2σ AD 1042-1222)

This sample was decomposed and degraded charcoal of, presumably, a single piece of wood in a burn layer at ~60 cmbs in Tufu XU-4 (Fig. 6.55 above), interpreted to represent vegetation burn off prior to ditch construction. The type of wood could not be discerned, so the possibility of inbuilt age cannot be ruled out. However, the date is consistent with the other dated ditch-and-parcel complex of similar characteristics, which suggests that the date was not adversely affected. The sample is interpreted to provide a maximum age for the feature.

Beta-359275 (Tufu XU-5, small diameter wood) 460±30 (2σ AD 1412-1468)

This sample was a single piece of small diameter wood, likely a twig or small tree taken from 40 cmbs Tufu XU-5. In any case, the sample is short-lived to medium-lived with minimal or modest inbuilt age (J. Huebert per. comm.). This sample was collected from a transition that might mark the extent of fill to create the ditch bund, an area defined by a lens of dense charcoal, which is interpreted as evidence of vegetation burning prior to the

construction of the ditch-and-parcel complex. Based on this interpretation, this sample offers a maximum age for the construction of the feature.

Terraces

Beta-359272 (A'ofa XU-9, *Cocos nucifera* endocarp) 730±30 (2σ AD 1224-1298)

This sample was a single piece of coconut endocarp collected from the inside of a retaining wall 48 cmbs in A'ofa XU-9. Coconut endocarp is a short-lived material with minimal inbuilt age. Because of the sample's association with the inside base of a retaining wall, it is interpreted as a maximum age of terrace construction.

Beta-359273 (A'ofa XU-10, *Hibiscus tiliaceus*) 480±30 (2σ AD 1408-1452)

This sample was a single piece of *Hibiscus* collected at 36 cmbs in A'ofa XU-10 from an area of increased charcoal concentration. *Hibiscus*, though not long-lived, has the potential to exhibit modest inbuilt age (Allen and Huebert 2014:261), but likely no more than 50-60 years. Therefore, the determination provides a maximum age of feature construction, the date perhaps, given some potential inbuilt age, slightly older than the terrace.

Beta-366727 (Tufu XU-6, *Artocarpus altilis* wood) 900±30 (2σ AD 1039-1210)

This sample was a single piece of *Artocarpus* wood collected from the front of a terrace at 36 cmbs in Tufu XU-6. Excavation revealed a possible stratigraphic change at 35-55 cmbs, an area of high charcoal density. The differences between layers were modest and charcoal, though in a greater density within the aforementioned depth range, was found throughout the excavation. *Artocarpus* can live for several decades and this determination may include some inbuilt age (Allen and Huebert 2014:262, Table 1). Given these limitations, the sample could provide a maximum age for terrace construction, and, combined with the possibility of inbuilt age, the determination could be older than the terrace. However, this sample also dates landscape use and the presence of economic trees in the interior.

Circular Depressions

Beta-372702 (A'ofa XU-3, *Artocarpus altilis* wood) 180±30 (2σ AD 1652-Post-1917)

This sample was a single piece of *Artocarpus* wood collected *in situ* from beneath a thick layer of shell, fishbone, and sea urchin spine 90 cmbs in A'ofa XU-3. Unfortunately, the determination intercepts the calibration curve at a significant wiggle, creating a large age

range. This is further confounded by the fact that *Artocarpus* can live for several decades (Allen and Huebert 2014:262), and some inbuilt age cannot be ruled out. Since few people, as indicated by the Wilkes expedition, resided on Ofu by the early 1840s and it is improbable that activities associated with this depression occurred thereafter, the date likely reflects activity that occurred between AD 1644 and AD 1840. Because this sample was taken at the bottom of the faunal deposit, I interpret this determination to date immediately prior to the deposition of the marine fauna.

A Preliminary Chronology of the Ofu Interior Uplands

On present evidence, permanent settlement of the interior, demonstrated by the construction of earthen structures, commenced at the beginning of the 2nd millennium AD in the 11th or 12th centuries AD (Beta-354139, 2 σ AD 1024-1155; Beta-361291, 2 σ AD 1042-1222; Beta-366727, 2 σ AD 1039-1210). Some use of the interior occurred prior to this based on the timing of terrigenous deposition on the coast indicative of upslope forest clearance, but this marks more intensive and permanent use/habitation. On a radiocarbon scale, the construction of earthen structures in Tufu and A'ofa occurred contemporaneously.

The three terraces that were dated indicate an expansion of activity upslope over time (Fig. 6.59). Likewise, the most recent terrace, Feature 78 (XU-10, Beta-359273, 2 σ AD 1408-1452), is the smallest of the three, and similar small terraces in high slopes with limited basalt paving might also be late constructions (Class 1N). The earliest constructed terrace is the largest that was dated (Beta-366727, 2 σ AD 1039-1210). However, this is more uncertain given the material, long-lived wood, dated from beneath Feature 83. The chronological relationship between residential features in Tufu and A'ofa remains ambiguous since only three terraces were dated and coral was found on only one of these. Depressions are associated with two of the dated terraces. One depression that was located on Tufu Feature 83 (Beta-366727, 2 σ AD 1039-1210) had only a modest amount of stone edging (two boulders) and was, therefore, classified as non-edged. The other, located on a terrace (A'ofa Feature 3) within 3 m of A'ofa Feature 2 (Beta-359272, 2 σ AD 1224-1298), did have a stone edge (more than four boulders). This temporal relationship is tentative and needs to be tested with future research, but it raises the possibility that these depressions were built at a similar time as the terraces. No ditch-and-parcel complexes were associated with any dated terrace.

The dates of ditch-and-parcel complexes formed two groups, pre- and post-AD 1400, which correspond to single branch features and networks (Table 6.14). Broadly speaking,

early ditch-and-parcel complexes tend to be smaller, singular features located near terraces and depressions (Beta-354139, 2 σ AD 1024-1155; Beta-361291, 2 σ AD 1042-1222). More specifically, terraces are situated within 5 m of both single branch features that date to the beginning of the 2nd millennium AD, one directly downslope (Tufu Feature 17) and the other downslope and to the side (A'ofa Feature 102).

Later ditch-and-parcel complexes were constructed to form networks, but dates from these produced a larger range (AD 1412-1924). The earliest example of a network (Beta-361291, 2 σ AD 1412-1468), dating in the 15th century AD within the Tufu unit, possesses only two branches and is located in high slopes (ca. 25 degrees). The other ditch-and-parcel network dated from Tufu dates to the 16th-18th centuries AD and is located in a position seaward of the HFD mean centre (Beta-366726, 2 σ AD 1498-1795). It appears that this latter example was also constructed earlier than ditch-and-parcel networks in A'ofa, though there is overlap at two standard deviations. Radiocarbon determinations of networks from A'ofa are more difficult to interpret, as the two samples possess large age ranges that extend into the historic period (Beta-366724, 2 σ AD 1690-1924; Beta-372703, 2 σ AD 1695-1919). However, several lines of evidence can be used to reduce the size of this range. The lack of mention of the existence of ditch-and-parcel complexes by ethnographers who visited the island, in conjunction with statements by the Wilkes expedition indicating that few people inhabited Ofu in the early 1840s, implies the features were built and used prior to the 1840s. Their prehistoric age is further suggested by the spatial patterning of these features. Specifically, the construction of ditch-and-parcel network does not appear to have bisected or disturbed other features. Therefore, the ditch-and-parcel complexes that were confidently dated from A'ofa were most likely constructed sometime in the 17th-18th century AD.

The single depression that was dated indicates use of the feature class for refuse disposal in the 18th century AD or later (Beta-372702, 2 σ AD 1652-1917). Data is not available to evaluate whether this depression was constructed and used for previous purposes earlier, though such a situation is plausible. No other depressions were dated, but some depressions might have been constructed at the beginning of the 2nd millennium AD given their association with other feature classes (discussion above). One of these features possessed stone edging, while only two boulders were situated around the rim of the other.

As a whole, these chronological data document a pattern of continual occupation expansion and infilling, from the initial habitation of each HFD zone through to

abandonment. Those features located more on the peripheries, as defined as proximity to zone boundaries, date later in the sequence. This is especially true of ditch-and-parcel networks, which generally are found near the boundaries of each zone or in seaward positions, and date to the end of the prehistoric period. Terracing, too, expands over time. While only three were dated, their spatial and temporal distribution suggests progressive expansion into higher slopes, which is equated with movement into more marginal areas. Given this evidence, the synchronic spatial patterning of each zone only reflects the last use of each location, the end of a long sequence of development. The spatial distribution of features at the beginning of the 2nd millennium AD (11th-13th centuries AD) appears to have been more dispersed across the landscape.

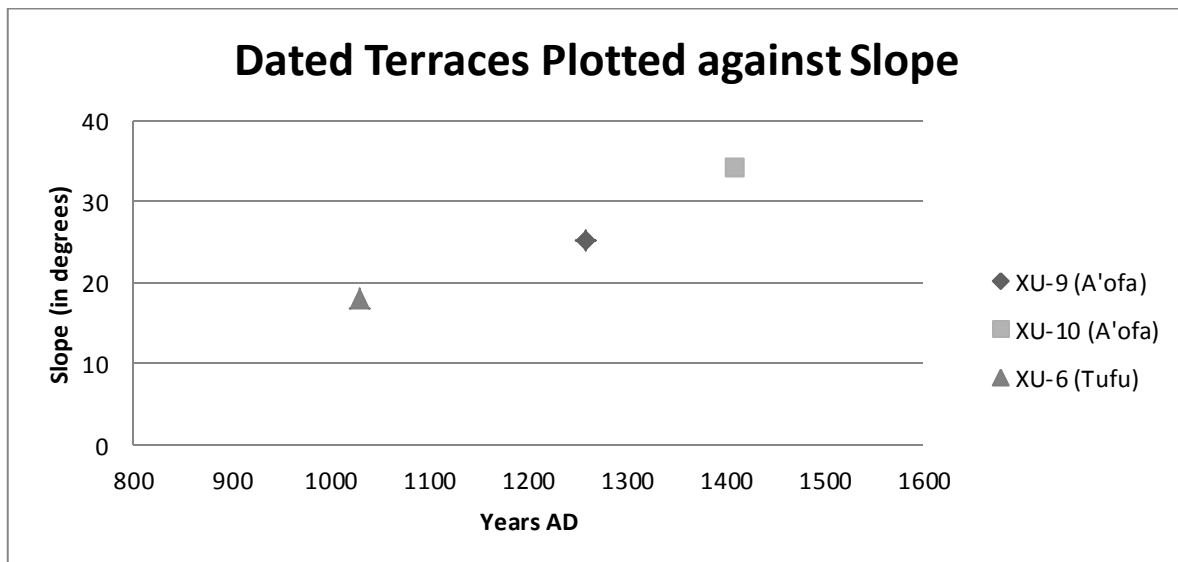


Figure 6.59 Dated terraces plotted against slope showing a trend of expansion into higher slopes over time

Table 6.14 Dated ditch-and-parcel complexes on Ofu

High Density Zone	Ditch-and-Parcel Type	2 σ Range
A'ofa	Single Branch	AD 1024-1155
Tufu	Single Branch	AD 1042-1222
Tufu	Network (two branches)	AD 1412-1468
Tufu	Network	AD 1498-1795
A'ofa	Network (small)	AD 1695-1919
A'ofa	Network	AD 1691-1924

Chapter Summary

This chapter has presented the results of detailed survey undertaken in the interior uplands of Ofu, along with limited test excavation. Survey and excavation was conducted in two locations. In each location, a series of depressions, terraces, and ditch-and-parcel complexes were identified in high number, and additional features, ditched terraces and central open spaces, were identified in low densities. Variation was apparent within feature classes, which represents functional differences. Ditch-and-parcel complexes appear to have been used for agricultural activities, but were separated into networks and single branch features. Depressions likely functioned in numerous ways, and stone edged depressions possess attributes consistent with recorded examples of *masi* pits. Terraces served both residential and non-residential functions.

Patterning was observed in the distribution of these features at multiple scales. In each zone, both centre: periphery and seaward: inland patterns are apparent. Residential terraces are found seaward of non-residential terraces and economic vegetation is found seaward of secondary vegetation. In both zones, positions seaward of the mean centre are occupied by large ditch-and-parcel networks that do not appear associated with any residential features. Stone edged depressions, interpreted as *masi* pits, and single branch ditch-and-parcel complexes are often associated with terraces.

Excavation was limited, but a preliminary chronology of the feature classes was created. There is a correlation between the chronology of terrace construction and expansion upslope, with those in lower slopes constructed earlier. A chronological difference was noted between the two ditch-and-parcel types, networks and single features. Single branch features were built at the beginning of the interior sequence, while networks were not built until the last few hundred years before European contact. Little is known of the chronology of depressions. One that was dated is evidence of activity associated with the feature class in late prehistory, while two that are associated with dated terraces raise the possibility that some were constructed at the beginning of the 2nd millennium AD.

The next chapter synthesises the results of the last two chapters to identify and describe the changing location, timing, and management of agricultural activities on Ofu. A course of agricultural development on Ofu is then presented that situates agricultural change within a wider environmental and cultural context.

Chapter 7: Analysing Agricultural Development on Ofu

In Chapters 5 and 6, I presented the results of survey and excavation conducted on the coast and interior of Ofu Island. This fieldwork is the source of a dataset constructed to examine changing patterns of agriculture from island colonisation to historic contact. Particularly important for understanding and explaining agricultural development is the location, timing, and management of agricultural activities. In this chapter, these are evaluated based on evidence from this project and from other projects that have been conducted on Ofu (ASPA site files; Best 1992; Clark 2011, 2013; Kirch and Hunt 1993a,b). These sections employ similar lines of evidence analysed from different points of view to create a robust picture of the production system through time. The final section describes the course of agricultural development on Ofu and situates it into a wider socio-ecological framework.

The Spatial and Temporal Patterning of Agricultural Activities

Identifying the location and timing of different agricultural activities is a fundamental first step in understanding the development of an agricultural system. Evidence of this can be direct, such as agricultural infrastructure and charcoal of economic taxa, or indirect, such as vegetation patterns, patterns of soil deposition, or the presence of synanthropic non-marine molluscs. In this section, I synthesise the evidence from the coast and interior of Ofu to present a model of where and when agricultural activities occurred.

The populations that colonised Ofu Island occupied the narrow coast flats (Clark 2011, 2013; Kirch and Hunt 1993b; Chapter 5: XU-4, Beta-354137). Carbonised remains of only a few plants have been found within deposits dating to the 1st millennium BC, most notably *ti* and coconut (Va'oto, Jennifer Huebert per comm. 2014 (ID), Beta-366730, 2350±30, 2σ 515-375 BC). The density of synanthropic non-marine molluscs at To'aga increased over the period of ceramic use (from initial colonisation to the 5th or 6th century AD) (Kirch 1993b:118-120) (Table 7.1), and this pattern may be evidence of the formation and expansion of anthropogenic vegetation at To'aga by the end of the 1st millennium BC (Layer IIA-1, Beta-25033, 1σ 362-145 BC, Kirch 1993c:87; see also Hunt and Kirch 1997:121). A layer made up of terrigenous sediments dates to shortly after colonisation at To'aga based on stratigraphic position (Layer III on the Main Trench of To'aga, Kirch and Hunt 1993a:51, 56; not directly dated), and charcoal in the layer suggests at least some

clearance of vegetation on slopes inland of the area by burning, perhaps for gardening. These various lines of evidence indicate that cultivation was practiced on the island in the 1st millennium BC, but that it might have been spatially restricted around areas of occupation. There is no evidence that signals residential use of inland areas.

Table 7.1 Counts of non-marine molluscs in the main trench of To'aga (data from Kirch 1993b:119, Table 8.1)

(number of samples)	Layer IIC (3)	Layer IIB (3)	Layer IIA (2)	Layer IIA-1 (1)
<i>Assiminea</i> sp.	25	129	93	84
<i>Lamellidea pusilla</i>	30	27	5	14
<i>Gastrocopta pediculus</i>	35	94	26	19
<i>Lamellaxis gracilis</i>	5	23	7	11
Total (with all natives)	97	275	137	128
Snails/l³	116	330	200	336

Over time, the contribution of terrigenous sediments to the coastal soils increased through erosion. The rate of terrigenous deposition increased after Layer VIc in XU-4 of Ofu Village, continuing into the latter half of the 1st millennium AD in Layer VIa (top of Layer IV in XU-2/4, Beta-380263, 2 σ 895-1021) (Fig. 7.1). At To'aga, increased terrigenous sedimentation occurs at the beginning of the 1st millennium AD and likely continued through the rest of the cultural sequence (Kirch and Hunts 1993a:56, 68, 78). The presence of particulate charcoal in these deposits supports the role of humans in their formation and connections with forest clearance upslope. The lack of evidence of interior residential activities at this time implies that forest clearance is most likely associated with the spatial expansion of agricultural activities. The scale and location of this expansion is unclear, but it could have occurred either across the coastline, on the slopes overlooking the coastline, or perhaps in the low elevations of the interior. A land snail column analysed by Kirch from Unit 3 of To'aga is also informative (Kirch 1993b:119). The top of the basal layer, from where the first sediment sample was taken, dates to the 1st millennium AD (Layer II, Beta-26463, 1 σ AD 561-663, Kirch 1993c:88). An increase in synanthropic non-marine molluscs is apparent from the lowest sample in the basal layer to the top sample in the surface layer (Table 7.2). This hints at the presence of an anthropogenic environment through the 1st millennium AD and, presumably, into the 2nd millennium AD, though a more precise chronology is unavailable. This collective evidence from the 1st millennium AD seems to signify a pattern of the expansion of agricultural activities.

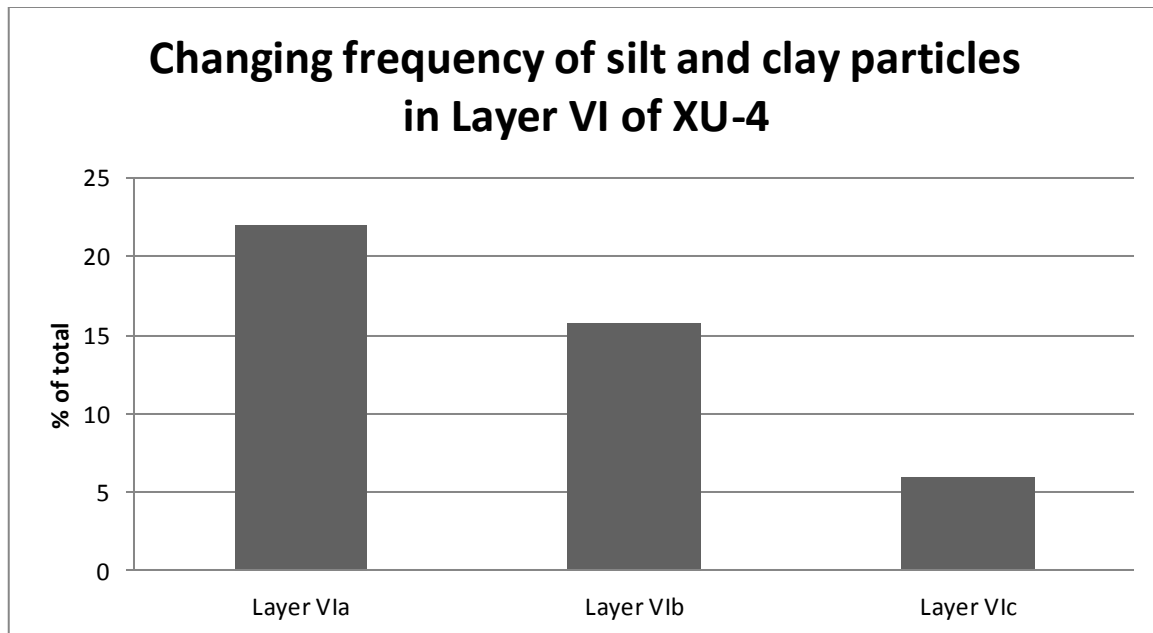


Figure 7.1 Frequency of clay and silt particles (terrigenous sediments) in Layers VI and VII of XU-4, Ofu Village. The bottom of Layer VIc dates to 2σ 781-511 BC and the top of Layer IVa dates 2σ AD 895-1021

Table 7.2 Counts of non-marine molluscs in Unit 3 of To'aga (data from Kirch 1993b:119, Table 8.2)

Sample Number (Layer)	2 (Layer II)	3 (Layer II)	4 (Layer I/II)	5 (Layer I)	6 (Surface)
<i>Assimineea sp.</i>	10	27	44	110	15
<i>Lamellidea pusilla</i>	2	6	3	18	0
<i>Gastrocopta pediculus</i>	6	9	7	27	0
<i>Lamellaxis gracilis</i>	3	8	10	13	3
Total (with all natives)	21	52	66	175	18
Snails/l³	71	184	280	735	68

The deposition of terrigenous sediments and the mixing of these sediments with local calcareous beach sands and coral improved the arability of the coastal flats (Kirch and Hunt 1993b:235). The dark organically enriched clay loam garden soils in XU-2 and XU-4 (Layer V) of Ofu Village attest to the cultivation of the area by the end of the 1st millennium AD or beginning of the 2nd millennium AD (after Beta-380263, 2σ AD 895-1021). Similar deposits have been identified by Kirch and Hunt (1993b:235) on the south coast, and these researchers have noted the inclusion of charcoal lenses within their colluvium strata, findings which they equate with garden activity on the coastal flat (Kirch and Hunt 1993b:49). The precise timing of the latter events at To'aga is not known, as no radiocarbon dates are available from these

deposits, but it is likely that they date to the last 1,500 years before European contact (Hunt and Kirch 1997:113, 116).

From the interior itself, initial evidence of agricultural activities appears in the form of charcoal and agricultural infrastructure (Chapter 6). Carbonised breadfruit and coconut wood was found beneath two terraces, and these remains are dated to the 11th-13th century AD (Tufu Feature 82, Beta-366727, 2 σ AD 1039-1210; A'ofa Feature 2, Beta-359272, 2 σ AD 1224-1298). The evidence is limited, but it does suggest that at least some economic trees were present in the area before the construction of surface features. More convincing evidence of agricultural activities is provided by the development of ditch-and-parcel complexes. Two of these features, one from Tufu (Tufu XU-4, Beta-361291, 2 σ AD 1042-1222) and one from A'ofa (A'ofa XU-7, Beta-354139, 2 σ AD 1024-1155), date to the 11th or 12 century AD, and their date ranges overlap at one standard deviation. On this evidence, the development of ditch-and-parcel complexes appears to have 1) occurred contemporaneously in the 11th and 12th century AD in Tufu and A'ofa; 2) been limited to single branch features; and 3) been spatially restricted in each zone.

At the inland extent of A'ofa, *Hibiscus* was dated to the 15th century AD from beneath a terrace and may also be evidence of cultivation of these slopes prior to the 15th century AD (A'ofa Feature 78, Beta-359273, 2 σ AD 1408-1452). *Hibiscus* is a common tree found in secondary forests in garden plots left to fallow (Webb and Fa'auma 1999:260), and usually grows in inland regions after a large disturbance (Webb and Fa'auma 1999:265). Whistler (2009:132) notes that "its dominance in inland forests may be an indicator that the areas were once plantations". The presence of the plant under the terrace raises the possibility of the cultivation of these slopes before construction of the feature (< 15th century AD), as the natural distribution of the tree is in littoral forests and mangrove swamps (Whistler 2009:132). However, this evidence is not conclusive.

The construction of non-residential Class 1N terraces (A'ofa Features 2 and 78), presumably used as temporary field shelters, implies the use of these slopes as well. The earliest of these features was built in the 13th-14th century AD, and the later example was constructed in the 15th century AD (Beta-359272, 2 σ AD 1224-1298; Beta-359273, 2 σ AD 1408-1452). The presence of these features attests to investment in the use of the wider landscape. That no permanent residential features have been identified in these areas of great slope (over 25 degrees) suggests that cultivation was the primary activity conducted here.

Two dated terraces is admittedly modest evidence, but the timing of the construction of these features might mark the expansion of agricultural activities into greater slopes over time.

The earliest dated ditch-and-parcel network was constructed in the 15th century AD (Tufu Parcel 1, Beta-359275, 2 σ AD 1412-1468), and is located in the steepest slopes of any in Tufu (as much as 25 degree slopes). The other dated ditch-and-parcel network in Tufu, Parcel 17, was constructed slightly later (Tufu XU-1, Beta-366726, 2 σ AD 1498-1795), and is located along the cliffs on the western boundary of the Tufu HFD zone. The timing of the construction of networks in A'ofa was somewhat later than in Tufu, with both of the dated examples from A'ofa being constructed in the late 17th century AD at the earliest (A'ofa XU-1, Beta-366724, 2 σ AD 1690-1924; XU-5, Beta-372703, 2 σ AD 1695-1919).

The expansion of agricultural activities indicated by the continued construction of agricultural infrastructure, ditch-and-parcel networks and Class 1N terraces, is supported by sediment evidence on the coast. Layers of colluvium were deposited in the 15th century AD and later, based both on the direct dating of colluvium (Layer IV of XU-4, Beta-372700, 2 σ AD 1498-1795) and the dating of earlier deposits (Layer VII of XU-1, Beta-332861, 2 σ AD 1408-1452; Layer VI of Trench 3, Beta-366731, 2 σ AD 1299-1413). The role of humans in the formation of these layers is attested by the presence of particulate charcoal. However, the clearance of forest that led to the erosion of these sediments could have been related to both residential and agricultural expansion, with both activities occurring in the interior at this time. The presence of dark organically enriched clay loam soils atop colluvium supports the occurrence of cultivation on the coastal flats in the 18th century AD or later (Layer III, XU-2 and XU-4; Layer II Trench 2 and 3; Layer IV, Trench 1; Beta-372698, 2 σ Ad 1695-1919).

Features representing possible storage pits have not been dated, but storage technology was certainly practiced at some point in prehistory based on the large number of depressions in the interior and the number of posited storage pits on the coast (Hunt 1993:24, 26; Kirch and Hunt 1993a:70-71). The location of depressions on or near dated terraces raises the possibility of storage after the construction of these terraces at the beginning of the 2nd millennium AD (Tufu Feature 83 and A'ofa Feature 2). This could signal the use of arboricultural resources, banana and especially breadfruit, shortly after the permanent occupation of the interior uplands. However, only one of these depressions possessed clear stone edging, which was used as a marker of storage pits in Chapter 6, and the functional assignment of either as a storage device is tentative.

Also of unknown temporal depth is the coastal marsh, an important cultivation zone today. Targeted research needs to be undertaken to document the formation of this environment, but a tentative sequence can be proposed to be tested in the future. The marsh is shallow, consisting of 30 cm of terrigenous sediments overlaying marine sand, a depth which points to the area being open to the sea until relatively recently. This may mean that the marsh did not form until after the coast had prograded towards its present configuration (refer to Chapter 5 or see summary below). It is after this point that infilling and accumulation of terrigenous sediments could have occurred. The timing of the deposition of colluvium on both the west and south coast suggest the formation of this environment in the 2nd millennium AD, and perhaps after the 15th century AD. Similar processes of 2nd millennium AD coastal marsh formation have been documented elsewhere in Samoa (e.g., Clark and Michlovic 1996; Goodwin and Grossman 2003; Hunt and Kirch 1988), and on other islands in the region (e.g., Allen 1998:17; Kirch and Yen 1982:328).

Vegetation patterns may provide insights into the maximal extent of cultivation techniques, namely arboriculture and shifting cultivation. There is a correlation between the location of HFD zones and the distribution of forests containing economic trees like breadfruit, coconut, Tahitian chestnut, and candlenut (Fig. 7.2). This correlation is suggestive of the presence of arboriculture in the past, and the modern vegetation distribution might even approximate the extent of arboriculture plantations. Tree crops (i.e., breadfruit and coconut) appear to be the primary component of this vegetation zone, but it is also possible that understory cultivation of crops occurred, a pattern identified ethnohistorically elsewhere (e.g., Addison 2006; Kirch 1994:181-182; Lepofsky 1994; Yen 1973:114-115).

Secondary forests, forests constituted by successional plants (e.g., *Hibiscus tiliaceus*, *Macaranga harveyana*, *Pipturus argenteus*), are located on the slopes inland of the economic forests. This vegetation type grows after disturbance, either human or naturally caused. Natural fires are a rare occurrence in Samoa, and it is unlikely that disturbance from cyclones would create a pattern wherein secondary forest is located upslope of economic forests and downslope of primary forest (e.g., *Dysoxylum* spp., *Ficus* spp., *Reynoldsia pleiosperma*). Instead, it would be expected that a pattern reflective of cyclone damage would be patchier. Cyclones and some fire may still have been a factor, but a full explanation of the pattern requires links to human activity. That few, if any, residential features are found in this zone, particularly in Tufu (Fig. 7.2), is evidence that the disturbance causing secondary forest

growth was largely related to cultivation. The distribution of secondary forests on Ofu could define the extent of shifting cultivation on the island.

This pattern where shifting cultivation is located inland of arboriculture plantations is reminiscent of the spatial layout of documented archaeological and historic cultivation systems elsewhere in the Pacific (Kirch 1994:176; Lincoln and Ladefoged 2014). If these vegetation patterns do mark the spatial extent of cultivation systems, shifting cultivation covered an area of ~114 ha, tree crops covered ~82 ha, and only ~3 ha of land was part of ditch-and-parcel complexes. How far these vegetation patterns extend into the past is unknown, but they likely developed over time as the area of occupation expanded. They possibly reached their present configuration at the end of the prehistoric sequence.

Based solely on evidence in this section, a model of the timing and location of cultivation techniques on Ofu is presented in Table 7.3.

Evidence of Agricultural Management

Different cultivation strategies are managed at different scales (Allen 2004; Kirch 1984, 1994; Kirch et al. 2004; Ladefoged and Graves 2008; Lepofsky and Kahn 2011). Documenting the level of agricultural management is reliant on proxies such as spatial proximity to other archaeological features or places of social significance (Lepofsky and Kahn 2011), the construction of labour intensive infrastructure (Allen 2004; Kirch 1984, 1994), or evidence of plot segmentation (Ladefoged and Graves 2008). Similar proxies are used to assess the level of agricultural management on Ofu.

The scarcity of evidence relating to cultivation in the first few hundred years after colonisation implies that food production was spatially restricted and there is no evidence relating to the management of production. During the first few centuries of the 1st millennium AD, Green (2002:138) has posited that the distinctive “house society” in Samoa began to develop. House societies are defined by the presence of a distinct corporate body, which, archaeologically, can be identified by the combination of various structures such as dwellings, cookhouses, storage pits, etc. (Kahn and Kirch 2013:51). These households, however, are difficult to identify in subsurface deposits, since a substantial area needs to be uncovered to locate them. Based on linguistic reconstruction (Kirch and Green 2001:215-218), political leadership in these incipient “house societies” would have been by a senior male at the family level, with production managed at that same level.

Table 7.3 The presence or absence of cultivation techniques through the cultural sequence. High confidence presence (X), potential presence (--). See text for discussion of evidence

Technique	Location	600 BC	400 BC	200 BC	AD 0	AD 200	AD 400	AD 600	AD 800	AD 1000	AD 1200	AD 1400	AD 1600	AD 1800
Shifting Cultivation	Coast and Interior	X	X	X	X	X	X	X	X	X	X	X	X	X
Arboriculture³	Coast and Interior	--	--	--	--	--	--	--	--	X	X	X	X	X
Anthropogenic Soil Cultivation⁴	Coast								--	X	X	X	X	X
Ditch-and-Parcel Single Branch Features	Interior									X	X	X	X	X
Class 1N Terraces (Field Shelters)	Interior										X	X	X	X
Ditch-and-Parcel Networks	Interior											X	X	X
Marsh Cultivation⁵	Coast									--	--	--	--	X
Masi Pits⁶	Coast and Interior									--	--	--	--	X

³ Potential presence based on the presence of coconut endocarp and wood in early deposits at To'aga, Va'oto, and Ofu Village. It is unknown whether this is from the native variety or from one that was introduced. There is a question of whether coconut use constitutes arboriculture, as a native coconut variety is known from Samoa. Though, arboriculture is indicated by linguistic evidence (Kirch and Green 2001). This says nothing about the scale of arboriculture.

⁴ Potential presence based on the date of the interface between Layers V and VI in Ofu Village XU-2. Cultivation occurred after this date.

⁵ Potential presence based on the assumption that the environment would not have formed until after coastal progradation and subsequent terrigenous infilling.

⁶ Potential presence based on the presence of two depressions located on terraces dated to the 11th-13th century AD. Masi pits were recorded at European contact.

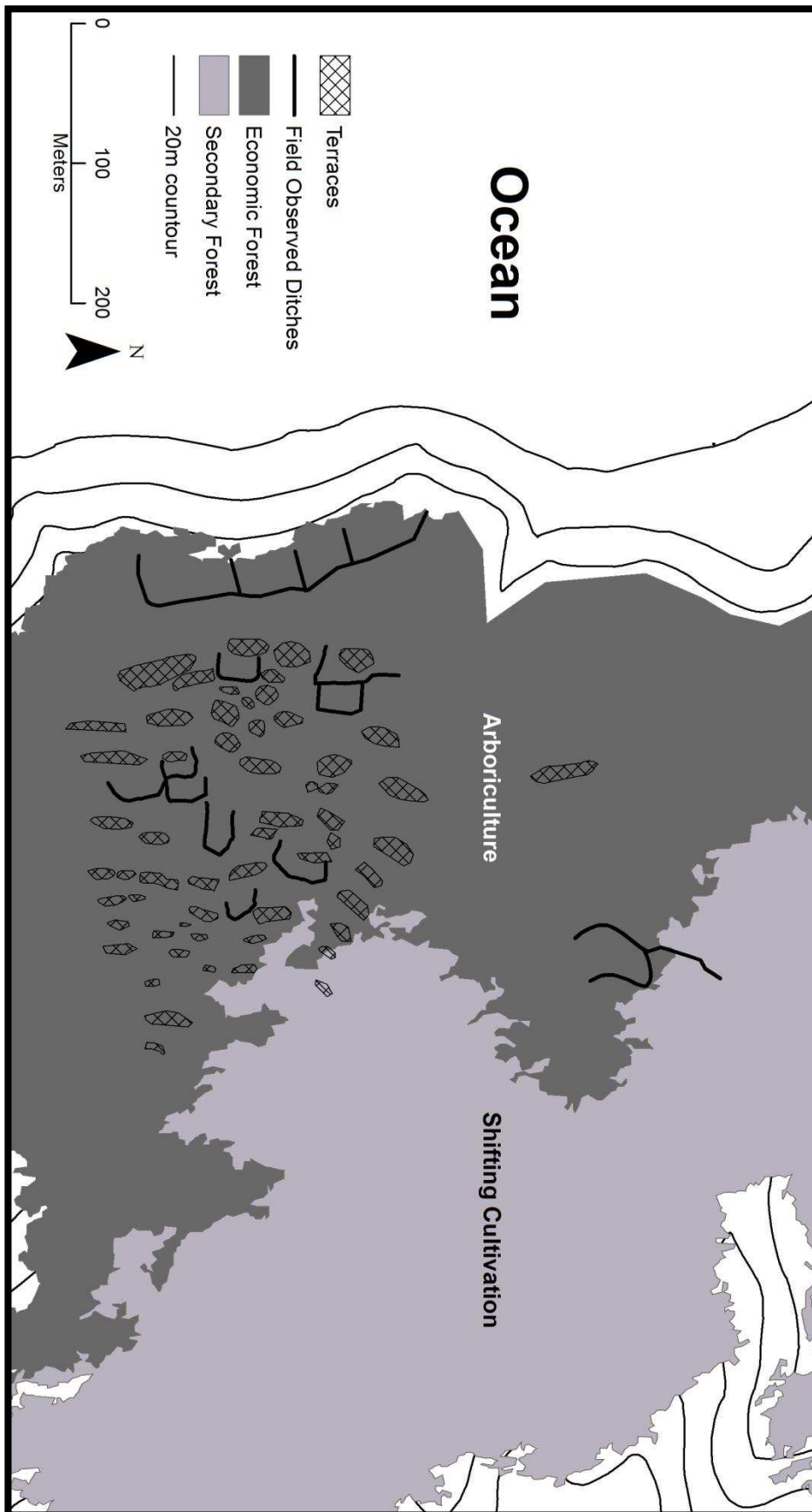


Figure 7.2 Proposed cultivation zones within the Tufu HFD zone

Empirical evidence informing on the social scale and management of agricultural resources on Ofu takes the form of agricultural infrastructure at the beginning of the 2nd millennium AD (Beta-361291, 2 σ AD 1042-1222; Beta-354139, 2 σ AD 1024-1155). Both dated ditch-and-parcel single branch features, A’ofa Parcel 3 and Tufu Parcel 10, are located within 5 m of a residential terrace. That residential terraces and depressions are situated in proximity could mean that these ditch-and-parcel complexes were part of household production, constructed and managed at that scale (domestic mode of production). However, a temporal correlation has not yet been demonstrated between these features.

Managerial changes are implied as ditch-and-parcel networks began to be built in the 15th-18th centuries AD (Beta-359275, 2 σ AD 1412-1468; Beta-366726, 2 σ AD 1498-1795; Beta-366724, 2 σ AD 1690-1924; Beta-372703, 2 σ AD 1695-1919). The length of ditches associated with networks is statistically greater than those associated with single branch features, with no overlap between the size distributions of the two (Fig. 6.54, Chapter 6). These data suggest that the construction of networks required a different scale of labour, and the increased labour requirements of networks hint that their construction involved a larger labour force. Though more labour was necessary to construct the features, it is unclear whether it necessitated the cooperation of multiple families. However, such cooperation and coordination is evidenced by the internal complexity of the features. The connection of multiple parcels (cultivation spaces) into one system implies cooperation among the groups using the different spaces. That these features were stretched across space associated with several residential terraces further implies cooperation.

The three largest networks were built in seaward positions of the A’ofa and Tufu HFD zones; two being seaward of the mean centre (A’ofa Parcels 20 and 21, $L^7 = 212$ m, $V \approx 425$ m³; Tufu Parcels 14-17, $L = 330$ m, $V \approx 660$ m³) and the third located along a stream that drains over the seaward cliff of A’ofa (A’ofa Parcels 24-27, $L = 347$ m, $V \approx 695$ m³). At least in Tufu, an open space is situated between a large ditch-and-parcel network and four large residential terraces (Fig. 7.3). The position of seaward ditch-and-parcel networks in both Tufu and A’ofa is socially important in the context of ethnographically documented perceptions of space in Samoa. Mead (1969:49) noted, “the term *i tai* (toward the sea) stands for the optimum position; the village on the seashore, the house on the sea side of the village, the place of honor in front of the house”. For Shore (1996:269), “the ‘front’... implies high

⁷ L=length, V=volume

rank, social authority, and socially visible and hence constrained behavior". The front (seaward) is the most visible place of villages, where you go to be seen, whereas the back (inland) is private. This front and back patterning of space extends into the prehistoric period, based on contact-era descriptions, archaeological evidence, and the ubiquity of the concept throughout Polynesia (Kirch and Hunt 1993b:18; Quintus and Clark 2012; Shore 1996:267, 272). From this evidence, it may be concluded that ditch-and-parcel networks in seaward locations were socially important features, and, based on ethnographic analogy, under the authority (*cum* management) of leaders. The space gave meaning to these structures.

The correlation between the four seaward-most terraces in Tufu and Parcels 14, 15, 16, 17 is also interesting (Fig. 7.3; see also Fig. 7.2). All four of these terraces have coral paving and are larger than average (Chapter 6). If an ethnographic analogy can be applied, the terrace's position seaward of the centre of the Tufu HFD zone coupled with size supports the idea that they were either status or communal structures. Each separate parcel (cultivation plot) might have been managed by the groups associated with each terrace. However, there is some uncertainty about precise divisions of Parcel 14 and 16 as dense vegetation precluded the examination of portions of the area. No other ditch segments were noted in Lidar, but future research must examine this proposition.

In comparison, single branch features might have continued to be managed at the household scale (domestic mode of production), given their association with residential features. But, these associated residential terraces are larger than average (Tufu Features 32, 37, and 80; A'ofa Features 6, 19, 100, and 104). This is consistent with the idea that these features were managed by socially prominent groups or persons as well. The development of this relationship is uncertain, though, as none of these terraces were dated.

The management of arboriculture, specifically through pit storage, is ambiguous. Logically, storage pits spatially associated with residential features were used and managed by each household, with the majority (8 of 12 in A'ofa) of small (2.0-2.9 m diameter) stone-edged depressions found on or within 10 m of terraces. Communal storage devices may also be present, with Feature 87 in A'ofa the best example. The volume of the depression is the second greatest measured, and only one stone edged depression, located on a terrace, is larger. Such a size, in conjunction with a spatial association with a ditched terrace interpreted as ceremonial/ritual structure (Quintus and Clark 2012), might suggest management of these storage devices at a scale different than that of the household.

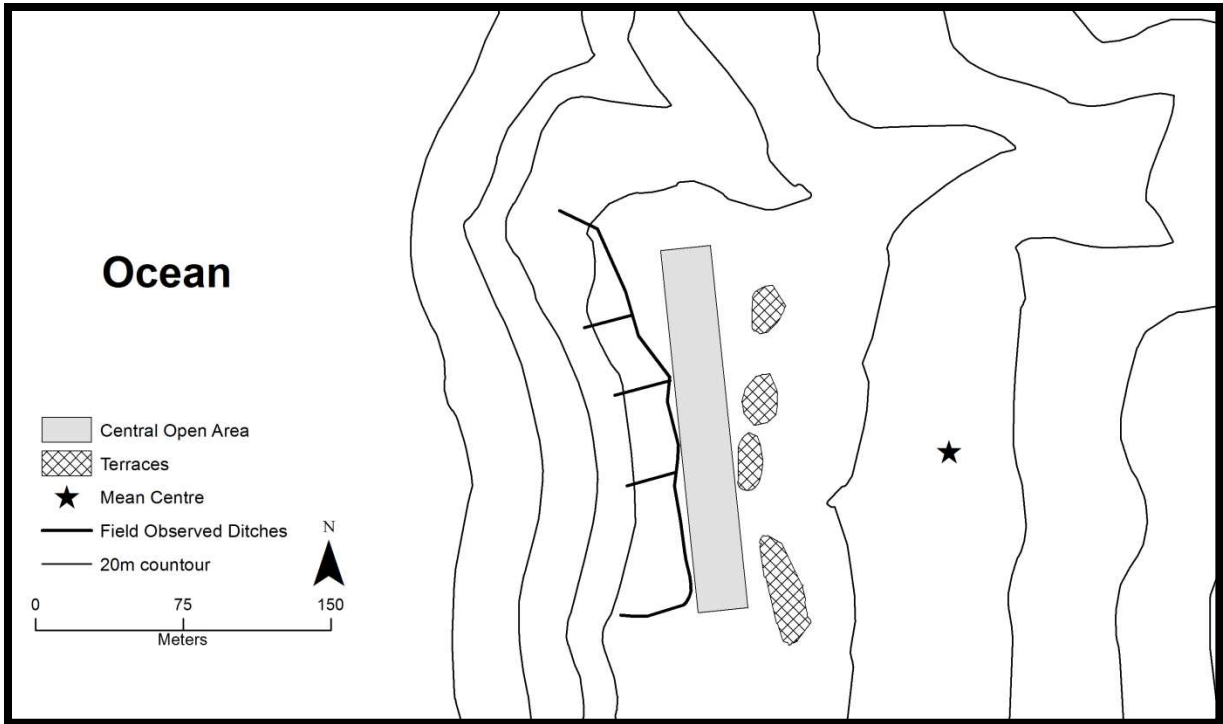


Figure 7.3 The correlation between a large ditch-and-parcel network, the proposed central open space, and four large terraces in Tufu

Situating the Course of Agricultural Change on Ofu

Sequences of agricultural change follow different courses (Morrison 2006, 2007). It is the comparison and evaluation of these different courses that leads to an understanding of both the general processes of agricultural change and the local circumstances that create unique characteristics of production systems. This section synthesises the information above in discussing the course of agricultural development on Ofu, situating it into a larger cultural-historical context.

Early Emphasis on Marine Resources

Significant debate has arisen regarding the importance of cultivation to colonising groups of West Polynesia (Best 1985; Burley 1999; Burley et al. 2001; Groube 1971; cf. Green 1979; Horrocks and Nunn 2007; Kirch 1997). Some scholars envisage equal importance between cultivation and foraging, while others suggest the primacy of foraging or farming. These opposing views are not unexpected given the environmental variability of the region, and it is likely that each island exhibits a somewhat unique combination of subsistence methods that correspond to those environmental differences (Clark 2013).

Regardless of whether marine resource exploitation was more important than food production, some form of starch cultivation was probably necessary for survival (Addison 2006, 2008; Davidson and Leach 2001).

On Ofu, only modest evidence of cultivation has been found within the earliest deposits on the island. At the same time, wild marine and terrestrial faunal remains are abundant (Aakre 2014; Kirch 1993b; Nagaoka 1993:201-206; Steadman 1993; Ofu Village Layer VIc of XU-4). This evidence, as Kirch and Hunt (1993b:242) noted, all suggests an “economic strategy integrating broad-spectrum exploitation of natural faunal resources...with agricultural production”. The lack of information pertaining to this period limits what can be inferred regarding the usage of products of cultivation. But, it appears that the ability of the population to survive was in some ways dependent on marine resource exploitation.

Expanded Cultivation in the 1st Millennium AD

In all three ceramic-bearing deposits on Ofu, the proportion of terrigenous sediments gradually increased in the 1st millennium AD and continued (Kirch and Hunt 1993a:56, 78; this project). Climate must be considered as a potential contributing factor of increased slope erosion, but the presence of particulate charcoal indicates that this process was in part due to vegetation clearance. Based on the lack of evidence of permanent residential settlement in the interior at this time, a likely reason for forest clearance is the creation of garden space and the expansion of cultivation. At the same time, the rate of marine exploitation remained stable (Nagaoka 1993). The totality of this evidence implies that agriculture gradually increased in importance in the sense that agricultural activities expanded.

A temporal pattern of the expanding scale of agricultural activities has been documented in the archaeological records of islands throughout the Pacific (e.g., Allen 1992:439-440, 1998:19; Allen and Craig 2009; Kirch 1984:156, 159-160, 1988, 1994; Kirch and Yen 1982; Lepofsky 1994; Lepofsky and Kahn 2011:325; Spriggs 1997:98-99; Valentin et al. 2011). Population growth and processes of adaptation to local environmental characteristics were certainly influential (Allen and Craig 2009), and some authors also relate these changes to human and climate-induced environmental change (Field et al. 2009). Within the latter category, the progradation of shorelines and the increased deposition of terrigenous sediments into lowland areas has been suggested to be important factors in the expansion of arable land and increased food production in some areas (e.g., Kirch and Yen 1982; Spriggs 1981, 1997).

Multiple overlapping factors may account for similar patterns on Ofu. For example, increased production could relate to population growth. Population growth after island colonisation is likely to have occurred, but archaeological evidence of this on Ofu is limited. It would be expected that if population growth occurred, the expansion of land use would be evident. There is continuity in many of the previously used areas on the To'aga coastal flat, though some expansion occurred in the middle or late 1st millennium AD (Kirch and Hunt 1993a:55-56). No evidence from Ofu Village indicative of population increase during this time has been identified, but only a relatively small area of the village was examined. Deposits dating to the 1st and 2nd millennium AD at Va'oto and Coconut Grove have been disturbed by modern land use. Given this, the lack of evidence of population growth may be due to sampling error and the lack of areal excavation.

Additionally or alternatively, coastal landscape evolution through the 1st millennium AD could have been a potential contributing factor to the expansion of agricultural activities. This model is detailed here, based on data from the west and south coasts, for future testing. To summarise the geomorphological sequence presented at the end of Chapter 5, the deposition of marine derived sediments and coastal aggradation was underway by the time the island was colonised (Layer VIc of XU-4 in Ofu Village, Beta-354137, Beta-383081, 2σ 781-511 BC), a reflection of the start of sea-level fall from the mid-Holocene highstand. Sea-level fluctuations did not reach a crossover point until the middle of the 1st millennium AD in the Fiji-Tonga-Samoa region (Dickinson 2003:494, 2009), but perhaps later on Ofu to account for local island subsidence. This crossover date is the point ambient high tide fell below mid-Holocene low tide levels, allowing sedimentation of previously submerged areas to more readily occur (Dickinson 2004). Previous marine environments became supratidal.

The shoreline of Ofu appears to prograde in line with the proposed crossover dates for other islands in the region (~AD 500 or later for Fiji and Tonga; Dickinson 2003:494). Stable beach ridges might have begun forming as early as the 1st century AD at To'aga, which is suggested by the development of paleosols indicative of vegetation growth above ceramic deposits (Kirch and Hunt 1993a:67, 78), though the exact timing of these events and relationships between units is unclear. The development of Layers VIa and VIb in XU-4 of Ofu Village may also represent beach ridge stabilisation, though this is also unclear from evidence reported in this thesis. The development of dark organically enriched clay loam layers on the west coast is more conclusive evidence that the active deposition of calcareous sand sediments had decreased by the 9th and 10th centuries AD in areas surrounding XU-2

and XU-4 of Ofu Village (Layer V). That the formation of these layers and the reduction of calcareous sedimentation were related to the progradation of the shoreline is supported by the nature of, and timing of land use on, areas seaward of XU-2 (Ofu Village XU-1, XU-3, Trench 3). Whereas calcareous deposition ceased or was reduced in back beach areas, it continued in areas seaward. The basal layers of seaward units are reflective of high energy deposition consistent with coastal progradation, featuring large particle sizes and coral boulders and cobbles (this project, Chapter 5; Kirch et al. 1993). Given this evidence, I propose that the dating of the transition between Layers V and VI in XU-2 and XU-4 of Ofu Village provides a minimum age for shoreline progradation (Beta-380263, 2σ AD 895-1021).

At least some landforms created by marine regression and coastal progradation were used by humans late in the 1st millennium AD at To'aga (Kirch 1993c:88; Kirch and Hunt 1993a:56, 60-62; Units 3, 13, and 17), but not until the 13th century AD on the west coast (XU-1, XU-3, and Trench 3). Even some prograded landforms of To'aga probably did not become available for settlement until the 2nd millennium AD (Kirch and Hunt 1993b:234). Why such variability exists in the timing of landscape change and subsequent human land use on the south and west coast is unknown, but it is possible that it relates to local topographic features or the configuration of the island. Specifically, the manifestation of island wide processes at local levels is dependent on local sediment sources and their impact on the sediment budget over time.

Even with variability, the consistent pattern in the location of ceramic-bearing deposits across the island (often ~100-150 m inland of the present shoreline) and the chronology of deposits situated seaward of ceramic-bearing zones is most plausibly explained by processes of marine regression, shoreline progradation, and coastal aggradation underway from island colonization to at least the beginning of the 2nd millennium AD. Based on the proxy measures of the chronology of human habitation in back beach areas, decreased calcareous sand deposition in back beach areas, and the timing of land use seaward of ceramic deposits, the most significant progradation of the terrestrial lowlands occurred during the 1st millennium AD (this project, Chapter 5; Hunt and Kirch 1997; Kirch 1993d; Kirch and Hunt 1993a,b).

The progradation of terrestrial lowlands may result in a reduction in the size of adjacent exploitable shallow marine environments. Declines in shellfish, and other reef resources (e.g. turtle), are well-documented on Tikopia (Kirch 1994:299-301; 2007b; Kirch

and Yen 1982), where late prehistoric landscape evolution decreased reef area by as much as 41 percent (Kirch 2007b:89). Changes indicative of reef destruction on Ofu have not been identified in faunal assemblages (Nagaoka 1993), but the area of shallow marine environments was likely reduced from progradation on the south and west coasts. Based on the model proposed here, coastal progradation since initial human colonization has buried ~100-150 m of these environments on the west coast. This would translate to a reduction of ~27 percent⁸ in shallow marine environments, and the drawings of Kirch and Hunt (1993b:233) suggest as much as a ~50 percent reduction on the southern coast. On the west coast, progradation could have changed the ratio of shallow marine environments to terrestrial lowlands from ~10:1 at the time of initial human colonization to ~2:1 in modern times. These figures are heuristic and were certainly variable around the island, but at least on the west and south coasts these changes to the ratio of different environments increased the amount of arable land on the coastal flats (this project, Chapter 5; Kirch and Hunt 1993b:235). The formation of garden soils near the west and south coast talus slopes was underway by the end of the 1st millennium AD or beginning of the 2nd millennium AD, after deposition of calcareous sands in the area was reduced (Kirch and Hunt 1993b:235; Ofu Village, Layer VI of XU-2 and XU-4, Beta-380263, 2 σ AD 895-1021).

When these findings are combined with the expansion of shifting cultivation on slopes to the inland of the south and west coast, as indicated by patterns of terrigenous deposition, the covariance of landscape evolution and increased production is highlighted. This broad correlation may be evidence that as coastal reconfiguration gradually changed the nature and, *possibly*, the productivity of the shallow marine environments, the human subsistence economy was somewhat modified to include expanding terrestrial food production. The expansion of agricultural activities might have been one avenue for increased food acquisition for a likely growing population after progradation had reduced the size of exploitable marine environments and increased the size of arable environments on the coast. Other avenues of increased food acquisition, such as off shore fishing, are not evidenced in the archaeological record. This situation is broadly comparable to evidence from Tutuila where, based on stable isotope data of human bones, 70-80 percent of the human diet was constituted by terrestrial plants by the 9th and 10th centuries AD (Valentin et al. 2011:478; Table 2, 3; e.g., WK-18056, 1065 \pm 34, 2 σ AD 895-1025).

⁸ This was measured as straight line distance in the centre of Ofu Village, from the edge of ceramic bearing deposits. The extent of shallow marine environments was defined by the extent of the modern reef flats, seaward of which there is a significant elevation drop.

Construction of Agricultural Infrastructure in the Interior Uplands

The earliest radiocarbon determinations from the interior uplands (Beta-354139, 2 σ AD 1024-1155; Beta-361291, 2 σ AD 1042-1222; Beta-366727, 2 σ AD 1039-1210) are chronologically situated between dates from the top of Layer VI of XU-2 in Ofu Village (Beta-380263, 2 σ AD 895-1021), a point when calcareous deposition was reduced in back beach areas, and three others from the basal units on landforms seaward of XU-2 (Beta-332861, 2 σ AD 1405-1452; Beta-366731, 2 σ AD 1299-1413; Beta-372699, 2 σ AD 1261-1387). The exact reason for permanent habitation in the interior is unknown. The intensity of residential or domestic occupation on the coast appears to decline or land use appears to become more dispersed, suggested by the lack of cultural material that has been identified on the coast dating to the last 1,000 years relative to earlier times (Chapter 5). This might suggest that a simple population growth model, where people began inhabiting the interior uplands because the lowlands were fully occupied, is unlikely. Population growth may still have been a factor, though. Additionally, the geomorphological record of the 2nd millennium AD shows periodic marine inundation of much of the coastal flats, perhaps due to storm activity, and increased terrigenous deposition after the 15th century AD may have restricted the residential use of back beach areas. Still, the coast was never abandoned, signalled by continued cultivation and marine resource exploitation, but the location of *major* residential activity appears to have shifted location to the island interior.

Upland areas are subject to flash flooding, erosion, debris flows, and landslides. As documented in Chapter 3, these hazards, often associated with cyclones, have a detrimental impact on some cultivation techniques. Tree cropping, especially, is vulnerable to destruction by high winds, and these trees may take years to recover. Fifty to ninety percent of mature trees can be blown over during cyclones (Clarke 1992:71), and 70-100 percent of the banana crop can be destroyed (Watson 2007:25-26). Slope gardens can be buried by high energy runoff, debris flows, or landslides from upslope, while they can also be stripped by erosion. Official losses of taro due to cyclone damage have been documented at up to 50 percent of the crop (Paulson 1993:46), though these crops can recover quickly (within two months).

The timing of permanent interior occupation around the 11th century AD corresponds with the construction of ditch-and-parcel complexes. These features have been shown to be effective at diverting water and sediment around garden plots (Chapter 6). These functions likely result in reduced losses of crops grown on parcels through the counteraction of damage

caused by high-energy run-off, debris flows, and erosion. Efforts to counteract effects of some hazards through the construction of ditch-and-parcel complexes may have been a trade-off between maximising annual yield and risk reduction, while at least maintaining the maximum yield that had been produced prior to the construction of the features. In other words, the construction of ditches enabled farmers to produce at least as much as before, but the counteraction of hazards helped to limit the probability of periodic shortfalls. The outcome of this was the reduced variance of year-to-year yields.

Apart from the counteraction of hazards, investment in ditch-and-parcel complexes likely increased yearly production. The cross-slope ditch branches likely limited run-off precipitation to the extent that soil erosion of the cultivation parcels was reduced. Reductions of soil erosion likely improved the long-term productivity of the environment by increasing or maintaining soil depth. Such ditching also reflects parcel permanence through the formation of boundaries. This does not imply that parcels were cultivated permanently, but it might be that fallow periods were reduced or that more intensive land use practices were introduced. The reduction of fallow periods, the construction of permanent plots, and the more intensive management of plant growth actually *reduces* labour in societies without the aid of metallurgy (Denevan 1992; Doolittle 2004). Forest regeneration can increase labour expenditure by increasing the time needed to clear garden space. By creating a permanent bounded cultivation space, these areas could be cleared of regenerating forests more effectively when in fallow. Additionally, bananas or other low labour crops may have continued to be cultivated in the parcel when plots were left in fallow, a pattern documented historically on 'Upolu (O'Meara 1990:57).

Below average yields from tree cropping and shifting cultivation that would be caused by hazards in some years could have resulted in an increased reliance on yields from protected gardens, which were less variable and potentially more productive. In this situation, the construction of infrastructure has the potential to change the social dynamics of food production by creating unequal access to the products of a more certain cultivation strategy. Evidence of unequal access is difficult to identify. However, since single branch feature ditch-and-parcel complexes are often associated with residential features, households inhabiting these residential features presumably had more access to products cultivated in these complexes. The situation appears to have changed by the 15th century AD.

Expansion and Investment in Landscape Capital after the 15th Century AD

Further development of cultivation techniques occurred in the 15th century AD, and continued through the rest of the prehistoric period. Ditch-and-parcel complexes began to be constructed in networks. Arboriculture and shifting cultivation on slopes might have begun to expand towards the extent defined by modern vegetation. Non-residential terracing expanded onto steeper slopes, more marginal areas. Cultivation continued around the slopes on the coast, attested by the presence of colluvium layers with particulate charcoal. Cultivation of the coastal flats likely continued, particularly after the formation of the coastal marsh. These developments appear geared toward increased production, with more area being put under cultivation. Increased production may be linked to population growth. However, little evidence is available to evaluate this proposition as few residential features have been dated in the island's interior.

More notably, this period saw changes in management apparently associated with the increased influence of a leadership group in food production. The construction of ditch-and-parcel networks would have required more labour expenditure compared to previous single branch features, and the internal complexity of ditch-and-parcel networks would entail a level of group cooperation and coordination in construction and subsequent agricultural activities. The largest networks are located in positions seaward of the centre of HFD zones, areas that ethnohistoric and ethnographic literature link with social authority. This collective evidence suggests the presence of a political system in which the management of some production was possible.

The chronology of supra-household influences on systems of production seen here, namely some ditch-and-parcel networks, is consistent with data argued elsewhere to be evidence of the growing influence of an elite class in the rest of the archipelago. Several researchers have proposed that changes to settlement patterns over the course of the last 1,000 years, such as the increased visibility of domestic architecture and the construction of monuments, are a reflection of the development of social hierarchy (Holmer 1980; Martinsson-Wallin 2007; Quintus and Clark 2012; Wallin and Martinsson-Wallin 2007). The investment in more permanent and labour intensive residential and non-residential architecture and expanded settlement sites is documented after the 13th century AD on many islands (Clark and Martinsson-Wallin 2007; Green 1969:102-104, 2002; Holmer 1980:102; Pearl 2004; Wallin et al. 2007:78). This is also roughly consistent with increased

sedimentation on Tutuila that is evidence of interior vegetation clearance that is hypothesized to be related to the expansion of cultivation and habitation (Clark and Michlovic 1996; Pearl 2006).

The few dates of star mounds, monumental structures thought to have served important functions in pre-contact socio-political relations, suggest they began to be constructed in the 15th century AD or later throughout the archipelago (Clark 1996:453; Herdrich and Clark 1993; Hewitt 1980; Martinsson-Wallin and Wehlin 2010). These features have been identified on Ofu and the highest density of star mounds in the archipelago is situated on the adjacent island of Olosega (Quintus and Clark 2012). None of these features have been dated on Ofu or Olosega, but the consistency of their chronology throughout the rest of the archipelago hints that the examples on these two islands were also built in the 15th century AD or later. Herdrich and Clark (1993) argue that star mounds mark increased status competition, and their construction as monumental and communal architecture might signify the use of *corvée* labour. Oral history suggests a similar sequence of a growing focus on hierarchy and the centralisation of at least some power after ~AD 1600 in the western islands of the group. This is the time of Salamasina, allegedly the first individual to hold the title of the four prominent districts and act as paramount chief of all Samoan Islands except those in Manu'a (Meleiseā 1995:24-25).

The best example of increasing elite influence on resource exploitation is the posited growing control of basalt on Tutuila (Winterhoff 2007; Johnson 2013). Within the last 1,000 years the degree of stone tool manufacturing increased in many quarries on the island (Addison 2010), and labour in the form of substantial infrastructure began to be invested in both production and defense at the larger sources (Best 1993; Winterhoff 2007:195). Winterhoff (2007) has argued that control of basalt resources became the source of power for elites on Tutuila within the last 1,000 years. A more precise chronology of the basalt industry is lacking, but Addison (2010:353) has argued, based on the geographical scale of material exported, for large scale production by the 14th-15th century AD, which may have peaked starting in the 16th century AD.

This discussion suggests that political development was an archipelago-wide process, with local manifestations on each individual island. Ofu adds evidence of the role of leaders in agricultural activities. At least on Ofu, this role appears to have been relatively limited, but potentially important based on associations with agricultural infrastructure.

Discussion of Factors Influencing Agricultural Development on Ofu

Three factors are commonly considered to be important in the development of agricultural systems in Polynesia: population growth, environmental variability, and political change (e.g., Allen 2004; Kirch 1994, 2006; Ladefoged and Graves 2008; Lepofsky 1994; McCoy 2006). Each appears to have been influential on Ofu.

That population grew throughout the Ofu cultural sequence is supported by the expansion of archaeological remains over time, illustrated by permanent residence in the interior and expansion thereafter. Given the distribution of archaeological features, based on an examination of the Lidar dataset, the late prehistoric population on the island appears to have been quite dense. However, more precise data regarding population growth is lacking, and it remains to be demonstrated to what degree populations grew at different points in the sequence; the quantification of this is a fruitful avenue of future research. Therefore, while the impact of population growth on agricultural development, or vice versa, remains unknown, preliminary assessment indicates that the two do broadly track one another, especially after people move into the interior uplands in the 11th or 12 centuries AD. With that said, population growth was but one factor that influenced strategies of cultivation.

The environment of Ofu created constraints and opportunities for cultivation. At a general scale, the environment is not conducive to the use of certain technologies, specifically flooded irrigation. No permanent streams are found and reliance on intermittent streams, while possible, would likely result in frequent yield shortfalls. Within the cultural sequence, prospects for increased food acquisition were both limited and enhanced by coastal reconfiguration. Coastal progradation may have reduced the size of the shallow marine environments that skirt the island, while at the same time landscape change created strips of arable land on the coastal flats. This production zone was formed by the deposition of terrigenous sediment influenced by vegetation clearance for cultivation upslope in conjunction with high rainfall, and these sediments were then mixed with calcareous sand and organic matter already on the coast. As food production became an increasingly important component of the subsistence economy and as people moved into the interior uplands, agricultural infrastructure was developed. The construction of ditch-and-parcel complexes reduced the effect of high energy run-off and soil erosion and, thus, probably stabilised year-to-year production.

The impact of political development on cultivation strategies appears to have been most marked toward the end of the sequence. Though little is known of the situation before the 15th century AD, it is after this point that ditch-and-parcel networks were constructed. In both Tufu and A'ofa, networks were built in socially prominent areas, seaward of the mean centre of each HFD zone, a position that may have continually affirmed their importance and control by political forces (following Shore 1982:48-51, 1996). The chronology of these features is consistent with the known chronology of star mounds throughout the archipelago (Clark 1996; Herdrich and Clark 1993), features known for Ofu and Olosega and assumed to date to a similar time as those on other islands in the archipelago. These developments are also consistent with the chronology of the development of the basalt tool industry on Tutuila (Addison 2010). This could mean that late prehistoric political development was an archipelago-wide process.

Teasing out the relative importance of these three factors in the analysis of long-term agricultural history is difficult, since there is a fundamental interconnectedness between the three. Unique circumstances of historic development create opportunities and constraints to the system. For instance on Ofu, the investment in agricultural infrastructure to offset effects of environmental hazards led to plot demarcation that could be more effectively managed, by both farmers and elites. One consequence of the construction of agricultural infrastructure on Ofu, whether intended or unintended, was the creation of an unequal agricultural landscape, with the yields of one technique likely more stable than the others. The influence of each factor created consequences that fed back into the system and created future causes (cf. Lansing 2007; Morrison 2006).

Chapter Summary

This chapter has analysed the results of field work presented in the previous two chapters by exploring how these data provide an understanding of the temporal patterns of the location, importance, and management of agricultural activities. By doing so, this chapter has accomplished the first two stages and addressed the first three questions that have guided this research, defined in Chapter 2.

Shifting cultivation appears to have been focused around the coast and in the adjacent interior slopes for the first ~1,700 years of occupation. In the 2nd millennium AD agricultural activities further expanded into the interior uplands at the same time that a portion of the population began to permanently inhabit these areas. With the residential move to the

interior, the importance of food production increased, evidenced by the investment in agricultural infrastructure in the 11th century AD and later, as well as the expansion of agricultural activities into marginal areas in the 15th century AD. It is also at this point that evidence of management can be identified. In the last 300-400 years before European contact, management of ditch-and-parcel complexes appears to shift from the household to communal level.

The final section brought this analysis together by summarising associated contextual information with the sequence of agricultural change on Ofu. The abundance of wild terrestrial and marine fauna in sites dating to the 1st millennium BC suggests that the economy was broad spectrum. The expansion of agricultural activities in the 1st millennium AD is consistent with the timing of the coastal landscape evolution. Landscape evolution created more arable land in the back beach areas of the coastline, and perhaps created the coastal marsh. Agricultural infrastructure built in the interior in the 11th and 12th century AD was likely a response to counteract common hazards of the Ofu environment that impact production. This created a production system within which different techniques had different year-to-year variance, with ditch-and-parcel cultivation likely being the most stable. Evidence that ditch-and-parcel techniques were managed above the household scale is found in the construction of networks in positions seaward of the HFD zone centres in the 15th century AD or later. These changes were part of long-term processes of agricultural development discussed in the next chapter.

Chapter 8: Discussion and Conclusions

This thesis has demonstrated that evidence of past agricultural activities can be identified archaeologically on Ofu Island, and that such evidence can be used to examine patterns of agricultural development. The previous chapter synthesised evidence of agricultural activities collected from Ofu Island and examined the changing location, timing, and management of cultivation techniques. A course of agricultural development was then placed into a wider socio-ecological context. The previous chapter, therefore, accomplished Stages I and II of the research design.

Stage III is undertaken in this chapter by addressing theoretical concepts discussed in Chapter 2 (i.e., intensification, expansion, risk management, social relations of production). The second section of this chapter compares the strategies and processes of agricultural development identified on Ofu with other documented strategies of cultivation and sequences of agricultural change in the Samoan Archipelago and elsewhere in Polynesia. The final section includes my concluding thoughts.

Restating and Evaluating the Problem

Kirch (1984:132) has argued that courses of agricultural development in Polynesia include three components: adaptation, expansion, and intensification. The identification of the last of these, intensification, has been of prime importance in Polynesia, and several trajectories of agricultural change in the region have been described as intensification processes (Kirch 1984:152; 2006). A temporal sequence of prehistoric agricultural change has been missing from the Samoan Archipelago, though evidence of variable cultivation strategies has been documented (e.g., Addison and Gurr 2008; Carson 2006; Cochrane et al. 2004; Davidson 1974c:157; Clark and Herdrich 1993; Holmer 1980; Ishizuki 1974; Kirch and Hunt 1993b; Quintus 2012). The lack of a sequence of agricultural development has led to a potential mischaracterisation of agriculture in Samoa as non-intensive and lacking in capital investment (e.g., Carson 2006), based largely on post-contact descriptions (e.g., Buck 1930). In contrast to changes that characterise the prehistoric sequences of most islands in the region, some researchers have argued that Samoan subsistence was stable through prehistory (Green 2002). This situation in Samoa has been cited as evidence that the intensification of production was not inevitable in the region (Leach 1999).

The data gathered and analysed in this thesis have been used to examine one course of agricultural development that occurred in the archipelago. The examination of this sequence allows for a critical empirical evaluation of whether intensification and/or other processes of agricultural development occurred.

Agricultural Expansion and Intensification on Ofu

Can agricultural development on Ofu, as described in the previous chapter, be classified as involving the process of agricultural intensification? Before addressing this question, it is first important to define the terms intensification, expansion, and intensity (Leach 1999). In this discussion, the term intensity refers to the amount of labour required for a specific cultivation technique; agricultural intensification refers to a process of increased labour input at a set spatial scale; and expansion refers to the spatial extension of cultivation techniques at a set level of intensity. At some spatial scales, expansion may not be contrasted with the process of intensification (Allen 2004:206; Athens 1999; Morrison 1995:165; Stanish 2006:364-365).

I argue at the largest spatial scale, that of Ofu Island, a sequence of intensification occurred from colonisation to historic contact. This is indicated by two criteria: the construction of agricultural infrastructure and the increased amount of land put under cultivation through the expansion of shifting cultivation at set levels of intensity. Both of these increased the amount of labour invested in agricultural activities at the island scale. The development of ditch-and-parcel complexes in the 11 and 12th centuries AD happened after shifting cultivation techniques had been employed earlier in the cultural sequence. This is a case of landesque capital intensification as defined by Kirch (1994). Ditch-and-parcel complexes created distinct cultivation plots, which likely altered the degree of labour invested to maintain each plot and also enhanced management capabilities. Above all, this technique was an innovation, allowing for the more effective use of a specific environment. The construction of these features required a one-time labour input that increased the long-term productivity through hazard counteraction of the sloping land, parcels, encompassed by ditching. The construction of ditch-and-parcel networks in the 15th century AD and later, a new technology, was a continuation of the intensification process. The development of networks increased the amount of labour invested in agricultural activities (further landesque capital investment) and probably resulted in higher mean yields at the island scale because it increased land under cultivation.

By some definitions, the expansion of agricultural activities at set levels of intensity could be characterised as a mode of intensification. On small islands such as Ofu, the use of the term land use intensification, as defined by Athens (1999), may be appropriate in taking the entire island as the region of study. Such situations also meet criteria of definitions of intensification proposed by Stanish (2006:364) and Morrison (1995:165). On Ofu, shifting cultivation was an important component of the production system throughout the cultural sequence, expanding around the coast and interior slopes through the 1st millennium AD, further into the interior uplands at the beginning of the 2nd millennium AD, and around the coast (marsh?) and into greater slopes of the interior uplands in the 15th century AD and later. These three periods of *expansion at set levels of intensity* led to increases in the area of land under cultivation and, therefore, higher labour costs when the island is taken as a whole. Presumably, this was accomplished by increasing the number of people working the land, as opposed to having a set number of individuals work harder. Each of these periods increased product extraction associated with agricultural activities.

Intensification can also be posited at the scale of individual HFD zones. This characterisation is largely derived from the development sequence of agricultural infrastructure. A change from single branch features to networks marks a change in the management of some agricultural activities, with the cultivation of at least some networks managed above the household scale. This process of creating larger and internally more complex agricultural infrastructure, which occurred from the 11th century AD to historic contact (18th century AD), increased the amount of labour invested in agricultural activities through landesque capital investments as well as the efficiency of production through the management of those activities. The sequence presumably also increased the concentration of production within each HFD zone by increasing the area of land under cultivation.

At the smallest spatial scale, that of individual plots, intensification is difficult to discern. Evidence of shifting cultivation in *specific* areas that were later modified with the construction of infrastructure is lacking. Clear evidence that these specific interior upland slopes were used for shifting cultivation before the construction of infrastructure may eventually be found, but such data are presently unavailable, based on the identification of a very small sample of carbonised remains of tree crops and possible secondary vegetation (n = 3). Similarly, evidence that ditch-and-parcel networks were constructed from previous single branch features, which would mark plot segmentation, does not exist.

Based on the discussion above, the question of whether intensification occurred on Ofu is a question of scale. At the island scale, a sequence of increased labour input that likely translated to the increased extraction of agricultural products has been documented. There is a clear increase in land under cultivation through time by way of the expansion of agricultural techniques at set levels of intensity, and populations began investing in agricultural infrastructure towards the end of the sequence that increased long-term production. Within each interior HFD zone, a sequence of increased production and labour investment is evidenced by the development of ditch-and-parcel complexes and the later construction of those features in networks. Still, even at the largest spatial scale, the degree of intensification that occurred on Ofu was modest in comparison to other islands in Polynesia (e.g., Kirch 1994; Ladefoged and Graves 2008; Lepofsky 1994).

Most of the Ofu agricultural sequence is defined by expansion of agricultural techniques at set levels of intensity into new areas. This is especially true of shifting cultivation systems, which appear to have been an important component of the production system throughout the cultural sequence, echoing the view of Leach (1999). The modern extent of secondary forest attests to its importance. These systems, which were likely spatially restricted when the island was initially colonised, had expanded over much of the island by the end of the prehistoric sequence. This increased the amount of land in cultivation, which increased the amount of labour invested into agricultural activities per unit of land at the island scale. This to some would not constitute intensification (Ladefoged and Graves 2008; Leach 1999), but to others it would (Athens 1999, Morrison 1995; Stanish 1994, 2006).

What is clear from this discussion is that the nature of agriculture on Ofu changed through prehistory, challenging the idea of cultivation strategy stability in the archipelago. Some cultivation strategies increased production and have ties to population and political change, and other strategies were a response to an environment that varied through time and space. These various strategies are discussed in theoretical terms in the next two sections.

Risk Management and the Ofu Sequence

Risk is linked to the predicted probability that certain environmental perturbations occur and create variance in production (Marston 2011:190; Winterhalder et al. 1999:303). In Samoa, food shortfalls related to damage caused by cyclones, debris flows, high energy run-off, and landslides are well known. Cyclones, especially, are semi-predictable and have a

periodicity which results in several severe events each generation. Severe cyclones are likely to inhabit social memory for periods between each event, as they do in modern times in reference to the events of 1987, 1990 and 1991.

Two risk management strategies were employed on Ofu: ditch-and-parcel complexes and storage pits. Ditch-and-parcel complexes were developed after people began inhabiting the interior uplands on a permanent basis at the beginning of the 2nd millennium AD. The chronology of storage techniques is unclear, but it is possible that they too developed shortly after sustained residence in the interior began. These two strategies illustrate the different ways in which populations manage risk in agricultural production. Populations attempt to ensure that a food supply is available at all times by reducing the variance of resource acquisition (Winterhalder et al. 1999) or by reducing the probability of a shortfall (Cashdan 1990:2-3). Very simply put, one strategy of risk management is to mitigate the variability of resource *production* to the extent possible. The other recognises the occurrence of production variability but attempts to lessen the effects by reducing the variability of resource *availability*.

Ditch-and-parcel complexes directly counteracted the hazards in the Ofu environment, protecting garden spaces. The strategy increased the mean yield, by increasing the land under cultivation, while also decreasing the variance of year-to-year yields by limiting the impacts of hazards (e.g., high energy run-off, debris flows) that increase the chance of shortfalls. Effective variance minimisation and improved year-to-year stability enables populations to persist through environmental perturbations (Allen 2004). In terms of a Z-score model, the ditch-and-parcel subsystem to the production system is a high mean and high kurtosis (low variance) strategy (Fig. 2.1). In this way, ditch-and-parcel complexes reduced the variance of resource *production*.

Storage reduced the effects of resource variability by way of temporal diversification (Marston 2011:193). Breadfruit and banana are extremely susceptible to storm damage from year-to-year, and though breadfruit produces twice a year, it is unavailable in February-March and October-November (Whistler 2001:29). Breadfruit and banana storage on Ofu increased the probability that these resources would be available both at an intra-annual and inter-annual scale. When a shortfall did occur, for instance when breadfruit and banana crops were destroyed during a cyclone, storage of past harvests could have been drawn upon. In this way temporal diversification via storage reduced the variability of resource *availability*.

The decision to employ these strategies on Ofu may have been linked to the expansion of agricultural systems and the growing importance of production in the subsistence economy. The role and scale of food production appears to have increased by the end of the 1st millennium AD, especially if comparisons with Tutuila can be made (Valentin et al. 2011). It is at this point that cyclones and other environmental hazards created increased variation in the food supply. When environmental perturbations cause predictable variations in the food supply, their counteraction becomes necessary (Halstead and O'Shea 1989:3). On Ofu, this was accomplished through the use of ditch-and-parcel complexes and storage pits. However, the construction of ditch-and-parcel complexes involved a far more substantial capital investment than did storage pits, and the employment of these strategies, ditch-and-parcel networks in particular, likely involved a larger effort, in both inception and construction.

Risky strategies were also employed on Ofu, specifically the expansion of production into greater slopes in the 15th century AD and later. Cultivation on steep slopes with higher probabilities of the occurrence of erosion and landslides would increase the likelihood of shortfalls and increase the variance of year-to-year yields. The development and use of two risk management techniques beforehand could have allowed the people to experiment with and pursue riskier strategies to increase production without falling below a minimum survival threshold. Given the evidence of at least some community integration and coordination implied by the construction of star mounds, ditch-and-parcel networks, and, perhaps, communal stores, shortfalls from risky techniques could be offset by community-level redistribution. In other words, the stabilisation of production at the beginning of the 2nd millennium AD may have allowed some people to employ risky strategies with knowledge that the risks associated with those strategies might be offset by other parts of the production system.

Such a situation is similar, though at a much smaller scale, to a process of expansion documented in the Leeward Kohala Field System on Hawai'i Island, Hawai'i. There, marginal lands were cultivated later in time, after substantial effort had been invested in agricultural production in more stable or optimal areas. Ladefoged and Graves (2008:785-786) have argued that cultivation in marginal areas was one of few remaining avenues by which to increase production and surplus in territorial units, and:

occupation of these areas was sustainable only if populations had direct links to more optimal zones. It was not until the social networks that came with the complex chiefdoms of the later prehistoric era were in place that these more marginal areas were viable.

Expansion of cultivation into greater slopes on Ofu may not have been feasible without the stabilisation of annual production and food availability with ditch-protected gardens and storage. Furthermore, the expansion of cultivation throughout the interior slopes, on the coast, and, perhaps, into the freshwater marsh may have acted as a spatial diversification strategy. Diversification would help to mitigate the impacts of localised hazards (e.g., landslides and floods), and cultivation in the freely draining freshwater marsh would be a source of increased and, perhaps, less variable production.

It is acknowledged that “producers do not begin anew each time they make a decision but are instead constrained by features of the landscape itself, that accretional product of the past” (Morrison 2006:73). Opportunities for development are often constrained or created by the consequences of past changes, a situation not only recognised in studies of agriculture but also in evolutionary biology and architecture (Gould and Lewontin 1979; Odling-Smee et al. 2003). Agricultural infrastructure on Ofu made an artificially stable environment by limiting year-to-year variance in production. In stable environments, strategies which maximize production are less prone to risk and potentially advantageous (Allen 2004:206).

This model relies on the assumption that the population was able to produce beyond subsistence needs in most years, so that surplus could be funnelled toward buffering short falls in bad years through community-level redistribution. The evaluation of this assumption is reliant on high resolution demographic data, which is lacking in this project. It has not been demonstrated that yields produced on the high slopes were not necessary to support the subsistence needs of the population. If these marginal areas were necessary components of the subsistence economy on a yearly basis, and decisions to cultivate this area was related to a growing population combined with increasing social demands, this scenario would be more like that argued by Allen (2004:220) for the development of agriculture in marginal areas of the Kona field system in Hawai’i. That is, the use of and reliance on marginal areas with inherent risk would have made the population more vulnerable to periodic shortfalls, especially after cyclones.

Agricultural Development and the Social Relations of Production on Ofu

Agricultural development is also tied to economic relationships among leaders and producers, interacting with developments based in ecology and environment. Limited data is available to evaluate the timing and nature of political economies in Samoa, but some evidence reported here for Ofu hints at changes in the social relations of production. Prior to the 15th century AD, all evidence on Ofu is consistent with a domestic mode of production. In and after the 15th century AD, social relations of production above the household scale are evidenced by the construction of ditch-and-parcel networks in socially prominent areas. The question, then, is how the situation had changed by the 15th century AD, and why did it involve the use of ditch-and-parcel techniques? This section presents a model addressing these questions.

The construction of agricultural infrastructure on Ofu in the 11th-12th centuries AD created a marked landscape and inscribed ownership to land. This technology also created a production system in which different cultivation techniques resulted in variable outcomes in any given year. As was discussed above, the cultivation of ditch-and-parcel complexes resulted in a lower yield variance relative to other techniques (e.g., shifting cultivation and arboriculture). The effects of cyclones can have a devastating impact on shifting cultivation systems and arboriculture, but these hazards (high energy run-off, debris flows, high winds) are counteracted by the ditching of parcels. I hypothesise that these two characteristics of ditch-and-parcel complexes, plot demarcation and yield stability, created conditions in which management of production and power generation through agricultural development were possible on Ofu.

In the context of the Ofu production system, the concentration of low variance production techniques, in the form of ditch-and-parcel complexes, formed a bottleneck (after Earle 2011a), especially in bad year in which yields produced by cultivating these gardens might have been needed to offset shortfalls of arboriculture and shifting cultivation. This is not to say that arboriculture and shifting cultivation were not productive or important, as they were, particularly in relation to the subsistence economy. Rather, opportunities were presented to those that managed a restricted cultivation technique that in some years was more productive than others. Assuming management of ditch-and-parcel networks that were risk management devices, in good years when food shortfalls did not occur, collective production from ditch-and-parcel complexes and other techniques may have created surplus.

Modest evidence of surplus can be found on Ofu in the form of archaeological features that would have required organised community labour (e.g., star mounds) and storage devices that could store excess food for leaner times (e.g., *masi* pits). During bad years, food production in ditch-and-parcel networks could be employed to offset lower than average yields from arboriculture and shifting cultivation that was the result of damage caused by hazards.

The role and influence of social production must be understood within context, in this case Polynesian cosmology. The strategies and outcomes discussed above conform to expectations of leaders within a political system based on the demonstration of *mana*. The precise meaning of *mana* is contextually dependent and extends beyond socio-political situations (Blust 2007; Codrington 1891; Hocart 1922; Firth 1940; Keesing 1984; Shore 1989), but there is agreement regarding its importance in reference to political action (e.g., Goldman 1970). *Mana* is pragmatic, something to demonstrate to prove your potency, efficacy, and ability to lead (Howard 1985; Shore 1989). Shore (1989:139) noted that *mana* is the active legitimising power linking status to the individual; as such it is fickle, dynamic, and unstable and needs to be demonstrated (Firth 1940; Howard 1985; Shore 1989, 1994). Potency and fertility were key concepts in this negotiation, in that they connected *mana* to activities in which these concepts were demonstrable. The importance of this demonstration cannot be overstated. Valeri (1985:89) recognised that:

What creates power as a moral reality is the real social effect of the arbitrary belief in somebody's or something's power. The reality of the effect reverberates on the cause, and this makes the cause dependent on the effect...the belief that a man is endowed with divinely originated *mana* will prompt many people to become vassals in order to benefit from his power; and this will make him all the more capable of delivering what his reputation promises.

Warfare and pigeon catching have been two activities posited for such demonstration in Samoa (Herdich and Clark 1993), and Shore (1989:141) illustrated that political power was signified by agricultural abundance or generative power. In Samoa, at least in myth, a failure of a chief to provide materially for his or her people is a failure of *mana* (Good 1980:34), which may result in the removal of his or her power. Such emphasis on generative power is present throughout the region. On Rotuma, especially in myth, “the concern is with the continual regeneration of life – with the fertility of the land and the people. The fundamental issue is one of harnessing the *mana* of the gods in the service of this goal” (Howard 1985:47). Howard (1985:67) further posited that in Rotuma “the central symbol is food; its abundance is indicative of a proper political order, its scarcity indicative of political malaise”. This

echoes the view of Mageo (2002:507) for precontact Samoa: “*mana* is a hypercharged life force manifest in an abundance of food”. For Polynesia as a whole, Shore (1989:138) has asserted: “whether through height or girth, brightness or generosity, chiefly *mana*...is expressed through images of abundance”.

In this sense, it is the responsibility of the leader to increase production to demonstrate abundance and to stabilise production to provide in times of shortfall; this responsibility is met with the opportunity for expanded political influence. A demonstration of productivity to increase individual prestige could involve conspicuous consumption in good years, and the importance of signs of excess is seen in ethnographic accounts of feasting in Samoa. Buck (1930:139) wrote that “at a feast, the portions of food are far in excess of what can be eaten in one meal”, and Krämer (1902-03, Vol II:152) noted “that every opportunity is seized to boast of one’s abundance and wealth”. Leadership influence over production in good years could have allowed wealth accumulation. The construction of some ditch-and-parcel networks in socially prominent positions (seaward of mean centre) would have more effectively displayed this wealth, and bestowed social meaning onto the ditch-and-parcel structures themselves. We might also speculate that the ditching was, at least at times, socially important in this context, and not just for risk management purposes. As Shore (1989:151) observed in regards to sources of power:

Images of binding of persons or objects pervade Polynesian symbolism. Most common, perhaps, are the ubiquitous restrictions imposed as a matter of chiefly prerogative on the harvesting of productive crops. These bans...were often accomplished by marking (sometimes literally encircling with a marker) the resource whose productivity was being tied up.

In contrast, elite management in bad years may have improved the efficiency of resource use and redistribution as Allen (2004) argued for Hawai’i. For Anuta, Yen (1973:139) noted that chiefly influence on agriculture only occurred after storms or tsunamis, when managerial redistribution was necessary. The construction and management of ditch-and-parcel networks on Ofu might have acted to solidify the role of elite managers as centres of redistribution. In fact, the efficient working of ditch-and-parcel complexes as risk management techniques, given the need for effective redistribution, may have relied upon its being part of a political economy. At the same time, the efficient working of the political order necessitated that the leader meet his or her responsibility to the people (e.g., food availability after hazards) (Thomas 1994). If he or she did not, they risked usurpation. This situation raises the possibility that while influence over risk management capabilities of

ditch-and-parcel techniques was one source of power for leaders on Ofu, it was also a necessary component of maintaining power. The leader was an agent of the collective and the ability to lead was tied to meeting that responsibility to provide, especially in small-scale chiefly polities like Ofu.

How and when ditch-and-parcel technology became managed by leaders is unknown, but the construction of ditch-and-parcel networks in socially prominent positions in the 15th century AD and later presents a minimum age for the development. The development and management of ditch-and-parcel networks marks a simple and small-scale political economy. The scale of this political economy is in no way similar to those documented in the larger polities of Polynesia, like seen in the larger islands of the Hawaiian Archipelago (Dye 2014; Earle 1978, 1997, 2012; Hommon 2013; Kirch 2010). Only a portion of the productive environment on Ofu can be said to have been managed by leaders (i.e., ditch-and-parcel networks), and there is no evidence that implies leaders were completely divorced from daily agricultural activities, even though some tribute was practiced historically (e.g., Mead 1969:69). The situation might be similar to that of Tikopia where Firth found that chiefs had obligations and opportunities in the economic system:

the major obligation of providing the chief's household with food falls upon the chief himself, his sons, brothers, and other immediate kin...there is no permanent and institutionalized court surrounding the chief, as in some of the larger Polynesian islands, which relieves him from ordinary labour (1939:19).

But, at the same time:

The chief is the head of the clan, its representative with the gods, mediator for his people in regard to the fertility of their crops. Hence his control of supernatural forces in the interests of his people on the one hand should be matched by his control of their material resources on the other (1936:376).

In summary, then, I propose that the role of food production in the political economy of Ofu was to support the maintenance of the social order through communal labour projects and redistribution. Questions remain as to the exact timing of changes to the political economy and how the political economy of Ofu fits within the wider social network of the Manu'a group. The latter is particularly important to recognise, and no data is yet available to evaluate the situation.

The Place of the Ofu in Polynesian Production Systems

The problem developed at the beginning of this thesis addressed the differences between Samoan production systems and those of similar Polynesian islands. In this section, the course of agricultural change on Ofu is examined within a Samoan and wider Polynesian context, highlighting similarities and differences.

Ofu and Samoan Production Systems

Little is known of the temporal development of agricultural activities on any island other than Ofu. On Tutuila, Carson (2006:18) has documented the construction of “residential clusters” interpreted to be associated with agriculture at the beginning of the 1st millennium AD (3rd-5th centuries AD), expanding thereafter, with a posited marked increase in the use of inland valley locations after the 13th century AD. On ‘Upolu, examples of agricultural infrastructure, drainage features, appear to have been built in the 13th-17th centuries AD, based on the spatial association of a possible drainage system with dated features (Ishizuki 1974:56), with some agricultural activity occurring before that time indicated by burning beneath the features. Similar drainage features may be present on the valley floor of Falefa on ‘Upolu (Davidson 1974a); these are morphologically the most similar agricultural features to ditch-and-parcel complexes on Ofu. Stone walls, possibly demarcating areas of habitation *and* cultivation, were built in Mt. Olo during the last 1,000 years with most investment in the 300-400 years before European contact (Jennings and Holmer 1980b).

The timing of the expansion of agricultural activities is broadly consistent with sedimentological data signifying increased erosion and deposition onto coastal flats. Clark and Michlovic (1996:155) have suggested that the clearance of forest on the slope around ‘Aoa Bay, Tutuila was a factor that led to the infilling of an ancient embayment. The timing of this sequence has not been well-established, but potential links between coastal landscape evolution and sea level fluctuation suggest it occurred in the 1st millennium AD (Clark and Herdrich 1988:174). In the last 1,000 years, the increased use of inland zones for cultivation and habitation has led to erosion across Tutuila (Clark and Herdrich 1988; Clark and Michlovic 1996, Pearl 2006). Specifically, Pearl (2006) has argued that the increased intensity of land use occurred in the 14th century AD and later, and that the process of coastal sedimentation in the last millennium was an archipelago wide process (Pearl 2006:64). This implies that such sedimentation was linked to both increased use of the interior zones and climatic fluctuations, such as increased precipitation.

The lone stable isotope study of human bone undertaken in the archipelago examined the diet of 14 individuals on Tutuila, with most individuals dating to either the 10th-11th centuries AD or the 15th-16th centuries AD (Valentin et al. 2011:478). The results of this study show that domesticates were a major component (70-80 percent) of the diet of all individuals studied (Valentin et al. 2011:479-480, Table 3), and that an increase in the terrestrial component of the human diet occurred over the last ~1,000 years of prehistory (Valentin et al. 2011:480). Though, this latter increase is modest.

These data and interpretations are comparable to trends identified on Ofu. Increased sedimentation observed on Ofu through the 1st millennium AD might correlate with the situation at A'oa Bay, though the precise timing of infilling there is yet to be established (see Clark and Herdrich 1988; Clark and Michlovic 1996). Second millennium AD sedimentation on Ofu (15th century AD and later) is comparable to that identified by Pearl (2006), but Pearl (2006:63) does suggest that sedimentation on Tutuila was most significant around the beginning of the 14th century AD. The use of ditch-and-parcel complexes on Ofu occurs slightly earlier (11th-12th centuries AD) relative to most dated agricultural infrastructure elsewhere in the archipelago (13th century AD and later); though, some early infrastructural development might be interpreted in the "residential clusters" identified on Tutuila (Carson 2006:18). Apart from the possible early examples on Tutuila, the temporal sequence of agricultural infrastructure, especially the larger examples such as ditch-and-parcel networks (this project) and the residential ward infrastructure on 'Upolu (Jennings and Holmer 1980), is congruent with evidence of a developing social hierarchy in the 15th century AD and later, which is indicated by settlement pattern studies, monumental architecture, and lithic resource intensification (e.g., Addison 2010; Clark 1996; Holmer 1980; Quintus and Clark 2012; Wallin and Martinson-Wallin 2007; Winterhoff 2007).

However, these regional patterns do not wholly reflect shared processes of agricultural development or similar agricultural systems. Local factors and historical contingency led to different responses to natural processes and development thereafter. Most apparent is the marked topographic variability across the archipelago, and this environmental variability may have influenced the development of production systems in Samoa.

Variable agricultural systems developed even on nearly connecting islands, Ofu and Olosega, separated by a 100 m wide channel. Food production on Olosega Island was based on shifting cultivation and arboriculture, systems divided by a large ditch feature stretching

the length of a large HFD zone (Quintus 2012). Upslope of this ditch were non-residential terraces, perhaps utilised as cultivation plots or temporary field shelters during the cultivation of the surrounding slopes. Downslope of this ditch was the residential settlement dispersed among a forest of economic crops, primarily coconut and breadfruit. The ditch itself was important socially as a division between residential and non-residential areas (Quintus and Clark 2012), but it was also a way to trap and divert sediment that resulted from erosion caused by forest clearance upslope (Quintus 2012). Ditches on Ofu served a similar purpose, as drainage devices, but the scale of construction was different, as was the composite nature of features (both ditches and parcels). The ditch on Olosega measures over 1 km in length; the total linear length of the largest ditch on Ofu was 347 m. The Ofu ditch-and-parcel complexes did little to protect most residential features, but, instead, “protected” sloping land, or parcels, that appear to have been cultivated.

The agricultural systems of these two islands originate from different histories and environmental circumstances, as indicated by differences in function. The construction of a single large ditch on Olosega implies a centralised labour project and community level cooperation and coordination. However, production management facilitated by the ditch-and-parcel networks on Ofu must have been operated differently on Olosega, particularly in light of no evidence of field permanence on the latter. While populations on both islands practiced arboriculture and shifting cultivation, arable land on Olosega is more limited than on Ofu simply based on island size. These differences in the nature of the production systems on these two islands may have had social impacts, reminiscent of Hawai’i and Rotuma (Kirch 1984, 1994, 2010; Ladefoged 1993, 1995). Historic-era conflict in the Manu’a Group often included the island of Olosega (Moyle 1984; Wilkes 1852), which is the smallest of the three islands. It is conceivable, though speculative, that differences in the production systems between the islands could have been one factor in historic-era aggression.

Ofu and Polynesian Production Systems

It is by the comparison of different courses of agricultural change that general processes and unique historical characteristics are documented (Morrison 2007). Even though many agricultural systems in the region were intensified (Kirch 1984, 1994), the use of multiple cultivation techniques is well-documented in several courses of agricultural development (e.g., Addison 2006; Allen 2004; Kirch 1994, 2007b; Kirch and Yen 1982; Kurashima and Kirch 2011; Lepofsky 1994; Lincoln and Ladefoged 2014).

This is comparable to the situation on Ofu where, by the end of the sequence, shifting cultivation, arboriculture, and ditch-and-parcel techniques were all practiced. The use of shifting cultivation at the beginning of the Ofu cultural sequence is consistent with evidence of the importance of the technique at the time of island colonisation from Futuna, Tikopia, Hawai'i, and the Society Islands (Athens 1997; Athens and Ward 1993; Kirch 1994; Kirch and Yen 1982; Lepofsky 1994). Though Leach (1999) has questioned the use of geoarchaeological evidence to infer the presence of shifting cultivation in the Pacific, the presence and expansion of shifting cultivation better explains the changing patterns of terrigenous deposition on the Ofu coast than does an explanation entirely implicating climatic influences or vegetation burning for residential purposes. The practice of shifting cultivation throughout the cultural sequence of Ofu is comparable to the ethnographic situation on Anuta (Yen 1973), the Society Islands (Lepofsky 1994), the Marquesas Islands (Addison 2006) and Futuna (Kirch 1994), where the technique was used alongside other strategies. This situation is likely for other islands in the region as well.

The development of arboriculture remains poorly understood on Ofu, though modern vegetation patterns and interpreted storages pits hint that it was an important component of the production system by the end of the prehistoric sequence. Ofu can be added to the list of islands where tree crops were an important source of staple foods (e.g., Huebert 2014; Kirch and Yen 1982; Lepofsky 1994), with the knowledge that the importance of these crops, especially breadfruit, likely waxed and waned during the prehistoric sequence. Arboriculture was an important development on small islands with high population densities. Tree crops, especially breadfruit, produce high yields while either allowing habitation or cultivation in the understory. In many places in the Pacific, arboriculture was and still is practiced in or near residential areas (Kirch 1994; Lepofsky 1994), as appears to have been the case on Ofu. When cultivation space is limited by residential activity on small islands, the expansion of arboriculture can be an avenue for increased production. Especially when paired with storage to counteract cyclone damage and increase food availability, arboriculture is an important subsistence component of production systems in spatially circumscribed environments (Huebert 2014).

The limited agricultural infrastructure documented on Ofu, the ditch-and-parcel complexes, is reminiscent in form and, presumably, function to dryland ditching identified on the North Island of New Zealand (Barber 1989). This could relate to shared environmental conditions that necessitated the management of erosion and high energy run-off. However,

the variability of ditching in New Zealand is far greater than on Ofu, as would be expected given the environmental variability of the mixed continental and volcanic context of New Zealand.

At the theoretical level, the importance of risk management techniques on Ofu adds to a growing body of literature that supports the proposition that agricultural infrastructure was developed to stabilise, not just increase, production in the region (e.g., Addison 2006; Allen 2004; Campbell 2001; Ladefoged et al. 2013; Lee et al. 2006; McCoy and Hartshorn 2007; Stevenson et al. 2002). These strategies reduced the impact of the most common hazards, specifically cyclones and erosion caused by high precipitation. These case studies, Ofu included, provide further evidence of the influence of environmental variability on subsistence strategies (e.g., Addison 2006; Allen 1992, 1997, 1998; Allen and Craig 2009; Field 2003; Huebert 2014; Kirch 1994, 2007b; Kirch and Yen 1982; Ladefoged and Graves 2008; Ladefoged et al. 2009, 2013; Riley 1973).

Often times, agricultural infrastructure was coopted by leaders for use to support the political economy; this situation is hypothesised for Ofu Island. Earle (2011a,b) argues that opportunities for the appropriation of production by chiefs are provided by bottlenecks that restrict access to goods. Such bottlenecks have been most readily documented in Hawai'i, where both dryland and wetland production created conditions where control was possible. Certainly, the construction of infrastructure on highly productive land lent itself to management, as has been noted by others (Earle 1978; 1997; Ladefoged and Graves 2008).

What the Ofu example adds to this discussion is the explicit recognition of the role of risk management infrastructure in the creation of production bottlenecks. Managerial influence over low variance cultivation techniques may provide leaders with a platform to demonstrate their ability to lead, their efficacy and *mana*. In some polities, the maintenance of power was not just tied to demonstrations of abundance through feasting but also demonstrations of resilience to destruction. Such a situation in which risk management technology was appropriated for political means has been documented outside of Ofu. Chiefs controlled larger storage pits in the Marquesas that could be used either for competitive feasting or to offset the effects of periodic drought and cyclone damage (Kirch 1991a). When chiefs in the Marquesas were not able to provide for their people, they could be removed from leadership positions (Allen 2010; Thomas 1990, 1994). The management of breadfruit storage pits may have enabled some Marquesan leaders to maintain their positions. Other

examples attest to the acquisition of power by individuals that could manage production after the previous leader had failed following environmental perturbations, such as Niue (Thomas 1994:115-116). These various examples raise the possibility that the control of systems of redistribution through authority over risk management technology was a key avenue of power acquisition and maintenance in some Polynesian societies.

Nevertheless, the sequence of agricultural change on Ofu is, in some ways, fundamentally different to others in the region. Ofu is a tiny island. For some perspective, its total size (7.3 km²) would constitute 12 percent of the Leeward Kohala Field System on Hawai'i Island. This size means that no wet and dry dichotomy exists to influence the course of agricultural development on the island as it did in larger islands and archipelagos of Polynesia (Barrau 1965; Kirch 1994). The lack of permanent stream flow has restricted the use of wetland techniques to natural marsh zones on the coast, and there is no evidence of flooded irrigation. Because Ofu has steep topography, only some areas can be cultivated. Microenvironmental diversity is limited, restricting the use of diversification techniques to some extent. Impacts of storm activity cannot be offset by areas of the island that are less severely impacted because all areas are impacted about the same. In the last 30 years, cyclones and other tropical storms have resulted in the near abandonment of Sili village on Olosega and the need for increased transportation of food from Tutuila.

The collection of these characteristics reduce the comparability between Ofu and many other courses of agricultural development in Polynesia, such as those identified in Futuna/Uvea, the larger islands in the Hawaiian Archipelago (e.g., Hawai'i Island, Maui, Molokai), and Mo'orea (Society Islands). For instance, in identifying intensification on Ofu, I have considered the scale of analysis and the impact of scale on the characterisation of processes of agricultural development. Consideration of the scale of analysis highlights important differences in the scale of intensification documented on Ofu in comparison to other islands. Even though many processes of agricultural intensification were qualitatively similar throughout Polynesia, in that they involved the increased input of labour through the construction of infrastructure or decreased fallowing at a set spatial scale, the degree to which systems were intensified was variable. Infrastructural development on Ofu was limited to ditch-and-parcel complexes, which were spatially restricted. For the most part, increased production was accomplished through the expansion of shifting cultivation and, presumably, arboriculture at set levels of intensity. Depending on one's definition of intensification and the scale of analysis, intensification may not have occurred on Ofu. This is in contrast to such

places as Hawai'i Island, for instance, where significant infrastructural developments occurred over large stretches of land in both wet and dry environments as part of processes of expansion and intensification (Ladefoged et al. 2009, 2011).

A number of factors likely contributed to the relative lack of intensification processes on Ofu, such as the natural productivity of this tropical environment, both terrestrial and marine. Another interesting difference between Hawai'i Island and Ofu, however, is the nature and scale of the political economy. It may be that the differences in the scale of the intensification process seen on the two islands were partially related to differences in social pressures. On Hawai'i producers were pressed to support the political economy through ideology and force (Dye 2014; Earle 1997, 2011a, 2012). McCoy (2006:308-313) has proposed that some rain-fed agricultural systems on Moloka'i may have been built for social production; a view somewhat in concert with the recent opinions expressed by Dye (2014) for leeward systems on Hawai'i Island. This was not the case on Ofu.

Not surprisingly, the *course* of agricultural development on Ofu is more like that of Tikopia, a small Polynesian outlier comparable in size to Ofu, than any other. This highlights the role of island size. In both cases environmental change had an impact on subsistence, with progradation directly burying portions of shallow marine environments. Shifting cultivation was a key factor in landscape evolution on both islands, and the sequence of deposition appears to be generally comparable; increased sedimentation occurred in the 1st millennium AD on Ofu and in the middle to late 1st millennium AD on Tikopia (Kirch and Yen 1982:316). Progradation and colluvial infilling appear to have been the catalyst for the formation of freshwater marshes on both islands (Kirch and Yen 1982:84), though this is less clear on Ofu. On Tikopia, landscape evolution subtracted 41 percent of exploitable reef area by the end of the prehistoric sequence (Kirch 2007b:89), which is roughly comparable to the situation on Ofu. It may be that the degree of change to ratios of different productive environments is an important consideration in trajectories of subsistence change on small islands. After, arboriculture became a component of each system, but to a greater degree on Tikopia where 95 percent of forest is tree crops and cultigens (Kirch 2007b:90). Investment in arboriculture formed a key risk management resource signalled by the presence of storage pits (Kirch and Yen 1982:63 for Tikopia), and increased long-term production system sustainability (Vitousek and Chadwick 2013). It also offered an opportunity to increase production in an environment with a high population density by increasing the vertical capacity of the food production system.

This evidence highlights the influence of island size on agricultural development, but size is a complex issue and the influence of size on cultural practices often depends on proximity to other islands. Isolation is a characteristic of insularity (Fosberg 1963), but some islands are more isolated than others (Terrell et al. 1997 with included comments). Ofu is part of a wider archipelago, and is in proximity to two other small islands. Ofu was, at least to some degree, autonomous, but frequent contact between the islands of the Manu'a Group is known ethnographically (Mead 1969). On the other hand, the relative isolation of Tikopia is well documented (Firth 1936), as it is not part of a larger archipelago, though evidence of prehistoric contact is also clear (Kirch and Yen 1982).

Key differences in agricultural development exist between Tikopia and Ofu that may stem from differences in degree of island isolation. On Tikopia, the use of shifting cultivation techniques declined as arboriculture became an important component of the production system (Kirch 1994, 2007b:89-90), while shifting cultivation persisted through the cultural sequence of Ofu. At some point, pigs were eliminated from Tikopia, and there were strict cultural norms that influenced population levels (Firth 1936; Kirch 2007b:95). Neither of these occurred on Ofu.

The decline of shifting cultivation on Tikopia may be thought of as a way to maintain the long-term potential of the landscape as a growing population necessitated that more land be brought under cultivation and landscape evolution decreased the natural productivity of some marine environments. The increased utilisation of arboriculture increased sustainability through environmental management, specifically erosion control and the increased vertical capacity of the production system. The shift to a production system based on arboriculture, the extirpation of pigs, and the development of cultural attitudes toward population control were logical outcomes of the need for production stability and the inability of populations to increase human carrying capacity through periodic exchange. The inhabitants of Ofu certainly invested in risk management systems that stabilised their production systems, as discussed above. But, pressures to transform the agricultural system based solely on ecological factors were not as great in comparison to Tikopia because of social relationships with Ta'u and Olosega. It is conceivable, though speculative, that sustainable population levels could be managed in Manu'a through periodic population fission and relocation on the three islands. The situation may have changed by European contact as conflict between the three islands occurred. The relationship among the islands of Manu'a is a fruitful avenue for future research, but was beyond the scope of this thesis.

To summarise this section, the comparison of agricultural development among Ofu and other islands in Polynesia illustrates how similarities and differences develop as a result of the intersection of environment, history, cultural practices, and demography. These factors were important in all courses of agricultural change, but it was their differential combination that led to local developments in agricultural systems. Because of this, no two courses of agricultural development were the same. Variability is the basis for archaeological interpretation, and information gleaned from case studies contributes to our understanding of the relative importance of different factors through space and time, as well as the general processes that underlie most courses of agricultural development.

Conclusions

This thesis has presented the results and interpretations of a research project explicitly geared towards understanding prehistoric agricultural systems in the Samoan Archipelago. In this respect, it provides significant contributions at the local, regional, and theoretical level. The key contributions of this thesis are summarised below by addressing the aims of this research as they were presented in the introductory chapter.

Addressing the Aims of this Thesis

Before this study, Samoan agricultural systems were described as involving “neither intensive labor nor large-scale capital investment” (Carson 2006:6), and Samoa was highlighted to illustrate that the process of intensification was not inevitable in the Pacific (Leach 1999). Nonetheless, researchers agreed that there was a paucity of archaeological research on Samoan agricultural systems (Burley and Clark 2003), that the lack of an archaeological examination of Samoan agricultural systems was a gap in our knowledge (Kirch 1999:328), and that such examination of agricultural development in Samoa was necessary (Leach 1999:333).

The course of agricultural development on Ofu provides empirical evidence contradicting the assumption that 19th century AD subsistence systems in Samoa are simply extensions of the prehistoric situation. On Ofu, the cultural sequence of settlement and subsistence exhibited marked changes. The trajectory of agricultural change is characterised by increased labour investment into agricultural activities, accomplished by increasing the area of land under cultivation and developing agricultural infrastructure. Some of these changes can be described as intensification at an island-wide or HFD scale, but agricultural

intensification was only a minor component of the course of agricultural development and the characterisation of the sequence as one of intensification is dependent on the spatial scale of analysis. Expansion at set levels of intensity and the innovation of techniques that modified the landscape appear to have been essential components of the sequence.

Kirch (2007a) and Vitousek (2002) have argued that islands are valuable model systems or natural laboratories for understanding long-term ecological and cultural processes. The situation of Ofu adds to the temporal depth of these natural experiments. Ofu and the rest of the Manu'a Group represent the eastern extent of the Lapita colonisation at the beginning of the 1st millennium BC. That the agricultural system developed in place in Samoa, and other places in West Polynesia (Kirch 1994), for some 1,500 years before the colonisation of East Polynesia provides insights into dynamics at work prior to expansion.

Based on added time depth, an insight that needs to be tested in the future relates to the development of agricultural infrastructure. Few examples of agricultural infrastructure have been identified in West Polynesia prior to the 2nd millennium AD, though pondfields may have been built on Futuna as early as the 8th century AD (Kirch and Lepofsky 1993:187). In most other areas (e.g., Kirch 1988; Kirch and Yen 1982), including Ofu as reported here, the prehistoric sequence of agriculture up to the 2nd millennium AD is characterised by a lack of archaeologically visible infrastructure. Even on Futuna, extensive and complex pondfields were not built until the last few hundred years prior to European contact (Kirch 1994). This is more in line with evidence in East Polynesia for the late construction of infrastructure (e.g., Addison 2006; J. Allen 1992; M. Allen 2004; Barber 2004; Dye 2014; Fuery 2006; Kirch 1994; Ladefoged and Graves 2008; Leach 1979; Lepofsky 1994; Rosendaul 1972), but here these developments occur much sooner after island colonisation relative to West Polynesia.

One hypothesis that may explain this situation is lower than expected rates of population growth for West Polynesia, as well as the continuity of small communities for some time after colonisation (see Addison and Matisoo-Smith 2010; Cochrane et al. 2013). However, more research is necessary to test whether this is truly the case, both in terms of the lack of agricultural infrastructure and ideas regarding slow rates of population growth, particularly on the large islands of 'Upolu and Savai'i. An alternative hypothesis is that systems of production in East Polynesia were changed after the introduction of the sweet potato at the time of colonisation, which caused reconfigurations of cultivation strategies (the

Ipomoean revolution, McCoy 2006:309-313). The testing of these ideas may be an interesting topic for future research.

Apart from adding temporal depth to the general sequence of agricultural change in the region, this case study on Ofu demonstrates the variability of the process of agricultural development in Polynesia, and illustrates some factors that bring about that variability. This study makes a contribution to the recognition of the importance of yield stabilisation in the long-term development of agricultural systems, building upon previous research (e.g., Allen 2004; Marston 2011). The use of two different risk management techniques on Ofu highlights the internal variability of risk management as well. Strategies that reduce the variance of production likely have very different consequences in comparison to strategies that reduce the variation of resource availability. Most strategies that reduce yield variance are capital investments in the landscape, like ditch-and-parcel complexes on Ofu. These can require substantially more labour, and sometimes more group cooperation and coordination, relative to storage or other techniques that reduce resource availability.

Not only does yield stabilisation increase the likelihood of long-term survival, but it also changes the direction of agricultural development. Evidence presented in this thesis suggests that the use of stabilisation devices created opportunities for future developments. One consequence of the use of infrastructure that created variability between different cultivation techniques on Ofu was the formation of conditions conducive to management by leaders. This situation highlighted the role of history and past development in courses of agricultural development (Lansing 2007; Morrison 2006). Kirch (1994) has argued that explaining agricultural change requires the examination of history and of process. History is important because unique characteristics of local cultural and physical environments, coupled with changes to those cultural and physical environments, present unique opportunities at the same that they present constraints (Gould 1986). Process is important because it highlights general constraints that lead to fundamentally different pathways, such as population growth, risk, or political economy.

What generates courses of agricultural development is the relationship between context (e.g., local environment and culture), process (e.g., intensification, expansion, disintensification), and the consequences of cultivation strategies (e.g., risk management, increased production). Process is embedded in history, and history is influential in process by providing the raw materials that effect development. Of key interest here was risk

management, which is dependent on the selective pressures of the environment intrinsic to the local environment. The consequences of risk management, given their own functions to either create or counteract pressures, influence directions of future change. Cause and consequence, products of history, partially construct process (cf. Morrison 2006, 2007). Agricultural trajectories are, therefore, feedback loops in which cause and consequence are continually interacting and transforming.

Studies of agriculture have moved well beyond unilinear models of change that privilege techniques of increased production. Still, continued research is necessary to both document the underlying conditions that result in general processes of development and the unique historic circumstances that lead to local production systems. All in all, these studies not only inform our understanding of how and why human populations choose to produce their food, but also contribute to our more general understanding of the intersection of human-environmental interaction and socio-economic relations.

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Appendix I: Feature Data

Table A.1 Feature information for A'ofa parcels

Parcel Number	Size (m ²)	Class	From Feature 19 (m)	From Centre (m)	Ext Centre (m)
13	172.63	1	27	89	68
14	236.5	1	23	54	40
4	324.29	1	101	155	123
10	460.75	2	184	251	225
16	511.52	2	50	119	112
2	617.03	2	182	117	151
8	640.56	2	217	273	241
15	644.91	2	59	19	46
6	667.5	2	145	184	148
11	714.53	3	137	208	189
9	800	3	209	271	241
7	803.3	3	186	246	215
21	811.02	3	277	305	326
5	830.74	3	137	140	104
12	835.54	3	67	62	25
18	844.77	3	188	218	237
19	891.52	3	146	194	204
25	931.61	3	332	373	388
20	952.4	3	250	281	301
17	953.56	3	60	120	121
26	1089.33	4	336	372	390
22	1127.51	4	275	269	301
27	1346.53	4	348	380	400
1	1371.62	4	476	406	418
3	1623.67	4	205	135	149
24	1693.01	4	318	355	369
23	3063.38	4	299	310	337

Table A.2 Feature information for ditch length in both occupation zones

Occupation Zone	Type	Parcel Number (s)	Size (m)
A'ofa	Single	1	92
A'ofa	Single	2	72
A'ofa	Single	3	114
A'ofa	Single	4	75
A'ofa	Single	5	82
A'ofa	Single	6	113

A'ofa	Network	7-9	170
A'ofa	Single	10	63
A'ofa	Single	11	85
A'ofa	Single	12	99
A'ofa	Single	13	51
A'ofa	Single	14	52
A'ofa	Single	15	83
A'ofa	Network	16-17	145
A'ofa	Single	18	100
A'ofa	Single	19	82
A'ofa	Network	20-21	145
A'ofa	Network	22-23	212
A'ofa	Network	24-27	347
Tufu	Network	1	185
Tufu	Network	2-3	154
Tufu	Single	4	59
Tufu	Network	5-7	161
Tufu	Single	8	77
Tufu	Single	9	41
Tufu	Single	10	69
Tufu	Single	11	73
Tufu	Single	12	72
Tufu	Single	13	118
Tufu	Network	14-17	330

Table A.3 Feature information of A'ofa terraces

Feature Number	Coral?	Length (m)	Width (m)	Area (m²)	Class	Elevation (m)
1	No	15	6	90	1N	165
2	No	11	5	55	1N	175
3	No	12	4	48	1N	172
5	No	15	6	90	1N	163
6	No	42	12	504	5N	154
8	No	7	5	35	1N	138
9	Yes	13	4	52	1C	134
11	No	8	5	40	1N	131
16	No	15	7	105	2N	114
18	Yes	20	14	280	3C	123
19	Yes	65	10	650	5C	120
28	Yes	8	8	64	1C	128
29	Yes	17	12	204	3C	129
30	Yes	19	12	228	3C	131

31	Yes	21	12	252	3C	127
32	No	19	11	209	3N	136
33	No	21	8	168	2N	143
34	No	20	8	160	2N	154
35	No	10	10	100	1N	152
36	Yes	21	14	294	3C	147
37	Yes	28	10	280	3C	119
38	Yes	16	7	112	2C	128
39	Yes	17	8	136	2C	130
41	Yes	10	7	70	1C	127
47	Yes	18	6.5	117	2C	123
49	Yes	21	15	315	4C	118
51	Yes	21	13	273	3C	119
52	Yes	25	12	300	4C	128
53	Yes	28	10	280	3C	141
57	Yes	26	15	390	4C	136
58	Yes	17	12	204	3C	136
59	Yes	26	13	338	4C	112
60	Yes	8	6	48	1C	113
64	Yes	14	10	140	2C	114
65	Yes	13	10	130	2C	113
66	Yes	17	11	187	2C	114
67	Yes	15	9	135	2C	115
68	Yes	20	12	240	3C	109
69	Yes	14	12	168	2C	110
70	Yes	21	8	168	2C	105
71	Yes	21	12	252	3C	102
72	Yes	18	13	234	3C	98
73	NA	16	7	112	NA	129
74	None	21	9	189	2N	90
78	No	15	6	90	1N	200
100	Yes	24	15	360	4C	75
101	Yes	31	15	465	4C	78
102	Yes	13	9	117	2C	117
103	Yes	8	7	56	1C	121
104	Yes	22	9	198	2C	82

Table A.4 Feature information of A'ofa depressions

Feature Number	Stone Lining (Present)	Diameter (m)	Depth (m)	Class
4	Yes	2.5	0.34	1E
7	Yes	2.9	0.48	1E

10	No	2.4	0.21	1N
12	No	4.1	0.63	3N
13	Yes	2.5	0.33	1E
14	No	4.5	0.63	3N
15	No	4.3	0.44	3N
17	No	2.4	0.41	1E
20	No	3.5	0.21	2N
21	No	3.4	0.39	2N
22	No	2.7	0.26	1N
23	No	2.4	0.41	1N
24	No	4.1	0.28	3N
25	No	3.9	0.33	2N
26	No	4.3	0.34	3N
27	No	3.9	0.93	2N
40	Yes	3.3	0.3	2E
94	Yes	2	0.2	1E
95	No	3.5	0.35	2N
96	Yes	3	0.8	2E
97	No	3	0.8	2N
98	Yes	2.3	0.5	1E
99	Yes	3	0.45	2E
42	Yes	2.7	0.41	1E
43	No	3.4	0.37	2N
44	No	2.8	0.22	1N
45	Yes	3.5	0.38	2E
46	No	3.6	0.31	2N
48	No	3	0.3	2N
50	Yes	2.8	0.46	1E
54	Yes	2.5	0.4	1E
55	No	3.8	0.24	2N
56	No	4.4	1.03	3N
61	No	2.8	0.27	1N
62	No	2.5	0.19	1N
63	No	3.1	0.28	2N
76	No	3*	0.3	NA
79	No	3	0.39	2N
80	No	2.8	0.23	1N
81	Yes	2.3	0.39	1E
82	No	2.9	0.28	1N
83	Yes	5.6	0.7	3E
84	Yes	3.2	0.55	2E
85	No	5	0.48	3N

86	Yes	2.7	0.3	1E
87	Yes	4.5	0.36	3E
88	Yes	2.4	0.16	1E
89	Yes	2.2	0.28	1E
90	No	-	-	NA
91	No	-	-	NA
92	No	-	-	NA
93	Yes	-	-	NA

Table A.5 Feature information of Tufu parcels

Number	Size (m ²)	Class	Distance from Centre (m)
9	225	1	77
6	317	1	58
4	394	1	87
5	400	2	52
3	455	2	89
8	570	2	35
11	575	2	179
12	610	2	187
10	635	2	63
7	640	2	82
16	956	3	171
2	980	3	109
17	1102	4	198
15	1191	4	149
1	1535	4	290
13	1702	4	171
14	1830	4	156

Table A.6 Feature information of Tufu terraces

Feature Number	Coral?	Length (m)	Width (m)	Area (m ²)	Class	Elevation (m)
1	Yes	26	18	468	5C	73
2	Yes	23.2	15	348	4C	85
4	Yes	16.3	13.1	213.53	3C	75
13	No	16	11	176	2N	96
15	No	6	3	18	1N	101
16	Yes	20	9	180	2C	106
17	No	20	5	100	1N	107
18	No	25	6	150	2N	109

20	Yes	24	9	216	3C	112
21	No	18	6	108	2N	120
22	No	15	6	90	1N	126
24	No	15	5	75	1N	134
25	No	9	4	36	1N	123
26	No	9	4	36	1N	131
27	No	18	6	108	2N	115
28	Yes	23	9	207	3C	113
29	Yes	11	4	44	1C	112
30	No	18	4	72	1N	112
31	Yes	18	8	144	2C	103
32	Yes	40	8	320	4C	87
33	Yes	40	9	360	4C	82
36	Yes	14.5	8	116	2C	75
37	Yes	23.7	13	308.1	4C	72
40	Yes	53	12	636	5C	73
41	Yes	23	12	276	3C	76
43	Yes	31	7	217	3C	80
47	Yes	15	6	90	1C	86
54	Yes	18	5	90	1C	110
55	Yes	26	9	234	3C	121
56	No	10	4	40	1N	135
58	Yes	36	6	216	3C	153
59	No	14	6.8	95.2	1N	163
60	No	9	6	54	1N	141
61	Yes	15	5	75	1C	127
62	No	8.5	3	25.5	1N	120
63	Yes	12	5	60	1C	77
64	Yes	9	6	54	1C	78
65	Yes	18	15	270	3C	80
66	Yes	19	10	190	2C	78
67	Yes	9.3	10.4	96.72	1C	81
68	Yes	18.6	10.6	197.16	2C	85
72	NA	30	10	300	NA	86
73	Yes	11.3	5	56.5	1C	100
76	Yes	30	6.8	204	3C	96
77	Yes	10.1	3.6	36.36	NA	90
79	Yes	10.3	4.8	49.44	1C	90
80	Yes	22	15	330	4C	71
81	Yes	32	10	320	4C	90
83	Yes	44	11	484	5C	96
L1	Lidar	15	5	75	NA	128

L2	Lidar	16	6	96	NA	125
L3	Lidar	11	5	55	NA	118
L4	Lidar	19	6	114	NA	118
L5	Lidar	23	6	138	NA	133
L6	Lidar	13	6	78	NA	133
L7	Lidar	30	8	240	NA	97
L8	Lidar	29	13	377	NA	98
L9	Lidar	28	13	364	NA	79

Table A.7 Feature information of Tufu depressions

Feature Number	Stone Lining (Present)	Depth (m)	Diameter (m)	Size Class
3	Yes	0.46	3	2E
5	Yes	0	1*	NA
6	Yes	1	4*	NA
7	No	1	3*	NA
8	No	0	4*	NA
10	No	0	3*	NA
11	No	0	2*	NA
12	No	0	4*	NA
14	No	1	6*	NA
19	No	1	2	1N
23	No	0.2	2*	NA
34	Yes	0.25	2.3	1E
35	No	0.18	2.9	1N
38	No	0.31	3.8	2N
39	No	0.31	2.3	1N
42	No	0.25	2.2	1N
44	No	0.3	2.1	1N
45	No	0.21	1.9	1N
46	No	0.3	2.5	1N
48	No	0.29	2.3	1N
49	No	0.4	3.1	2N
50	Yes	0.4	2.6	1E
51	Yes	0.29	2	1E
52	Yes	0.85	4.3	3E
53	Yes	0.27	2.2	1E
69	No	1.36	4.3	3N
70	No	0.41	2.5	1N
71	No	0.67	4.2	3N
74	No	0.36	2.6	1N

75	No	0.3	2.5	1N
78	No	0.14	1.7	1N
82	No	0.5	3.8	2N
84	No	0.4	3*	NA
85	No	0.4	1.9	1N
86	No	0	3*	NA