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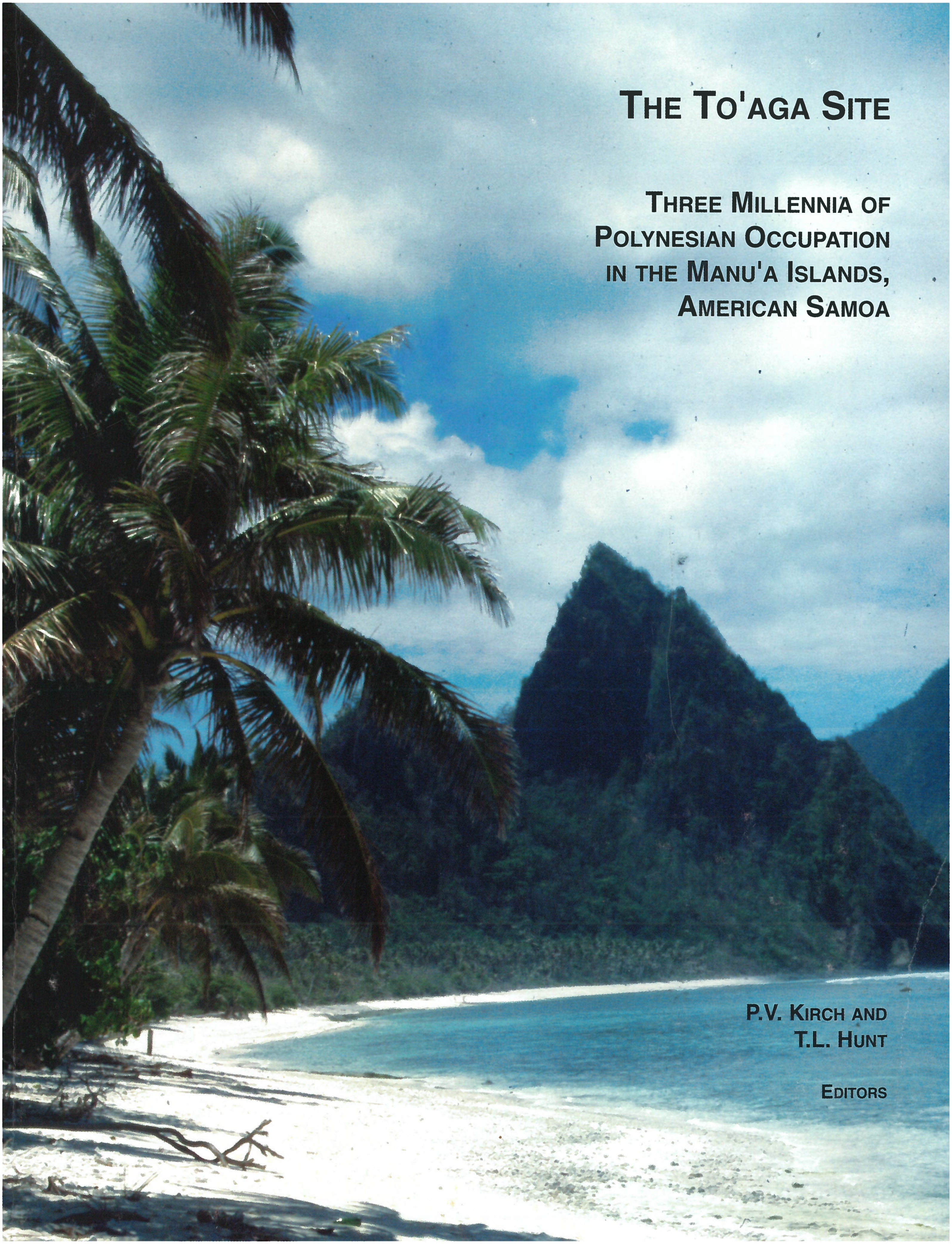

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THREE MILLENNIA OF POLYNESIAN OCCUPATION IN THE MANU'A ISLANDS, AMERICAN SAMOA

P.V. KIRCH AND
T.L. HUNT

EDITORS

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PHOTO BY PATRICK V. KIRCH

View of the completed 1987 main excavation at To'aga.

Cover photo: View of Ofu Island coastline fronting the To'aga site. The volcanic plug at Fa'ala'aga is visible in the distance. (Photo by P.V. Kirch)

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Dedicated to the memory of

JOHN KNEUBUHL

(1920-1992)

Citizen of Two Cultures

Tagaloa e, taumuli ai,
Tagaloa fiamalolo;
E mapu i le lagi Tuli mai vasa;
Ta lili'a i peau a lalo.
Fea le nu'u na lua'i tupu?
Manua-tele na mua'i tupu.

Tagaloa, who sits at the helm,
Tagaloa desires to rest;
Tuli from the ocean must rest in the heavens;
These waves below affright my breast.
Where is the land which first upsrang?
Great Manu'a first uprose.

(Mead 1930:152)

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CONTRIBUTORS

William R. Dickinson, Department of Geosciences, University of Arizona, Tucson, AZ 85721

Conrad Erkelens, Department of Anthropology, University of Hawaii, Honolulu, HI 96822

Terry L. Hunt, Department of Anthropology, University of Hawaii, Honolulu, HI 96822

Patrick V. Kirch, Department of Anthropology, University of California, Berkeley, CA 94720

Elizabeth Manning, Department of Anthropology, University of California, Berkeley, CA 94720

Lisa Nagaoka, Department of Anthropology, University of Washington, Seattle, WA 98195

David W. Steadman, Biological Survey, New York State Museum, Albany, NY 12230

Jason Tyler, Department of Anthropology, University of Washington, Seattle, WA 98195

Marshall Weisler, Department of Anthropology, University of California, Berkeley, CA 94720

* * *

PREFACE

In 1985 I received a request from the Historic Preservation Officer of American Samoa, Mr. Stan Sorensen, to submit a proposal for archaeological survey work in American Samoa. Realizing that the Manu'a Islands, lying at the extreme eastern end of the Samoan archipelago, were the most neglected part of the Samoan group from the viewpoint of prehistory, I suggested that we might undertake a reconnaissance of the three islands—Ta'u, Ofu, and Olosega—that make up Manu'a. A previous survey in 1962, by Y. Sinoto and W. Kikuchi of the Bernice P. Bishop Museum, had revealed the presence of various surface archaeological sites, but had failed to establish any significant time depth for the prehistoric occupation of these islands. The proposed reconnaissance was carried by Terry Hunt and myself from June to August, 1986 and resulted in the discovery of the first pottery-bearing sites in the Manu'a group, on Ta'u and Ofu, as well as a range of later prehistoric monuments and artifacts. (The results of the 1986 reconnaissance survey were subsequently published by Hunt and myself in *The Journal of the Polynesian Society*, Vol. 97, pages 153-83, 1988.)

From the results of our initial survey, it appeared that ceramic-bearing deposits exposed by a Works Department landfill at To'aga on Ofu Island were particularly promising for further archaeological investigations. Thus, in 1987 we proposed to the Historic Preservation Office a second phase of work at To'aga. In this second phase, we recommended a series of systematic subsurface test excavations in order to determine more accurately the nature and extent of the To'aga site deposits. This second field season in 1987 was again directed by Hunt and myself, with the assistance of Jason Tyler and Jean Gehman. (Preliminary results of this work were published in *Archaeology in Oceania*, Volume 25, pages 1-15, 1990).

The 1987 excavations revealed the presence of a deep, well-stratified prehistoric record in the To'aga area, with subsurface deposits spanning most—if not all—of Manu'an prehistory. These strata were so extensive, however, that we were not able to determine their limits in the 1987 field season. Therefore, a third season was proposed to define more precisely the full subsurface extent of the site. This work was carried out in the summer of 1989, with fieldwork co-directed by Hunt and me, and with the assistance of a team of students from the University of Hawaii and the University of California at Berkeley.

This monograph constitutes the final report of our three field seasons at the To'aga site. While our core objectives were those of site survey and inventory (with the aim of preparing a National Register of Historic Places nomination for To'aga), we have endeavored to go well beyond these minimal goals in the present work. Thus, we have carried out extensive analyses of much of the excavated material, including faunal remains, ceramics, and basalt artifacts. In addition, we have paid considerable attention to the geomorphological and geoarchaeological problems of site formation at To'aga, noting that these also impinge on cultural resource management considerations. We trust that these efforts contribute significantly to our knowledge of Western Polynesian prehistory as well as to site survey and inventory in American Samoa.

During the course of our three expeditions to Manu'a we have received the support and assistance of a great many individuals and organizations. Our primary source of funding has been the Historic Preservation Office of the Department of Parks and Recreation, Government of American Samoa, through grants from the U. S. National Park Service, Archaeological Assistance Division. Additional support has been provided by the Burke Museum of the University of Washington (for the 1986 and 1987 seasons), and the Archaeological Research Facility of the University of California at Berkeley (for the 1989 season). We are particularly grateful to Stan Sorensen, the Historic Preservation Officer of American Samoa, for his interest and support from the inception of this project. Anne Sauter of the Archaeological Research Facility at Berkeley assisted in various administrative matters. Tanya Smith carefully edited and produced this final monograph.

Two respective district governors of Manu'a have lent their support to the project: High Chief Aolaolagi Soli and High Chief Tufele Li'a. We are also pleased to record the support of the people of Ofu Village, especially High Chief Misa'alefua, High Talking Chief Faoa, Liulamaga Ta'ilele, Manu'a Peau, and Sina Peau. In 1987, Tito and Margaret Malae assisted greatly with housing and other arrangments. Likewise, in 1989 Manu'a Peau and her family provided housing, hospitality, and a sense of being at home with family.

Our field crews of Ivala Live, Fuave'a Ta'ilele, Tillis Thompson, Pauesi Malo, Eleloi Misa'alefua, Ele'ele Utuone, Paulo Su'e, and Opetaia Fa'amita were not only dedicated workers, but interested co-investigators. We also thank Jason Tyler, Jean Gehman, Elizabeth Manning, Conrad Erkelens, Melissa Kirkendal, Robert Holsen, Lisa Nagaoka, and Ann Rowberg, who assisted in the 1987 and 1989 fieldwork.

Prof. Roger C. Green of the University of Auckland kindly reviewed the entire manuscript, and we are most grateful for his insightful comments.

Throughout all field seasons, John and Dorothy Kneubuhl of Tutuila generously opened their home to us and to our assistants, and helped us in countless ways. John's profound knowledge of Samoan culture and history was a constant inspiration. His visit to our field site in 1989, arriving with only a suitcase crammed full of two large legs of lamb, mint sauce, and a bottle of good scotch whiskey, was an event not soon to be forgotten. It was with profound sadness that we learned of his death in Tutuila in February of 1992. As a small token of our esteem for John we dedicate this volume to his memory.

Patrick V. Kirch

Berkeley, January 1991

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INTRODUCTION AND RESEARCH DESIGN

PATRICK V. KIRCH AND TERRY L. HUNT

THE WESTERN POLYNESIAN ISLANDS—and particularly the large Tongan and Samoan archipelagoes—have long occupied a central focus in scholarly endeavors to decode the history of Polynesian origins and dispersals. Burrows (1939) recognized and defined the distinctive cultural patterns that set the Western Polynesian societies apart from those of Eastern Polynesia. With the advent of modern stratigraphic excavation and of radiocarbon dating in Polynesia during the 1950s, it became apparent that Tonga and Samoa had been settled considerably earlier than any other Polynesian archipelagoes. Furthermore, pottery assemblages from both Tonga and Samoa had obvious relationships with early ceramic complexes in Melanesia to the west (Golson 1962). Thus, when Suggs attempted his pioneering synthesis of Polynesian prehistory, he could rightly claim that "the islands of Western Polynesia were the earliest occupied of all the Polynesian triangle and the source of all subsequent settlements in Polynesia" (1960:101).

As archaeological knowledge of the Western Polynesian archipelagoes continued to accumulate, the relationship between the early Tongan and Samoan materials occasioned debate and controversy (e.g. Green 1967, 1968; Groube 1971). The presence of early (ca. 1200 B.C.) dentate-stamped, Lapita-style pottery in Tonga and, in Samoa of only later (ca. 200 B.C. to A.D. 300) Polynesian Plain Ware assemblages appeared to support the hypothesis of Tonga as the original Polynesia "homeland." In 1973, the discovery of a submerged Lapita site at Mulifanua off the 'Upolu coast in Western Samoa (Jennings 1974) brought the Samoan sequence back to a comparable antiquity to that of Tonga. Subsequently, early Lapita materials were recovered from a number of the smaller Western Polynesian islands, including Futuna (Kirch 1981; Frimigacci 1990), 'Uvea, and Niuatoputapu (Kirch 1988b). These discoveries indicate that the entire Western Polynesian region was rapidly explored and colonized by Lapita people during the penultimate centuries of the second millennium B.C.

In our current conception, the adjacent islands and archipelagoes of Western Polynesia constituted a *homeland region* in which a distinctive Ancestral Polynesian Culture emerged out of its immediate Lapita ancestor during the period from about 1000 to 500 B.C. (Kirch 1984; Kirch and Green 1987). Presumably, the processes of cultural change and differentiation during this time period were not uniform across all islands. Regular inter-island contact through exchange, however, kept each local community from becoming isolated and facilitated the spread of innovations. As Kirch and Green (1987) have argued, the reconstruction of Ancestral Polynesian Culture—not as a static entity, but as a dynamic and changing configuration over the course of 500 or more years—is a high priority for Polynesian prehistory. Only by understanding the technology, economy, settlement patterns, and socio-political organization of this ancestral culture can we provide a secure baseline for studying the subsequent development and diversification of later Polynesian groups throughout the vast Polynesian triangle. Reconstruction of Ancestral Polynesian Culture is essential if we are to disentangle those traits and institutions which are *shared retentions*, from those which are later *innovations* in various island societies.

The present monograph represents a modest contribution toward the ultimate goal of tracing the development of Ancestral Polynesian Culture out of its Lapita roots. The To'aga site, situated on the tiny island of Ofu in the Manu'a Group of American Samoa, spans virtually the entire three-millennium-long sequence of Samoa, but is especially rich in well-stratified materials dating to the period from ca. 3200 to 1900 B.P. Our research at To'aga was initiated in order to meet certain cultural resource management (CRM) demands, as part of an archaeological survey and inventory of American Samoan sites under the auspices of the Office of Historic Preservation of the Government of American Samoa (Pago Pago). Fortunately, the goals of this CRM project happily meshed with the objectives of academically oriented archaeological research, providing the opportunity to add to our knowledge of the early phases of Western Polynesian prehistory while at the same time addressing contemporary historic preservation and land use management concerns.

The To'aga site was discovered during our 1986 reconnaissance survey of the Manu'a Islands (Hunt and Kirch 1987), one of two sites containing pottery and thus dating to the earliest period of Samoan prehistory. In our subsequent 1987 and 1989 field seasons we concentrated on the extensive To'aga site, seeking to define the spatial extent of its deeply buried deposits, its chronology, stratigraphy, material culture, faunal assemblages, and other aspects of intra-site variation. As our investigations progressed, it became apparent that To'aga was of critical importance to understanding the first millennium of Samoan—and Western Polynesian—prehistory. No other site presently known in the Samoan archipelago encapsulates such a continuous stratigraphic record, nor one so rich in artifactual and faunal materials. Although the scope and extent of our excavations had to be limited by the CRM-funded nature of our project, we have nonetheless made every effort to push the analysis of our materials farther than is usual in such reconnaissance surveys. For example, using a transect sampling methodology, combined with detailed sediment analysis and radiocarbon dating, we have been able to test a model of shoreline progradation linked with a mid-Holocene higher sea level. This model has considerable geoarchaeological implications for the formation and subsurface burial of early Polynesian sites throughout the tropical central Pacific region. We have also pushed the analysis of the archaeological record of Ancestral Polynesian material culture at the To'aga site through detailed studies of pottery (including analysis of temper and of the chemical composition of clays), adzes (including EDXRF analysis of basalts), and other artifact classes. Likewise, the samples of faunal materials have been subjected to intensive studies, including extinct and extirpated avifaunal remains, molluscan and fish faunal assemblages, and terrestrial (synanthropic) land snails. In the fourteen chapters that follow, we and our collaborators present the detailed results of our field and laboratory investigations of the To'aga site.

BACKGROUND TO SAMOAN ARCHAEOLOGY

Although Buck (1930) reported on stonework and adzes, the first modern archaeological effort in Samoa was that of Golson (n.d., 1962) in 1957, resulting both in a general account of the range of field monuments and in the discovery of prehistoric pottery dated to the first century A.D. at Vailele, 'Upolu. The latter discovery was particularly significant in the then-emerging picture of Polynesian origins as rooted in an earlier Melanesian ceramic complex beginning to be known by the term "Lapita" (Suggs 1961; Golson 1971; see also Kirch 1988a). Following Golson's lead, a major archaeological program was organized for Western Samoa under the direction of

Roger C. Green (University of Auckland), with funding provided through the Bishop Museum's Polynesian Culture History Program. Between 1962 and 1967, this project brought seventeen archaeologists from nine institutions to Western Samoa for a coordinated series of investigations including surface surveys and excavations of sites spanning early settlement to the historic period. Published in two large volumes (Green and Davidson 1969, 1974), the results of this project are a landmark in Polynesian archaeology.

Subsequent to the conclusion of the Western Samoa project in 1967, but in time to be incorporated in the second volume of results (Green and Davidson 1974), an accidental discovery of classically decorated Lapita pottery at Mulifanua, 'Upolu extended the Samoan sequence back to the beginning of the first millennium B.C. (fig. 1.1). Furthermore, the geomorphological context of this find—a submerged site capped by nearly one meter of reef rock—demonstrated that tectonically induced changes in the Samoan landscape could have significant implications for regional prehistory.

In the 1970s, a project headed by Jesse Jennings of the University of Utah completed two seasons of archaeological research on 'Upolu Island and on the adjacent small islet of Manono, concentrating on settlement pattern surveys and excavation of both plain ware and aceramic sites (Jennings et al. 1976; Jennings and Holmer 1980). Of particular note is their work on settlement patterns in which they propose the concept of the "household unit" as an analytical category (Jennings et al. 1982).

As a result of these various projects, the outline of a prehistoric cultural sequence for Western Samoa is reasonably well attested (Davidson 1979). In conventional outline, this sequence begins with the occupation of the archipelago between about 1200-1000 B.C. by makers of classic, dentate-stamped Lapita pottery (represented by the presently submerged "Ferry-Berth Site" at Mulifanua). The first millennium B.C. witnessed changes in the composition of Samoan ceramic assemblages, particularly the loss of decoration and of more complex vessel shapes, ending with Polynesian Plain Ware assemblages around the time of Christ. Stone adzes and other aspects of material culture also changed with the pottery, and this sequence as a whole is viewed as documenting the development of an Ancestral Polynesian Culture out of an older Eastern Lapita culture (Kirch and Green 1987).

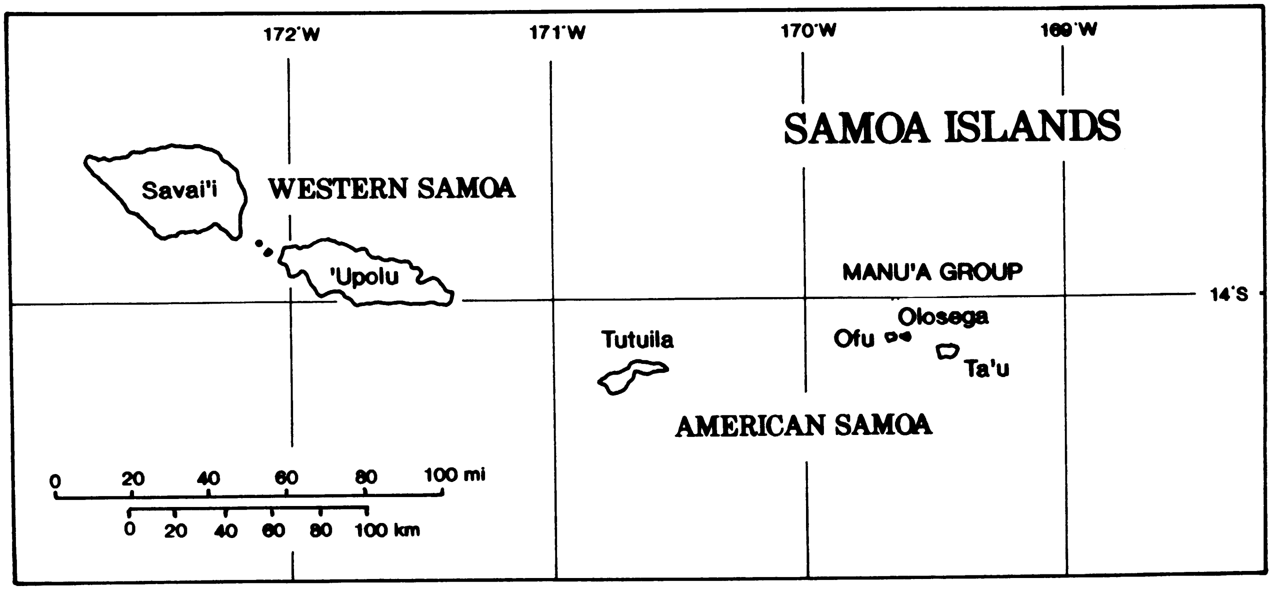

Figure 1.1 The Samoan Archipelago.

Ceramics ceased to be manufactured by about A.D. 300, and the paucity of archaeological materials during the next thousand years or so prompted Davidson (1979) to term this the "Dark Ages" of Western Polynesian prehistory. In the final millennium of the Samoan sequence a number of new developments are evidenced in the archaeological record, especially the construction of several new forms of field monuments, such as the star mound and ridge-top fortifications. These large constructions are believed to reflect the rise of powerful chiefdoms competing for land and resources.

The Samoan cultural sequence briefly outlined above parallels—in many key aspects—the sequences developed by archaeologists for other Western Polynesian islands, such as Tongatapu (Poulsen 1987), Niuatoputapu (Kirch 1988a), Futuna (Kirch 1981; Frimigacci 1990), and 'Uvea (Frimigacci, Siorat and Vienne 1984).

In contrast with Western Samoa, the archaeology and prehistory of American Samoa are less well known. The first modern archaeological survey in American Samoa was carried out by W. Kikuchi (1963, 1964) on Tutuila and Aunu'u Islands in 1961-62. Kikuchi's work provided an overview of the main kinds of surface sites, but was neither intensive nor systematic in its coverage. In 1962, Kikuchi and Y. Sinoto of the Bishop Museum extended the survey to the Manu'a Group and conducted minor test excavations on both Ta'u and Tutuila Islands. Disappointed by their results, Sinoto decided to abandon the Samoan project, and shifted his locus of field work to the Marquesas Islands of Eastern Polynesia (Emory and Sinoto 1965). Prior to 1980, the only other major field project conducted in American Samoa was that of Janet Frost (1978), who carried out limited test excavations at seven sites on Tutuila. There have also been several limited cultural resource surveys, carried out under contract to the National Park Service, the U.S. Army Corps of Engineers, and the Department of Public Works (Ladd and Morris 1970; Kikuchi, Palama, and Silva 1975; Silva and Palama 1975; McCoy 1977; Athens 1987; Hunt 1987). In 1980, J. Clark compiled a summary of all recorded archaeological sites for the American Samoan Historic Preservation Commission, based on three weeks in the field checking the locations and status of many of these sites (Clark 1980). Clark summed up the status of archaeological survey in American Samoa as of 1980 in these words: "the amount of land that has been intensively and systematically covered is small indeed" (1980:11).

Over the course of the past decade, archeological knowledge of American Samoa has increased substantially due to the efforts of the Historic Preservation Office of the Department of Parks and Recreation, Government of American Samoa. With funds made available by the U.S. National Park Service (NPS), the Historic Preservation Officer has commissioned a variety of archaeological reconnaissance and intensive survey projects in order to compile an inventory of significant sites on Tutuila and in the Manu'a Group. Given the rapid pace of economic development in American Samoa, many of the sites revealed through such survey projects have proved to be threatened by current or projected land use practices.

On Tutuila Island, a substantial multi-year project was devoted to the recording and detailed study of the Tataga-matau basalt adz quarry site, situated on a complex of ridges inland of Leone Village (Best, Leach, and Witter 1989; Leach and Witter 1987; Leach and Witter 1990). This site is of interest not only for its intrinsic importance to understanding the prehistory of Tutuila, but because the adzes produced at this major quarry have been shown to have been distributed very widely throughout the Western Pacific (Best, Sheppard, Green, and Parker 1992). Also on Tutuila, Jeff Clark and his associates have carried out a series of surveys and test excavations which have greatly amplified our understanding of the archaeological resources of American Samoa (Clark 1989, in press; Clark and Herdrich 1988, in press).

When the senior author was asked by the American Samoan Historic Preservation Officer to consider undertaking an archaeological survey in the archipelago, we decided to focus on the then-neglected Manu'a Group. The selection of the Manu'a Group as the focus of our project was motivated by several factors. First, the larger island of Tutuila was already receiving substantial attention from several other archaeological field teams, leaving Manu'a as a continuing *lacuna*. Second, because we were particularly interested in seeking ceramic-bearing sites dating to the first third of Samoan prehistory, we preferred to focus on several smaller islands where survey and subsurface testing could be concentrated on likely areas of early occupation.

Third, as the most easterly and somewhat isolated section of the Samoan archipelago, the prehistory and archaeology of Manu'a could conceivably exhibit significant differences from that of Tutuila, 'Upolu, and Savai'i. While such differences were predictable, primary fieldwork would be necessary for their documentation.

DESIGN OF THE RESEARCH

Over the course of three field seasons, our research focus in Manu'a evolved from extensive reconnaissance survey of the surface archaeology to intensive subsurface examination of buried archaeological resources. Our field investigations began in 1986 with archaeological reconnaissance of the three islands of the Manu'a Group: Ta'u, Olosega, and Ofu (Hunt and Kirch 1987, 1988). In 1986 ceramic-bearing sites were discovered at To'aga, Ofu Island and at Ta'u Village, Ta'u Island. In the 1987 field season, we focused on an intensive survey and systematic excavation of the site at To'aga (Site AS-13-1). Our results from 1987 (Kirch et al. 1989, 1990) revealed a deeply stratified site containing a long and continuous sequence of ceramics and dating to more than 3,000 years B.P. (Kirch et al. 1990). A site of this significance for either American or Western Samoa was previously unknown. A third season at To'aga was therefore designed to determine the nature and extent of buried archaeological remains for the entire coastal flat of southern Ofu (extending from To'aga to Fa'ala'aga). Thus, the primary objectives of our 1987 and 1989 fieldwork were to determine the nature, significance, and spatial and stratigraphic extent of the deposits at site AS-13-1. This fundamental step was accomplished primarily for the purpose of cultural resource management, including preservation and public interpretation. The data collected will be used to nominate site AS-13-1 to the National Register of Historic Places and to assure its preservation in the face of any future development plans.

While our Manu'a Project was designed first and foremost to address the CRM concerns of the American Samoa Historic Preservation Office, we also regarded the project as an opportunity to tackle several major research problems of Samoan archaeology and prehistory. Especially in the 1987 and 1989 field seasons, when we concentrated on the well-stratified and extensive subsurface deposits at To'aga, it was possible to design the field and laboratory strategies to address the following research problems:

1. A major objective was the establishment of a temporal framework and prehistoric sequence for the Manu'a Islands. Prior to the commencement of our project, it was uncertain whether the Manu'a Group would prove to have been colonized at approximately the same time as the other Samoan Islands, or whether the main changes and trends in the Manu'a sequence (such as the timing of ceramic change and eventual cessation of pottery manufacture) would parallel those on Tutuila, 'Upolu, and Savai'i.

2. A second research goal was to determine the nature and magnitude of environmental change during the period of prehistoric Polynesian occupation of the Manu'a Islands. Interdisciplinary research on other central Pacific islands over the past two decades had shown that human activities frequently have resulted in major changes to the vegetation, fauna, and landforms of island ecosystems (e.g., Kirch 1984:123-51; Kirch 1988b:247-50; Kirch and Yen 1982; Bayliss-Smith et al. 1988:12-43). At the same time, natural environmental changes such as sea-level fluctuations, also were known to have affected site distribution and the geomorphology of coastal lowlands. At the To'aga site, we had the opportunity to address such issues of human-induced and natural environmental changes over a 3,000+ year sequence. In particular, we were interested in determining the geomorphological history of the To'aga coastal plain, a narrow strip of intensively used land (see chapter 2, Kirch). To this end, we developed a morphodynamic model of landform changes at To'aga (chapter 4, Kirch) which we were able to test on the detailed data of site stratigraphy (chapter 5, Kirch and Hunt), radiocarbon chronology (chapter 6, Kirch), and sedimentological analysis of the excavated deposits (chapter 7, Kirch, Manning, and Tyler).

3. A third major issue concerned the reconstruction of certain aspects of Ancestral Polynesian Culture, especially the nature of its settlement patterns and subsistence economy, which were rather poorly evidenced on archaeological criteria (as opposed to historical linguistic reconstructions, see Kirch 1984:53-67). Because the To'aga site spans the entire first millennium B.C.—the period during which Ancestral Polynesian Culture developed out of its

Lapita ancestor—and because the site's calcareous sandy deposits preserve a wide range of organic materials, this was again an excellent situation in which to tackle this research issue. In particular, we expended considerable effort in the analysis of the extensive suite of vertebrate and invertebrate faunal materials recovered from the excavations (see chapter 13, Nagaoka and chapter 14, Steadman).

4. A more specific research topic is the explanation of ceramic change in Western Polynesia, including aspects of technology, formal variation in vessel shape and function, and the eventual disappearance of pottery. The To'aga site, with a particularly long sequence of stratified deposits, yielded a ceramic assemblage spanning virtually the entire period of pottery manufacture in Samoa. We therefore decided to focus on a detailed examination of these ceramics, from several analytical perspectives, in order to refine our understanding of ceramic change in the Samoan archipelago (see chapter 9, Hunt and Erkelens; and chapter 10, Dickinson).

5. A fifth research issue focussed on the role of inter-island exchange of such material items as ceramics and basalt adzes. Oceanic prehistorians have increasingly come to realize that such exchange was extremely important in maintaining contacts between island societies (e.g. Kirch 1988a, b; Hunt 1989). In the case of materials from To'aga, we resolved to investigate the role of inter-island exchange through an intensive study of the ceramic and basalt adz artifact assemblages (see chapter 9, Hunt and Erkelens; and chapter 12, Weisler).

In sum, our field and laboratory studies of the To'aga site was oriented by these five research issues, combined with the problems of site delineation and significance-assessment dictated by the CRM nature of our contract with the American Samoa Historic Preservation Office. Because the funds for fieldwork were limited, we knew that we would be unable to carry out extensive subsurface excavations or exposures of large areas. Thus, our field strategy had to be designed to obtain the kinds of data relevant to the research issues cited above in the most cost-effective manner. In addition to intensive survey of surface archaeological features located throughout the To'aga area (Hunt, chapter 3), we concentrated on a series of systematic transect test excavations following methods elaborated by Kirch in previous fieldwork on Tikopia and Niuatoputapu (Kirch and Yen 1982; Kirch 1988b). These transect excavations allowed us to define the spatial extent of the site, especially the deeply buried, pottery-bearing deposits, to gain an overview of the stratigraphic sequence and to obtain sizable samples of ceramics, other portable artifacts, and vertebrate and invertebrate faunal remains. Further details of our sampling and excavation methodology are provided in chapter 5.

As the various chapters to follow demonstrate, the To'aga site is a unique and highly significant archaeological resource, encapsulating three millennia of Samoan prehistory. As the pace of development and land use change quickens in American Samoa, this site is likely to come under increased threat. It is our hope that in addition to contributing to our understanding of Polynesian and Samoan prehistory, this volume will serve to heighten awareness concerning this valuable archaeological resource. The To'aga site deserves to be carefully protected and its non-replaceable resources managed so that future generations will have the opportunity to further advance our knowledge and understanding of the past.

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2

OFU ISLAND AND THE TO'AGA SITE: DYNAMICS OF THE NATURAL AND CULTURAL ENVIRONMENT

PATRICK V. KIRCH

Every Manuan thinks first of his own village, then of his island, then of Manua as a whole—a tiny archipelago set off from all the rest of Samoa. There may be rivalry between villages; there have even been wars—internecine conflicts between Fitiuta and the three villages of Tau and between Ofu and Olosega—but against the outside world Manua presents a solid front.

Mead (1930:51)

THE MANU'A ISLANDS, ISOLATED from the main Samoan islands by 100 km of often-turbulent ocean, form a geographically and culturally distinctive cluster at the eastern extreme of the archipelago (fig. 2.1). Being closest to Tutuila, Manu'ans had the greatest interaction with the occupants of that island (a pattern that continues today with Manu'a and Tutuila comprising the Territory of American Samoa). Although sharing in most respects the classic characteristics of Samoan culture, Manu'ans nonetheless regard themselves as different and distinctive. Mead (1930:9) commented on this distinctiveness, for example in the lack of emphasis on "war, its paraphernalia, its ritual, and its gods." She opined that "the chief historical value of Manua lies in her easterly and isolated position, offering a valuable check upon cultural traits which are intrusive in western Samoa" (1930:9). Such isolation, however, was relative and should not be overemphasized; as our archaeological investigations have revealed, the prehistory of Ofu shares much in common with the westerly islands of Samoa, and prehistoric inter-island contacts can be documented in the transport of basalt adzes (see Weisler, chapter 12), and perhaps of pottery as well (see Hunt and Erkelens, chapter 9). Thus, despite considerable isolation, Manu'a was never a "closed system."

The three islands of the Manu'a Group—Ta'u, Olosega, and Ofu—form an intervisible cluster and comprised a political unity in ancient times. Ta'u is by far the largest island (table 2.1) and dominated the group politically, being the seat of the Tui Manu'a paramount line of chiefs. Olosega and Ofu are practically adjacent to each other, separated only by a narrow and shallow strait, now spanned by a concrete causeway. They are similar in size, Ofu being slightly smaller (3.4 km^2), but rising to a loftier summit (at 638 m) than Olosega.

Ofu and Olosega are visually exquisite, their youthful volcanic profiles thrust abruptly out of the Pacific, rising to basalt pinnacles often shrouded in mist. Narrow ribbons of blindingly white coral sand form a no-man's-land between the rank green of tropical vegetation and the blue-green mosaic of coral reefs. Sheer cliffs towering hundreds of meters above To'aga, Sili, and other villages provide nesting sites for the white-tailed tropic birds that ride the trade winds battering the islands' mass.

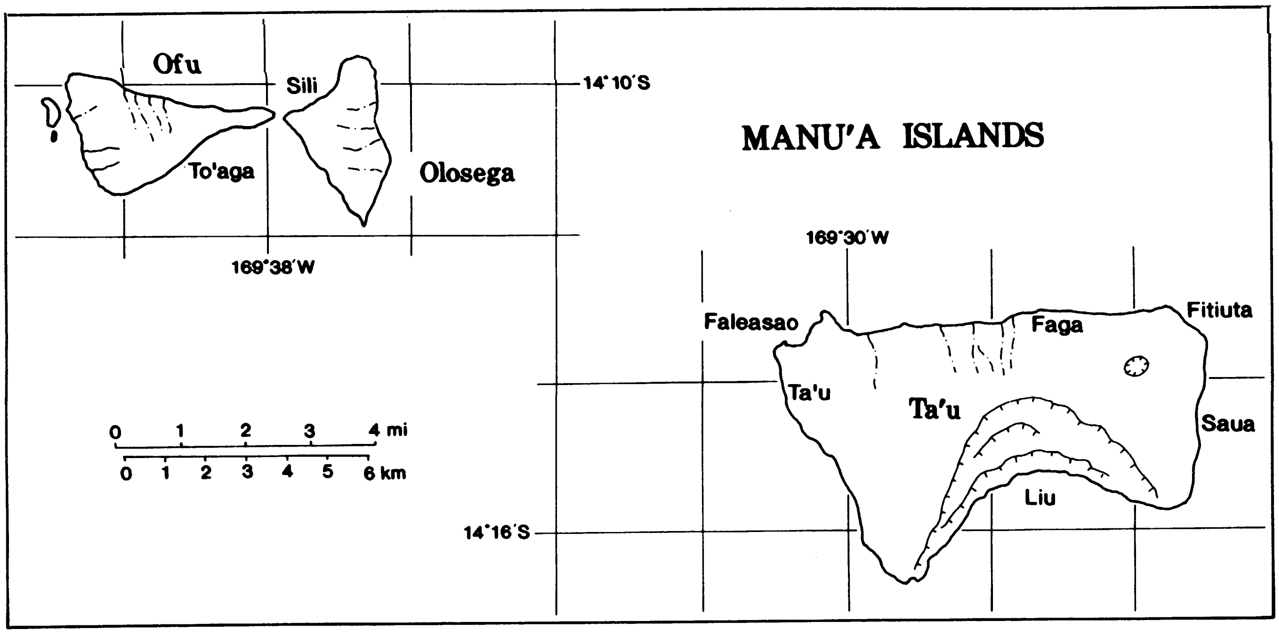

Figure 2.1 Map of the Manu'a Islands.

Perhaps the most striking feature of Ofu's environment is its precipitous topography, and the scarcity of flat land. No less than ninety-one percent of the total island area consists of slopes greater than 30 degrees. Due to its geological youth, the steep sides of the volcanic cone have not yet been significantly incised by streams, the principal weathering being major landslides resulting from faulting, and creating sheer cliffs. The only level terrain is found around the margins of the island, at the critical land-sea interface, where a narrow coastal terrace has been constructed primarily from coral sand, with the addition of some talus and colluvium from the slopes inland. This coastal zone, ranging from 50 to 150 meters wide, is unevenly distributed, being found along the western and southeastern coasts but not along the north coast, except for a small strip at the northeastern point. The To'aga site occupies the longest span of coastal terrace land on the island, along the southeastern shoreline. This coastal terrace was a critical microenvironment for the Polynesian occupants of Ofu, first as the setting for their villages, and second as a major zone of garden land. More importantly, the narrow coastal terrace is a highly dynamic environment. Understanding the morphodynamics of this land-sea interface is essential not only to reconstructing the prehistoric sequence of the To'aga site itself, but more broadly for an understanding of Manu'an prehistory.

In this chapter, I outline the main characteristics and resources of the Ofu Island environment that were significant to the prehistoric Polynesian inhabitants with their horticultural and fishing economy. I also pay considerable attention to those aspects of the contemporary environment—both physical and biotic—that inform us about the dynamics of environmental change. Polynesian archaeologists have now abandoned an earlier perspective that viewed island ecosystems merely as static backdrops to cultural developments. Increasingly, archaeological investigations throughout Polynesia are yielding striking evidence of ecological change: forest clearance and vegetational succession, extinction and extirpation of birds and other biota, alluviation of valley floors, sea level changes, and so forth (e.g., Kirch 1982, 1984; Steadman 1989; Flenley and King 1984; Olson and James 1984; McGlone 1983). Some of these changes resulted from natural processes; others reflect the impact of human populations themselves, colonizing isolated and biologically-vulnerable islands for the first time (Fosberg 1963). The prehistory encapsulated within the To'aga site is as much a history of environmental dynamics as of cultural changes in pottery types or adz forms.

Table 2.1
Environmental Characteristics of the Manu'a Islands

Characteristic	Ta'u	Olosega	Ofu
Area (km^2)	28.5	4.5	3.4
Highest Point (m)	965	494	638
Area <30% slope (%)	41	10	9
Coastline (km)	32.5	13.3	10.4
Population (1980)	1,146	340	254

GEOLOGY AND GEOMORPHOLOGY OF OFU ISLAND

Initial studies of Ofu geology by Friedlander (1910), Daly (1924), and Stearns (1944) were based on short reconnaissance surveys. Although Stearns spent only one or two days in Manu'a, he was able to produce "a remarkably accurate geologic sketch map" (Stice and McCoy 1968:429). The most intensive study to date was carried out by Stice and McCoy (1968), whose report and geologic map of Ofu we have drawn upon for the following summary. Subsequent work by Natland (1980) and McDougall (1985) has corrected certain errors made by Stice and McCoy in dating the island's geological formations.

Ofu and Olosega comprise an integral geological complex "of volcanic cones that have been buried by lava flows from two coalescing shields" (Stice and McCoy 1968:443). At least five cones make up the Asaga Formation; these include a "composite cone exposed in the cliff behind To'aga," as well as "an explosion breccia cone with an associated intrusive plug at Fatuaga Point" (1968:443-44). The latter plug is exposed as the visually impressive spire at the eastern point of Ofu (fig. 2.2). Stice and McCoy believed that the Asaga Formation was of lower Pliocene age, although this has now been shown to be incorrect (see discussion below). All of these Asaga Formation cones were subsequently buried by lava of the Tuafanua Formation, from the A'ofa and Sili coalescing shields. "After summit collapse of the shields, volcanism decreased so that a sea cliff about 300 feet high was cut around the islands" (1968:456). In the To'aga area, the high cliff seems to have resulted from a combination of faulting and sea erosion. Finally, renewed volcanism resulted in the construction of the tuff cone of Nu'utele Islet, as well as in several hawaiite and olivine basalt flows that filled in deeply eroded stream valleys on western Ofu.

Whereas Stice and McCoy (1968) regarded the geological history of Ofu to have extended over a fairly long period, from the lower Pliocene through to the late Pleistocene, recent work by Natland (1980) and McDougall (1985) has confirmed that the island is very recent in age. McDougall reports that "these volcanoes are quite youthful, confirmed by unpublished K-Ar ages from this laboratory [Australian National University] averaging 0.3 Ma for Ofu/Olosega and less than 0.1 Ma for Ta'u" (1985:318). As Natland argues, "there can be little doubt that both Tau and Ofu-Olosega are substantially younger than the shield volcanoes of Tutuila, which were extinct and extensively eroded before drowning of the Pleistocene reefs" (1980:721). Indeed, the Samoan chain illustrates a typical instance of linear, "hot-spot" progressive volcanism, with the islands increasing in age from east to west. (Recent, renewed volcanism on Savai'i is evidently due to the proximity of the western end of the archipelago to the Pacific Plate margin.) The youthful age of Ofu and Olosega is of considerable importance to the geomorphology and geoarchaeology of the To'aga site, as we shall argue in greater detail in chapter 4. This is because the islands are still tectonically unstable, due to point-loading on the oceanic crust, and thus are undergoing a phase of subsidence (Menard 1986).

The rocks of the island consist primarily of olivine basalts, hawaiites, and ankaramites which were extruded as both pahoehoe and aa lava flows, interbedded with various pyroclastic tuffs and breccias. Intrusive rocks consist primarily of dikes, and of the plug at Fatuaga Point, a "hypabyssal intrusion of ankaramite" (1968:449). A major swarm of near vertical dikes runs through the central spine of Ofu, and is clearly visible in the cliffs behind the To'aga site. Stice and McCoy report that "the razorback ridge of eastern Ofu is the topographic expression of a dike complex about 400 feet wide. The dikes are nearly vertical . . . Most are dense basalt, although olivine basalt, ankaramite, and feldspar-phyric basalt also are present" (1968:449). We were particularly interested in this dike complex as a possible source of dense, fine-grained basalt that could have been exploited by the prehistoric occupants of Ofu for manufacture of adzes or other flake tools. The recent road cutting at Fa'ala'aga provided an opportunity to examine this dike cluster at close hand, and to collect samples for XRF compositional analysis (see Weisler, chapter 12). As shown in figure 2.3, the dikes are closely spaced, cutting through older, weathered basalts of the Asaga Formation. On the edges of several of these dikes, where they came into contact with the older basalts, we observed glassy "chills" of low-silica volcanic glass ("obsidian"), up to 2 cm thick. Although of poor quality, such volcanic glass could have been exploited for the production of small flakes. The appearance of local volcanic glass flakes in archaeological contexts in the Manu'a Group is thus a distinct possibility.

We did not observe other possible sources of fine-grained basalts suitable for adz manufacture, except for a rather weathered dike exposure on the edge of Mako Ridge at about 350-400 m elevation (also sampled for XRF analysis). It is entirely possible, however, that prehistoric Manu'ans exploited small exposures of suitable basalt or hawaiite for adz manufacture. We are not aware of any adz quarries in the Manu'a Group, but this negative evidence certainly does not preclude local adz manufacture.

There has been relatively little stream erosion on Ofu, and the radial drainage pattern is poorly developed. A number of shallow valleys drain to the north and to the west from the slopes of Tumutumu Mountain. All of these are intermittent, flowing only after heavy rains. "The stream valleys are all youthful and nowhere exceed 50 feet in depth" (Stice and McCoy 1968:455).

The main erosional forces at work on Ofu since the cessation of volcanism have been marine wave attack and mass wasting, especially landslides. As noted above, an extensive sea cliff more than 100 m high "was carved into the island by the sea" (Stice and McCoy 1968:455) during the late Pleistocene to early Holocene. These high cliffs, such as the one behind the To'aga site, "originated by faulting and/or foundering," but were certainly extended and modified by marine erosion. Landslides continue to be active erosional forces, contributing to the talus screes that border the inland edge of the coastal terrace. "Individual blocks also work loose from the cliff face and fall, forming talus slopes that extend almost continuously around the islands at the base of these cliffs" (1968:455). One such massive block fell between our 1987 and 1989 field seasons: measuring at least 4 m in diameter, this giant boulder crashed through the banana and breadfruit orchards near the western edge of To'aga to land by the roadside, a daily reminder of the geological dynamism of Ofu. Similar large blocks dot the surface of the To'aga site, and one of these was modified in late prehistory for use as an adz grinding stone (see Hunt, chapter 3). For the prehistoric occupants of the To'aga site, such falling boulders posed a continual hazard. As Stice and McCoy relate, a local legend tells of a young girl who "was killed by a large block that rolled across the reef at Sili, where she was fishing" (1968:456). We have no reason to doubt the veracity of this story.

RESOURCES OF THE ISLAND

For a society based traditionally upon intensive root and tuber crop horticulture, and on arboriculture, *climate* is more than an abstract

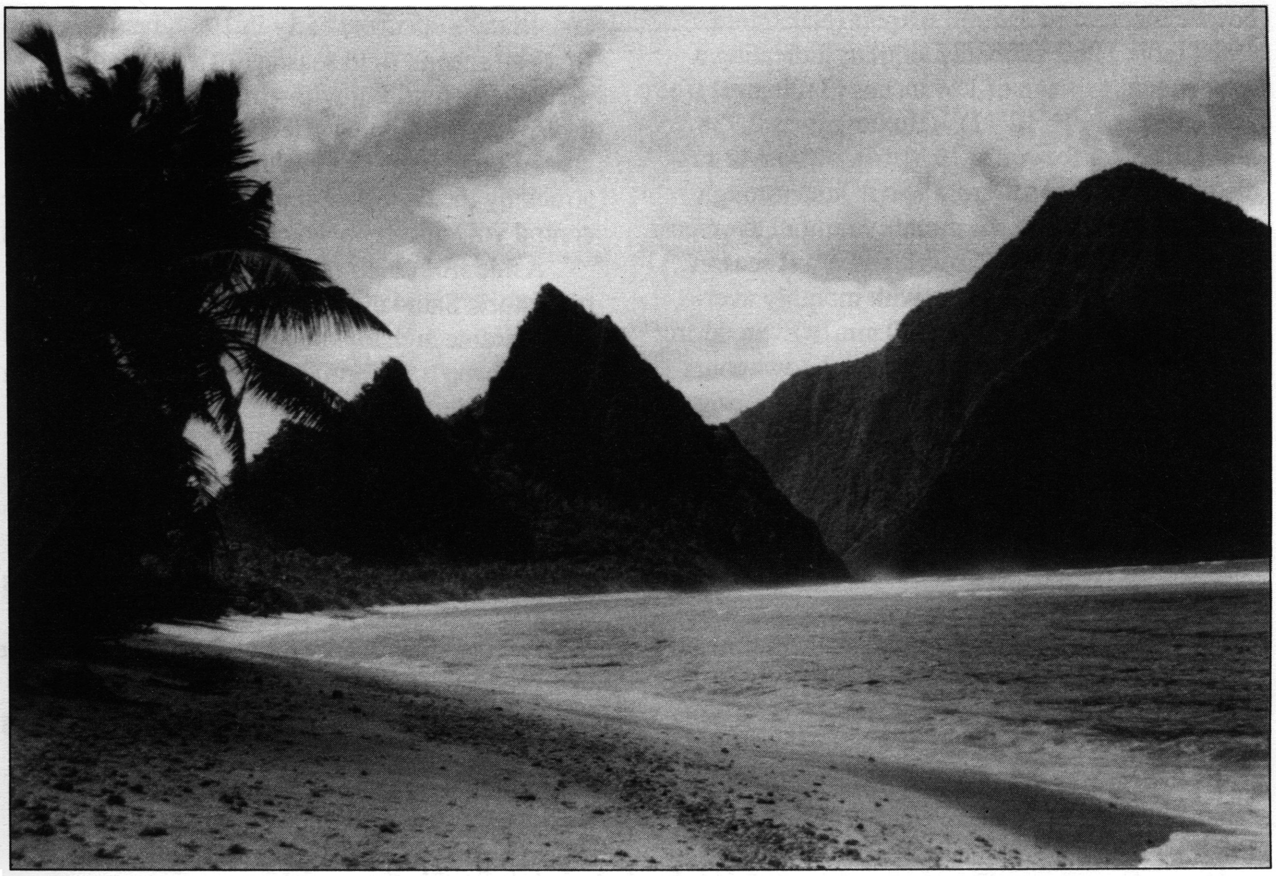

Figure 2.2 View of the exposed volcanic plugs at Fa'ala'aga, from the beach at To'aga. The high mountain on the right is the summit of Olosega Island.

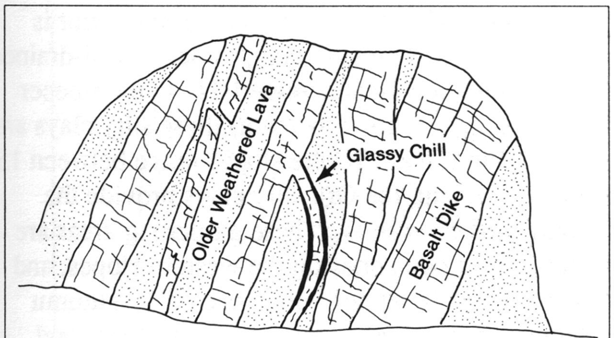

Figure 2.3 Sketch of basalt dikes exposed in the road cut across the Le'olo Ridge at Fa'ala'aga.

concept. The Samoan archipelago lies within the humid tropics. Buxton, who spent much time studying the natural history of Samoa, summed up the climate thusly: "As the temperature is nearly constant, as rain is abundant and well distributed, and as the islands are surrounded by the ocean, it follows that the atmosphere is moist at all times and seasons" (1930:17). Indeed, relative humidity usually ranges between 80 and 86 percent, with the temperature varying only between 25.7-26.2°C. Buxton also observed the effects of such humidity on humans: "the perspiring entomologist soon learns to recognize that his comfort depends entirely on the wind, for the warm damp air does not cool him unless it is in motion" (1930:18). Green (1969:4) echoed these remarks from the viewpoint of the field archaeologist, quoting Curry (1962) to the effect that the Samoan climate is at "the upper limit of thermal comfort for half-naked men at rest."

There is, however, a distinct and significant seasonality to the Samoan climate, expressed most clearly in patterns of rainfall and of wind direction. We have no rain gauge records for Ofu itself, but the records for Tutuila Airport (Nakamura 1984, table 1) are probably similar, indicating a total annual average of 124 inches [3100 mm] (see also Coulter 1941:10-11). (Buxton gives 2,738 mm [107.8 in] for Apia [1930:16].) There is a distinctly drier season from about June through September, in which the monthly rainfall averages about 6 or 7 inches [175 mm], and a wet season from October through May, with monthly averages of from 11-14 inches [350 mm]. Even during the "dry season," however, torrential downpours may occur, as beset us all too frequently during the 1989 fieldwork at To'aga. As elsewhere in Western Polynesia, this seasonality played an important role in scheduling the agricultural calendar, particularly the clearing and planting of swidden cultivations (Kirch 1978, forthcoming). In some years, the dry season may be particularly acute or lengthy, and the resulting drought can significantly reduce agricultural yields. During the wet season, the opposite may occur, with torrential rains and serious flooding. "Some floods are associated with hurricanes and tropical storms, but flooding can occur at other times as well" (Nakamura 1984:3). The dry season also corresponds approximately to the period of prevailing trade winds (from about April through September). During October to March the winds are more variable, and westerly reversals occur. This latter period was important to early Polynesian voyagers, as it allowed exploratory voyages from west to east (Finney 1985; Irwin 1981, 1992).

In addition to the annual pattern of seasonality, there are stochastically recurring environmental hazards that seriously affect Samoan life. We have already mentioned the problem of periodic drought, which can inhibit agricultural production. Even more severe are the hurricanes or tropical cyclones that periodically lash the islands. Coulter notes that "Samoa suffers hurricanes at irregular intervals during the hotter season" (1941:12). Visher (1925:27, table 6) indicates an average annual frequency of two to three hurricanes in the Samoan area, although not all of these are equally intense, nor do their paths always cross the Manu'a Group. When a hurricane bears directly down on the islands, however, the effects are often devastating—to crops and orchards, to houses, and to human life itself. The most recent hurricane to lash Manu'a occurred early in 1987, between our first and second field seasons. Ta'u Island was particularly hard hit, with virtually every house destroyed; the area was declared a Federal disaster area. Flying in to Ta'u in June of 1987, one was struck by the devestation of the forest cover of the central volcanic cone which had not yet recovered.

Aside from their obvious significance to the prehistoric Samoan population, hurricanes have considerable archaeological importance as agents of landscape transformation, and of site formation as well as destruction. The torrential rains unleashed during these events can cause severe flooding and result in major landslides and in the deposition of colluvium and alluvium. Storm surges and high energy waves are capable of moving large quantities of sand and larger clastics (up to boulder size) in the coastal zone. During our 1986 reconnaissance survey on Ta'u Island, we observed a massive rampart of coral cobbles and shingles at Saua which had been thrown up during a previous storm surge. We shall give further consideration to these high-energy processes below, and elsewhere in this monograph (see especially chapters 4 and 6), as they obviously played a significant role in the geomorphological history of the To'aga site.

Ofu soils are young and undeveloped, a reflection of the island's geological youth. The soils have been mapped and described by Nakamura (1984). Most of the steep interior is covered with "Ofu silty clay," a deep, well-drained soil formed in volcanic materials. In the steeper areas (slopes 40 to 70 percent) these silty clays are covered in forest. Where slopes range between 15 and 40 percent, the Ofu silty clays provide the main gardening soils. These gardening areas are confined to two zones on the western slopes, and to one area on the northern slope of Tumutumu Mountain (fig. 2.4). The very steep slopes and talus regions lying inland of To'aga, and along the northern coast, are described as "Fagasa family-Lithic Hapludolls-Rock outcrop association, very steep" (Nakamura 1984:11). At the inland edge of the coastal terrace are found strips of "Aua very stony silty clay loam" (1984:10), described as "very deep, well drained soil . . . on talus slopes . . . formed in colluvium and alluvium derived dominantly from basic igneous rock." These areas

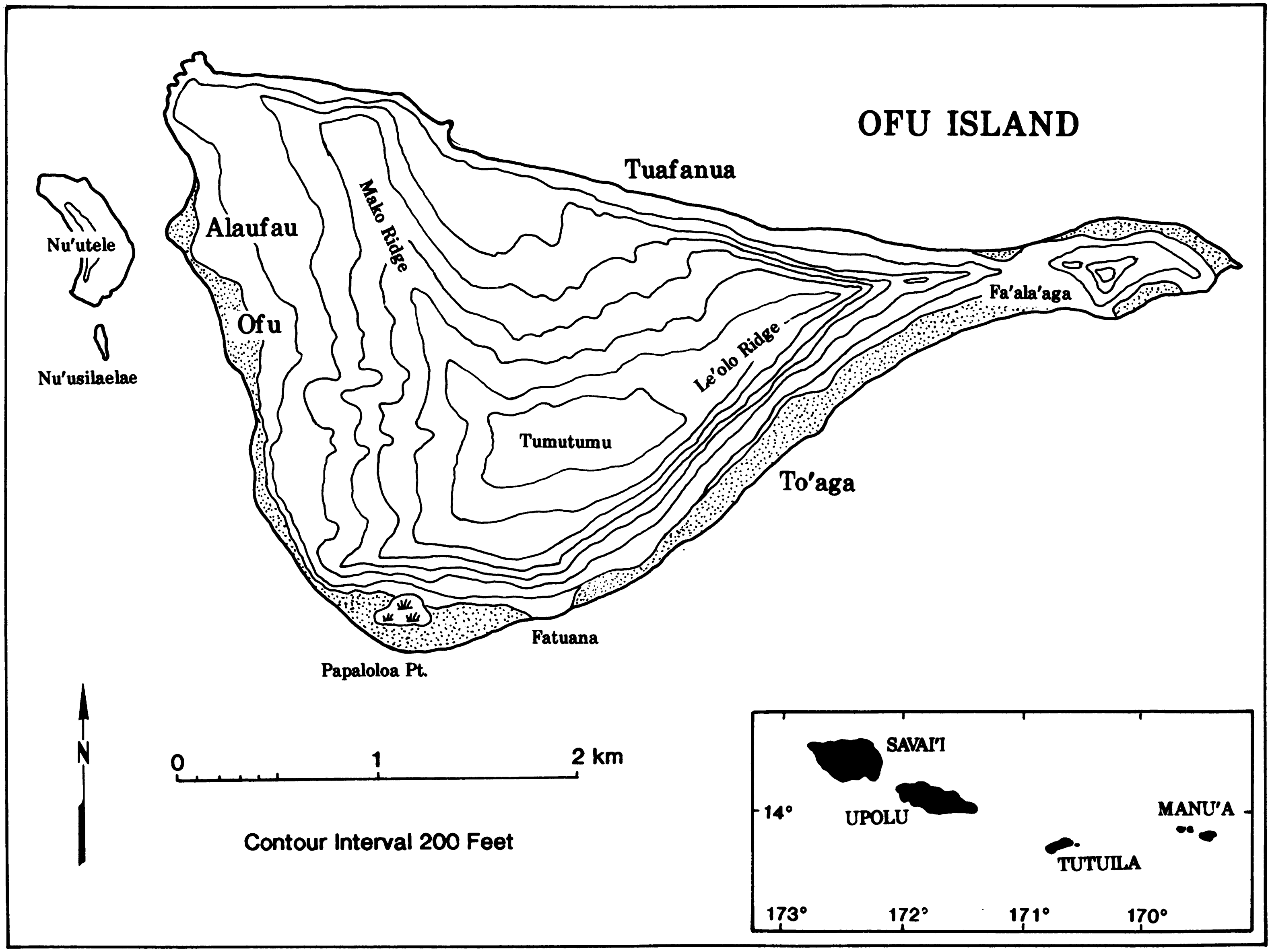

Figure 2.4 Map of Ofu Island. The stippled area represents the narrow coastal plain formed of unconsolidated sediments of Holocene age.

are used for subsistence gardening, primarily of tree crops such as breadfruit and bananas. Finally, the coastal terrace itself, as at To'aga, consists from the pedological viewpoint of "Ngedebus mucky sand" (Nakamura 1984:15). This is a "somewhat excessively drained soil . . . derived from coral and sea shells."

The natural vegetation of Manu'a has been significantly modified in the lower elevations by three millennia of human land use. The coastal terrace, as well as the less precipitous mountain slopes, comprise a mosaic of coconut stands, breadfruit and banana orchards, and aroid gardens interspersed with second growth (further discussion of coastal terrace vegetation below). On the higher and steeper slopes, however, the original rain forest vegetation persists. Yuncker, who studied the flora of Manu'a, lists of total of 421 species for the three islands, including mosses and pteridophytes as well as flowering plants (1945:4). The Samoan root-tuber and tree crop complex, of course, is wholly adventive to the archipelago, having been introduced and established by the early colonists.

The terrestrial fauna of the Manu'a Group is very restricted in vertebrates, somewhat richer in invertebrates (especially land molluscs and insects). The only indigenous mammal is the fruit bat, *Pteropus samoensis.* These are commonly seen soaring over the forest canopy high above the To'aga site, especially at dusk. The diminutive Pacific rat, *Rattus exulans*, was introduced by early Polynesian settlers, and its bones are common in the archaeological deposits at To'aga (see Nagaoka, chapter 13). Also purposively introduced by the Polynesians were the domestic pig (*Sus scrofa*) and dog (*Canis familiaris*).

The richest diversity of vertebrates is among the birds, both native land birds and nesting seabirds (Watling 1982). In the higher elevation forests on Ofu are found the *lupe* or Pacific Pigeon (*Ducula pacifica*) and the Crimson-Crowned Fruit Dove or *manutagi* (*Ptilinopus porphyraceus*); both are occasionally taken for food. White-Collared Kingfishers, *ti'otala* (*Halcyon chloris manuae*), of which there is a distinct Manu'a subspecies, are frequently perched high on poles or telephone wire along the coast. Common in the coastal bush at To'aga and elsewhere on the island is the *ve'a* or Banded Rail (*Gallirallus philippensis*), often seen making its characteristic headlong dash across the dirt road from the security of one patch of undergrowth to another. The *iao* or Wattled Honeyeater (*Foulehaio carunculata*) is abundant in the banana groves at To'aga, where it feeds on banana flower nectar. This bird is sometimes hunted by young Samoan boys, who then pluck and roast the tiny carcasses over a fire in the bush. (Having sampled this delicacy myself, I can attest that while there is little flesh, it is sweet and a delicious complement to roasted bananas.) Also present on Ofu is the Polynesian Starling, *mitivao* (*Aplonis tabuensis manuae*).

A number of seabirds, and some migratory species, also nest on Ofu. The White-Tailed Tropic Bird, *tava'e* (*Phaethon lepturus*), nests in the high cliffs towering over the To'aga site. These elegant birds, soaring high overhead, were always a wonderful visual diversion from the perspective of a grimy test pit. A seasonal migrant, the Golden Plover or *tuli* (*Pluvialis dominica fulva*) is also seen along the coast at To'aga.

The contemporary avifauna of Manu'a is only an impoverished remnant of the pre-human bird life. Archaeological excavations throughout Polynesia have revealed a significant pattern of bird extinctions and extirpations due to human-induced forest clearance and habitat destruction, and to direct predation (Olson and James 1984; Steadman 1989; Steadman, Pahlavan, and Kirch 1990; Steadman and Kirch 1990). As reported by Steadman in chapter 14, the To'aga excavations added further evidence of this widespread pattern of avifaunal extinction and extirpation. These faunal depletions are just one aspect of the dynamic nature of Polynesian ecosystems within the span of human occupation.

The only other vertebrates indigenous to the island are a number of lizard species in the families Geckonidae and Scincidae.

There is a rich endemic and indigenous insect fauna, but this is of little archaeological relevance. More important from the viewpoint of the prehistorian are the land snails, which include a number of endemic and indigenous taxa, as well as several species which have been introduced by humans, prehistorically as well as after European contact.

Among the important families represented in Samoa are Partulidae, Assimineidae, Tornatellinidae, Helicinidae, and Microcystinae. Land snails frequently preserve well in archaeological deposits, including those at To'aga, and are excellent indicators of microenvironmental change. Several synanthropic 'garden-snail' species, including *Lamellaxis gracillis*, were inadvertently transported around the Pacific basin by prehistoric people, presumably with crop plants and adhering soil. Their appearances in archaeological contexts are therefore important signals of habitat modification, and indirect evidence for horticulture. In chapter 8, I present an analysis of land snails recovered from the To'aga excavations, and their implications for environmental change at the site.

Finally, we cannot ignore the marine environment, so crucial to the indigenous Samoan economy. Ofu is surrounded by a fringing reef, widest and most sheltered on the western side (opposite Ofu Village). The reef is a complex mosaic of micro-habitats and a source of shellfish and fish for the human population. A diverse array of molluscs occupy the reef flat and algal crest, including various bivalves such as *Periglypta reticulata, Tridacna maxima, Hippopus hippopus*, and *Asaphis violascens*, and gastropods such as *Trochus maculatus, Turbo setosus, Nerita* spp., *Cypraea* spp., *Drupa* spp., *Thais armigera*, and *Conus* spp. Many of these species were heavily exploited by the occupants of the To'aga site and occur in dense concentrations in the midden deposits (see Nagaoka, chapter 13). Also present on the reef are spiny lobsters (*Panulirus* sp.), sea slugs (holothurians), sea urchins (echinoderms), octopus, and various edible seaweeds. Approximately 800 species of inshore fishes occur around Ofu (Jordan and Seale 1906) and are still taken by the Samoans with a variety of traditional fishing strategies, using spears, nets, hooks, and other gear. Farrell's description of fishing activities in Western Samoa is equally appropriate for Ofu:

> In the lagoon itself there is some activity at almost any time, day or night. Hundreds of yards from shore, near the edge of the reef, women hunt for sea foods between the breaking of the larger waves. Fishermen in small canoes (*paopao*) equipped with goggles and spear search the placid waters inshore, while in shallower waters nets are tossed to enshroud passing shoals of small fish. Further out, midway between the shore and the reef, fish traps are built of hard-driven, close-spaced stakes and wire netting, or of mounds of coral rock. Into these traps fish are driven by 'beaters'; later the catch is shared (1962:179).

Among the fish commonly taken are jacks (*Caranx* spp.), parrot fish (*Scarus* spp.), wrasses (Labridae), and acanthruids. Bones of these fishes also occur in great frequency in the To'aga archaeological deposits. The open sea beyond the reef is less heavily exploited but is the zone of the prized tunas (Scombridae) and flying fish.

Marine turtles (*Chelonia mydas* and *Eretmochelys imbricata*) are rarely sighted in the waters off Ofu today but must have nested on the island's sand beaches in substantial numbers prior to early Polynesian settlement. The bones of these turtles are one of the most commonly occurring taxa in the To'aga faunal assemblages.

THE CULTURAL AND SOCIAL LANDSCAPE

As in all Polynesian islands, the landscape of Ofu is culturally and socially ordered. This includes the system of land use, the pattern of land tenure, and the village settlement pattern and its internal structure, all of which have evolved over several millennia. One goal of our archaeological investigations in Manu'a has been to contribute to an understanding of how this distinctive cultural and social landscape has developed over the course of prehistory. A brief description of some of the key aspects of the contemporary landscape is therefore apposite, as an ethnographic reference or 'endpoint.'

Farrell eloquently evokes the essence of the Samoan settlement pattern of "villages . . . strung like beads unevenly along the thread of the coastline" (1962:177). Mead elaborates: "The cliff behind, the sea before it, defines the ground plan of a Manuan village, which may spread out in either direction as far as the land permits" (1930:45). On Ofu today, there is only one such village (with two named sectors, Ofu and Alaufau), strung along the western coastal terrace. This village lies conveniently between the widest and most sheltered expanse of reef flat and lagoon (protected by Nu'utele and Nu'usilaelae Islets), and the largest expanse of arable mountain slope inland. Previously, the zone of coastal villages extended around most of the southern and southeastern parts of the island, including the To'aga area (see Hunt, chapter 3). There is also limited evidence that some occupation may have extended inland into the intensive gardening zone in late prehistoric times.

Although in the past decade or two most houses on Ofu have been rebuilt using western materials—largely concrete with corrugated roofs—the ground plan of the village remains essentially traditional. The central focus is the *malae* or "village green" where important ceremonies and feasts may be held, the church, and the guest house of the high chief (which functions also as a council house for the *fono*). The individual households, strips of land that extend in principle from the beach to the mountain slope, spread out on either side of the sandy roadway. Traditionally, a household had three main structures: a guest house, the main dwelling, and the cookhouse (Handy and Handy 1924; Buck 1930:8-97). Mead aptly described the Manu'an guest houses "which stand by the sea, are round and high—circles of posts about four feet high topped by a twenty-foot thatched circular cone. They stand upon a foundation of small stones which rises in slightly higher, narrowing concentric circles, each terrace about five or six inches high, and edged by larger stones" (1930:46). The main dwelling or sleeping house was traditionally the long house (*fale o'o*), with rounded ends. The cookhouse or shed is the *fale umu*, literally house which shelters the *umu* or earth oven (Buck 1930:13). These are situated farthest from the guest houses: "a small shack supported on four pillars and roofed, not with sugar cane thatch but with mats woven of palm leaves" (Mead 1930:48).

The layout of house types within the household complex reflects a distinctive social and symbolic structure to the village organization. The main axis of orientation is perpendicular to the beach, the interface of land and sea, and thus extends in two directions: *i tai*, toward the sea, and *i uta*, inland. The seaward direction is higher ranked, associated with chiefs and persons of status; inland is lower ranked, associated with production and with the economic basis of society. Mead describes the seaward-inland dichotomy thusly:

> The term *i tai* (towards 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 the front of the house. And as the trails lead back from the village over narrow stiles, through stony places, swamp places, into deep gulches, and up slippery inclines; so the channel marks the way out to sea (1930:50).

This structural dichotomy between land and sea, and the way in which it organizes the spatial structure of the village, is a widespread—and therefore probably ancient—pattern within Western Polynesia, including Fiji. Sahlins (1976:37-45, fig. 6), for example, has described this structure for Fiji, and in another paper (1981) has outlined some of the cultural associations between the sea and high-ranking chiefs. The Polynesian Outlier of Tikopia (Firth 1936; Kirch and Yen 1982) likewise has a characteristic spatial organization very much like that described above for Samoa, with household units differentiated along a seaward-landward axis, canoe houses toward the beach, cookhouses inland, with the main dwelling mediating between. (The Tikopian dwelling itself is divided into seaward:male and landward:female divisions; see Firth [1936].) Similarly, on Niuatoputapu Island in northern Tonga, the prehistoric coastal villages appear to follow this pattern (Kirch 1988). And in Futuna Island, Burrows (1936) describes a village structure very reminiscent of the Manu'an situation. In sum, this kind of cultural and symbolic ordering of space along a seaward-landward axis has a wide distribution in Western Polynesia, and arguably has a deep prehistory in the region as a "structure of the long run" (Braudel 1980). Our transect excavations at the To'aga site provided some evidence of a coastal village settlement pattern that may also have been organized in this characteristic Western Polynesian model some 2,500 years ago.

TO'AGA: LAND USE AND VEGETATION PATTERNS

While the formation of the coastal terrace at To'aga was primarily a geomorphological phenomenon controlled by such external factors as sea level change, tectonics, and their effect on sediment budget (see Kirch, chapter 4), humans have also played an active role in the evolution of this landform. In chapter 5, for example, we shall argue on the basis of our stratigraphic data that the input of terrestrial sediments onto the coastal terrace increased after human colonization due to forest clearance and agricultural activities on the talus slope and mountain. Perhaps the most obvious effect of humans, however, results from the patterns of land use and vegetation on the coastal terrace, for the whole zone constitutes an anthropogenic, managed environment from the phytogeographic perspective. The coastal terrace of Ofu provides the only flat land on the island, the setting for both villages and for certain kinds of intensive horticultural and arboricultural production. The development of this pattern of intensive land use is one problem that we have attempted to address in our archaeological investigations at To'aga. As background to this study, it is necessary to characterize the patterns of land use and vegetation found on the To'aga coastal terrace today.

Vegetation Transects

Yuncker's (1945) study of the Manu'an flora enumerated the plant resources of the islands, but neglected patterns of plant distribution. In 1987 and 1989 we recorded the horizontal distribution of dominant species along three of our transects across the To'aga coastal terrace that had been cleared for archaeological subsurface sampling (see Kirch and Hunt, chapter 5 for further details of these transects). One of these, Transect 7, is graphically depicted in figure 2.5. Although there are minor differences in the distribution of species, the same overall pattern is evident in all transects. Whistler (1980) described and illustrated most of the species recorded in these transects. Three main vegetation zones can be discerned, from seaward to landward:

1. **Strand Vegetation**. Beginning at the high-water mark and extending to the seaward edge of the coastal road is a zone dominated by halophytic, littoral species. Overhanging the beach are *Scaevola taccada* and *Messerschmidia argentea*, with the vines *Canavalia maritima* and *Ipomoea pes-caprae* trailing over the sands. Larger trees surmounting the beach ridge include *Barringtonia asiatica* (traditionally used for fish poisoning), *Hernandia nymphaeifolia*, *Cocos nucifera*, and *Terminalia samoensis*. *Pandanus tectorius* and *Hibiscus tiliaceous* shrubs dominate the inner edge of this zone, lining the sandy roadway.

2. **Arboricultural-Horticultural Zone**. Commencing on the inland side of the road, and extending across the width of the coastal terrace to the base of the talus slope is the main zone of economic plants. Coconut palms dot the area, especially toward the seaward half of the zone, where the soil is sandier. The breadfruit tree, *Artocarpus altilis*, commences not far from the roadway and is the main upper story dominant across the terrace. Under and between the breadfruit and coconuts are planted a number of fruit and root crops, the most important being *Eumusa* bananas and the large aroid, *Alocasia macrrorhiza*. Some taro, *Colocasia esculenta*, and the historically introduced American aroid *Xanthosoma saggittifolia*, are also found, although in lower frequency. The *Alocasia* aroids are often densely planted in clearings which, after cropping, are secondarily planted in bananas. In some areas, the understory beneath the coconut palms and breadfruit trees is a tangle of second growth shrubs, dominated by *Hibiscus tiliaceous* and *Macaranga stipulosa*. Other useful trees occuring less frequently through the zone include *moso'oi* (*Cananga odorata*), the flowers of which are used for scenting coconut oil, and *fisoa* (*Colubrina asiatica*), which has medicinal value and can be used as a soap substitute (Whistler 1980:41).

This zone of tree, fruit, and root crops also exhibits a high frequency of feral or naturalized species which are commonly cultivated in Oceanic agricultural systems, and which unquestionably are present in the To'aga area as survivals from an earlier phase of (presumably) more intensive cultivation. These include the *ti* plant, *Cordyline fruticosum*, the arrowroot, *Tacca leontopetaloides*, the bitter yam, *Dioscorea bulbifera* (which twines in great abundance over the trees and shrubs of this zone), and in lesser quantities, the *a'a* or *Pueraria lobata*. All of these plants are recognized by the Ofu people as having edible subterranean roots or tubers and are regarded as potential famine resources. They are part of the complex of plants that Barrau (1965) has termed "witnesses of the past," indicators of earlier cultivation practices in the Pacific islands.

3. **Talus Slope Vegetation**. The main zone of economic plants terminates abruptly at the base of the talus slope, strewn with large volcanic boulders.

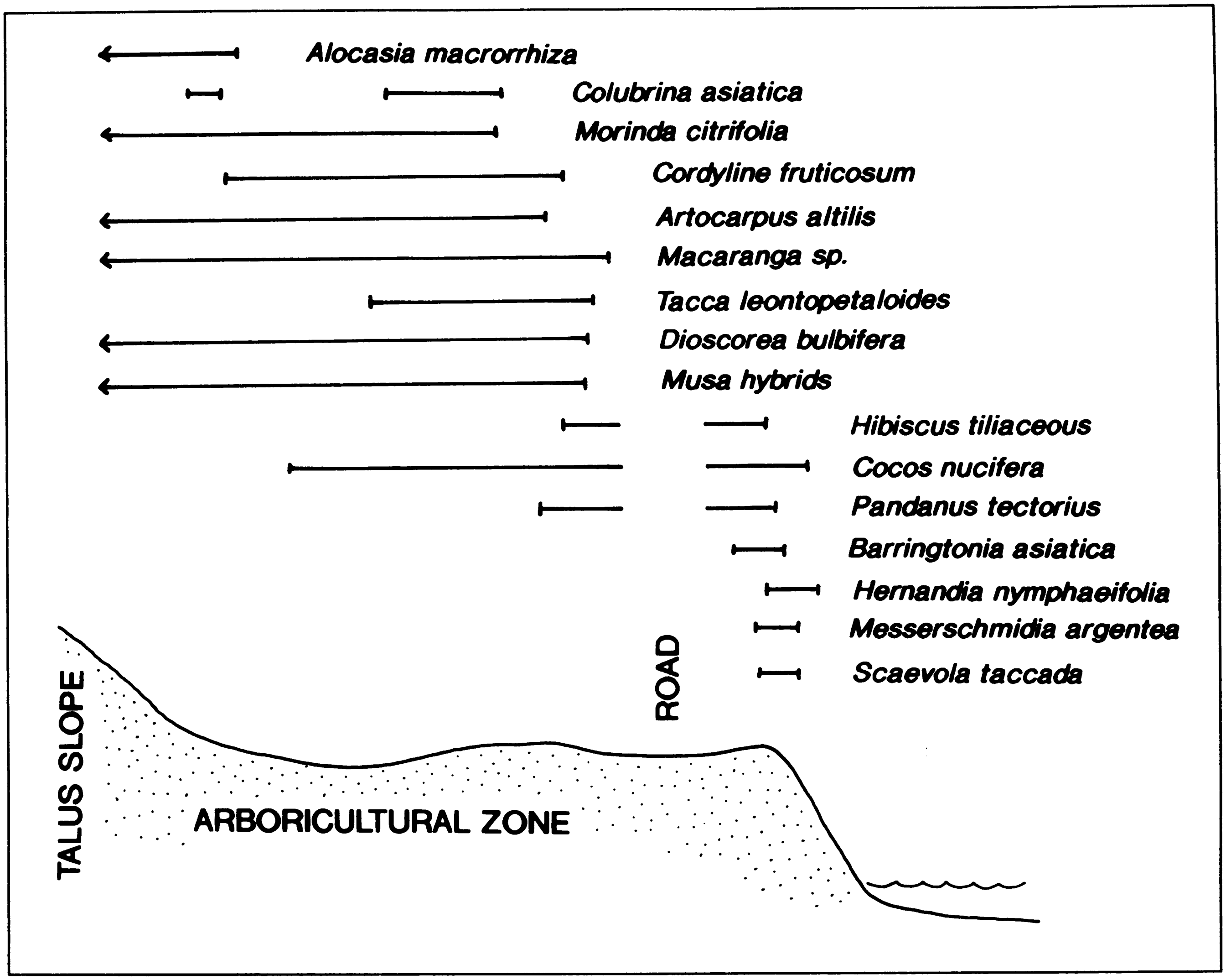

Figure 2.5 Distribution of major floral dominants along Transect 7 at To'aga.

A few breadfruit trees and the occasional banana plant may be found extending a few meters up the slope, but the main dominant here is *Hibicus tiliaceous*, which forms a dense tangle over the boulders, and larger forest trees such as *Erythrina varigata* and others.

Land Use and Site Formation

Although no longer a locus of permanent village habitation, the To'aga coastal terrace remains an important zone of intensive horticulture and arboriculture for the Ofu Island population, as indicated by the analysis of vegetation patterns. Indeed, on an island where flat land comprises less than nine percent of the total area, the economic importance of this coastal terrace to the human population cannot be overemphasized. It is certain that the pattern of intensive cultivation of this area extended back at least into late prehistory, but it remains an archaeological problem to determine just when this pattern first developed.

The pattern of land use in prehistory must also have had consequences for archaeological site formation processes. For example, the clearance of indigenous forest cover on the talus slope above the flat would have exposed unstable soil and rock, and thus accelerated erosion and deposition of colluvial sediment onto the coastal terrace. Cultivation on the flat itself would have resulted in a continual reworking of the upper soil layer (through the actions of digging sticks as well as through floral-turbation by plant roots and tubers). The mixing of terruginous and calcareous sediments through cultivation would have created a well-drained, highly fertile edaphic medium which itself was probably more suitable for root crop cultivation than either the heavy colluvial clays, or the calcareous sands themselves (see Kirch and Yen 1982).

In the chapters to follow, we pay particular attention to several lines of evidence that point to the gradual, historical development of the intensive land use pattern at To'aga. These lines include evidence for changes in the rate of deposition of colluvial sediments, stratigraphic evidence of buried soil surfaces, evidence of reworking of soils, and the presence of several species of synanthropic land snails that are markers of Oceanic horticultural activities.

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3

SURFACE ARCHAEOLOGICAL FEATURES OF TO'AGA

T. L. HUNT

THE SAMOAN LANDSCAPE has been shaped by a long history of human settlement and resource exploitation. Such evidence of settlement and land use, both past and present, is distributed more-or-less continuously across the island landscapes of Samoa. Isolated artifacts, features, sites, and site complexes cover much of the Samoan Islands and vary significantly in relative density (e.g., Davidson 1974:242). The continuous nature of archaeological remains, often expressed in terms of "non-site archaeology" requires documenting the distributional patterns of material culture in space (Thomas 1974; Dunnell and Dancey 1983). This is in contrast to isolating "sites" as dense clusters and ignoring the lower density distributions that inform upon a variety of prehistoric activities and their spatial distribution. The "non-site" approach has proven useful elsewhere in Oceania where the vestige of entire settlement-subsistence patterns have been documented (e.g., Green 1980; Kirch and Yen 1982; Weisler and Kirch 1985). Ideally, entire archaeological landscapes (spatial patterns) must be recorded in detail, although this ultimate objective must usually be met through the gradual accumulation of survey data over many years of effort.

This chapter describes the surface features recorded along systematic transects on the coastal terrace of To'aga (Site AS-13-1). As elsewhere in Manu'a, the "site" was defined by natural landscape boundaries rather than by the relative density of artifacts or architectural remains. Thus, Site AS-13-1 comprises the area from the shoreline to the steep slopes and cliffs, the coastal terrace described in detail in chapter 2.

Field Methods

A systematic survey of the surface features at To'aga was accomplished using transects set from the beach to the steep slopes of the interior cliffs. In 1986 a baseline was set out along the coastal road with lateral transects about 30 meters in width made at every 100-meter interval. This resulted in 18 survey transects that covered approximately 4.4 hectares of the coastal terrace. Shrub vegetation, often dense, was cleared from these transects. Without extensive clearing of ground cover and other vegetation, some areas had very poor surface visibility. This means surface features were undoubtedly missed, even in transects cleared of some vegetation.

All surface features and artifacts discovered on the transects were recorded for provenience, described, and many were also mapped using a tape and compass. Other features encountered during fieldwork (in all three seasons) were recorded in the same way. Finally, well-known features or monumental constructions were located with local guides and recorded as well.

Transects oriented perpendicular to the shoreline traverse the greatest range of geomorphic diversity that may correlate with variation in settlement, land use, and age of surface features. Surface data acquired along systematic transects can be used to produce maps (with interpolations as desired) that reveal pattern and structure in the archaeological remains. In short, this kind of systematic strategy provides a means to record, in some detail, the spatial configuration and variety of archaeological remains while producing an informative, albeit partial, picture of the broader archaeological landscape.

Results

Much of the coastal land of the south coast of Ofu Island, from the areas known properly as To'aga to Fa'ala'aga, appears to have a near continuous distribution of archaeological remains on the surface. In most areas where vegetation permitted visibility of the ground surface, evidence of habitation and land use was present. Figure 3.1 shows the location of archaeological surface features recorded in the survey transects. These features, shown by consecutive numbers, are listed and described in table 3.1.

The surface features recorded include basalt and coral boulder alignments usually of curved and oval form (house foundations) with coral and basalt pebble paving (*'ili'ili*, e.g., figure 3.2); small oval or rectangular boulder alignments that appear to mark burials or are simply the partial remnants of house foundations; a massive, fine-grained talus boulder used for multiple (twelve) grinding basins/surfaces (figure 3.3); pits with associated boulder slab lining in several places, probably the remains from the production of fermented breadfruit (*lua'i masi*); and long (inland-seaward oriented) single course alignments which appear to have served (and may continue to serve) as land boundary markers.

Particularly noteworthy is a complex that includes the locally well-known Tui Ofu Well (Feature 23, figure 3.4) and Tui Ofu Tia (monumental tomb, Feature 24, figure 3.5). Situated near the eastern end of the coastal flat of southern Ofu (near Fa'ala'aga), these monumental constructions are traditionally associated with the high-ranking title Tui Ofu ("king of Ofu"). The Tui Ofu Well is a relatively elaborate construction of waterworn basalt boulders arranged in a rounded form that includes a sloped concourse as well as a small paved court around the excavated shaft. The depth of the shaft from the surrounding court is 2.1 m. The Tui Ofu Tia (tomb) comprises a crudely terraced mound of basalt boulders (both rough and waterworn) that is set in against the massive talus and steep slope rising on the inland side of this area. A small pit lies among the boulder rubble on the uppermost terrace of the mound. No artifacts or other cultural materials were observed at the structure, except that ornamental plants, such as crotons, have been planted around the base of the mound.

The survey along transects has yielded data on only part of the surface record at To'aga. Other features will be found with more intensive coverage of the area. A more complete survey of surface remains at To'aga will require extensive clearing of vegetation which restricts access to parts of the coastal lands or obscures visibility.

The geomorphic evidence (described in chapters 2, 4 and 5) suggests that the present surface at To'aga is less than 1000 years B.P., and very recent in some areas where colluvial and eolian (i.e., primarily calcareous beach sediment) deposition continues. Thus the surface evidence represents late prehistoric and historic activities on the coastal terrace. This observation is supported by excavation and geomorphic data (Kirch and Hunt, chapter 5). Many of the surface features are probably pene-contemporaneous, at least in archaeological time-frames.

The surface features at To'aga are similar in their formal variability to those documented elsewhere in Manu'a (Hunt and Kirch 1988) and other islands of Samoa (e.g., Clark and Herdrich 1988; Davidson 1974; Green and Davidson 1969, 1974; Jennings et al. 1976, 1982; Jennings and Holmer 1980). The architectural remains present at To'aga do not reflect the full range known for

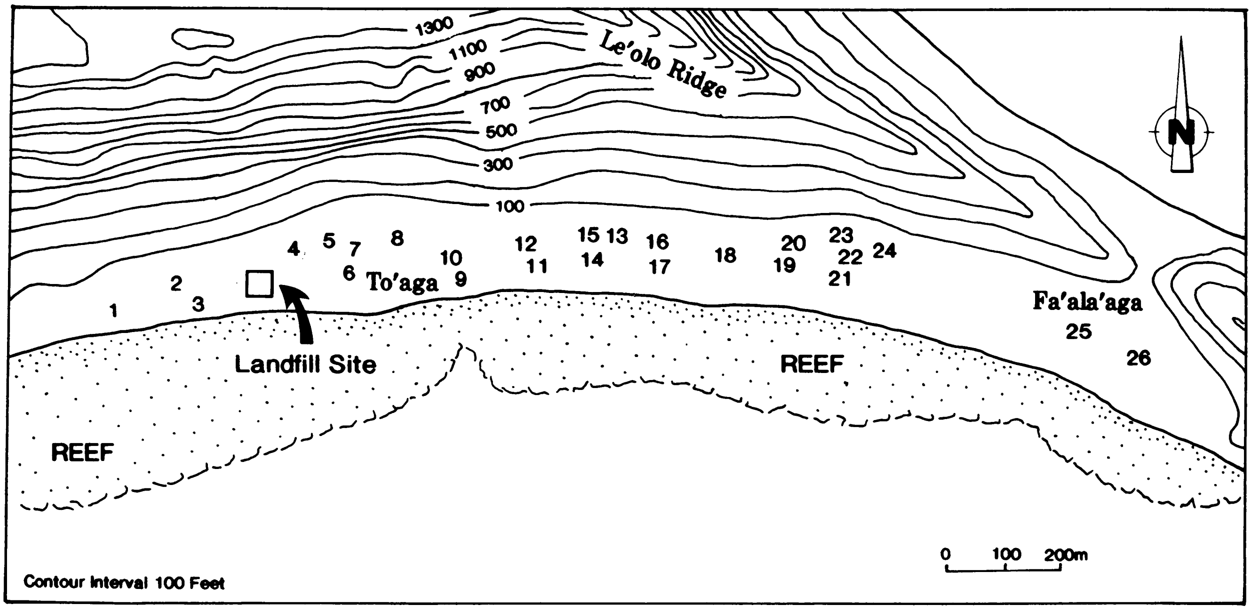

Figure 3.1 Map of the southern portion of Ofu Island, from To'aga to Fa'ala'aga, showing the location of surface archaeological features (1-26) of site AS-13-1.

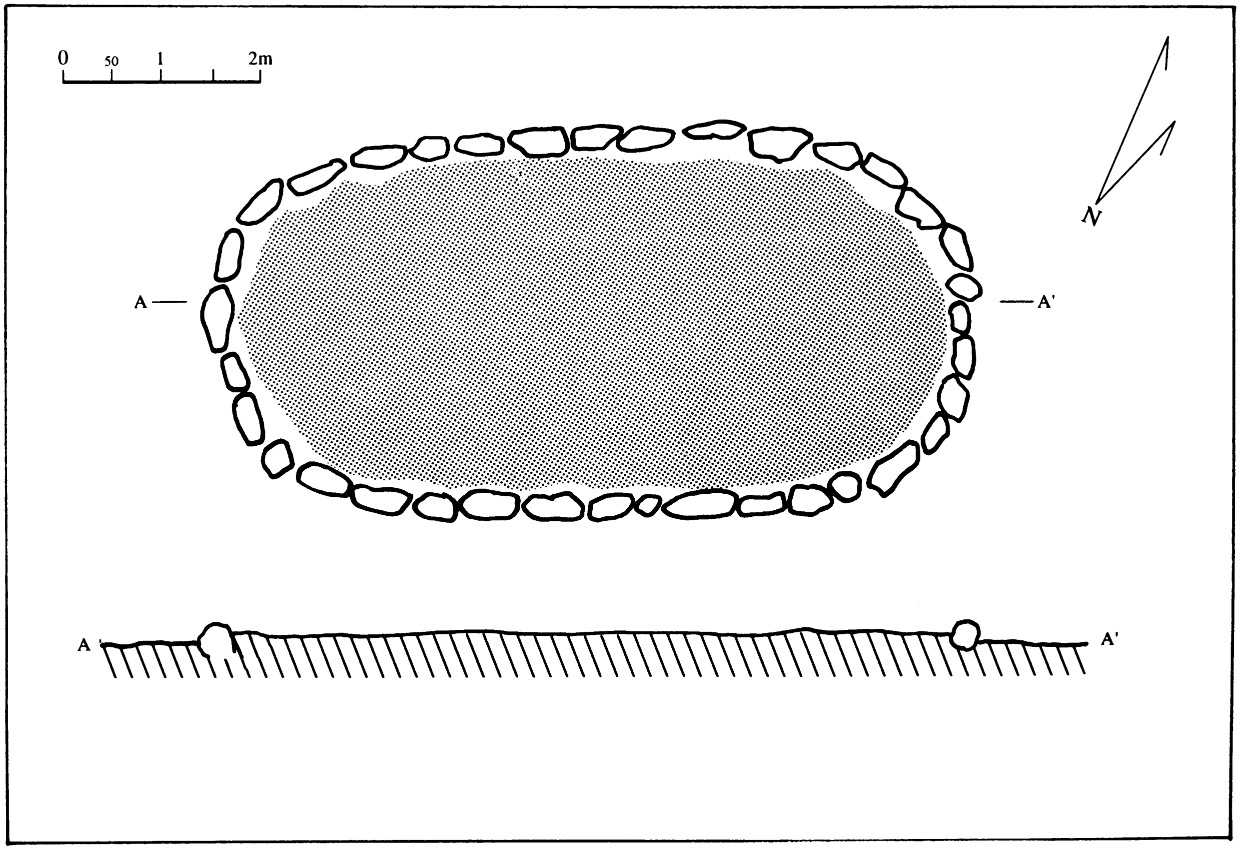

Figure 3.2 Plan of round-ended stone house foundation (Feature 19); the shaded area is paved with coral and basalt gravel (*'ili'ili*).

Table 3.1
Surface Archaeological Features at To'aga

Feature	Description	Form	Possible Function	Dimensions
1	Gravel-filled platform	Rectangular	Burial	2.30 x 1.15 m
2	Boulder alignment	Curvilinear	Partial house foundation	5.5 m
3	Boulder alignment	Curvilinear	Partial house foundation	5.0 x 3.0 m
4	Talus boulder with 12 ground facets	Concave surfaces	Adz grinding stone	2.35 x 1.65 m
5	Boulder alignment with gravel fill	Oval	Partial house foundation	2.10 m
6	Coral gravel	Irregular	House floors	Extensive
7	Coral gravel	Irregular	House floors	Extensive
8	Boulder-lined pit	Round	Masi pit	2.80 m
9	Cement pylons	Square	Naval medical dispensary	---
10	Boulder alignment with gravel	Curved	Partial house foundation	8.10 m
11	Boulder alignment	Linear	Partial house foundation	6.7 m
12	Boulder alignment, gravel, and shell midden	Linear	Land boundary marker	19 m
13	Boulder-lined pit	Round	Masi pit	4.70 x 4.0 m
14	Boulder alignment	Linear	Boundary marker	16.95 m
15	Boulder-lined pit, gravel, and midden	Round	Masi pit and habitation	pit 2.2 x 2.0 m; Dispersed
16	Boulder alignment and dense gravel	Oval	House foundation	6.75 x 3.30 m
17	Midden scatter	Irregular	Midden	>30 x 15 m
18	Boulder-faced earthen terrace	Rectangular	Agricultural?	35.45 m
19	Boulder alignment and gravel	Oval	House foundation	7.70 x 4.0 m
20	Boulder alignment	Linear	Land boundary marker	45 m
21	Boulder alignment and gravel	Oval	House foundation	13.0 x 6.50 m
22	Boulder alignment	Round	Animal enclosure?	14.50 x 17.0 m
23	Boulder paving and well	Round	Tui Ofu well	11.50 x 9.43 m
24	Boulder platform and terraces	Rectangular	Tui Ofu Tia (Burial mound)	10.30 x 9.10 m
25	Boulder alignment and gravel	Curved	Partial house foundation	2.95 x 2.30 m
26	Boulder alignment and gravel	Oval	House foundation	8.10 x 4.80 m

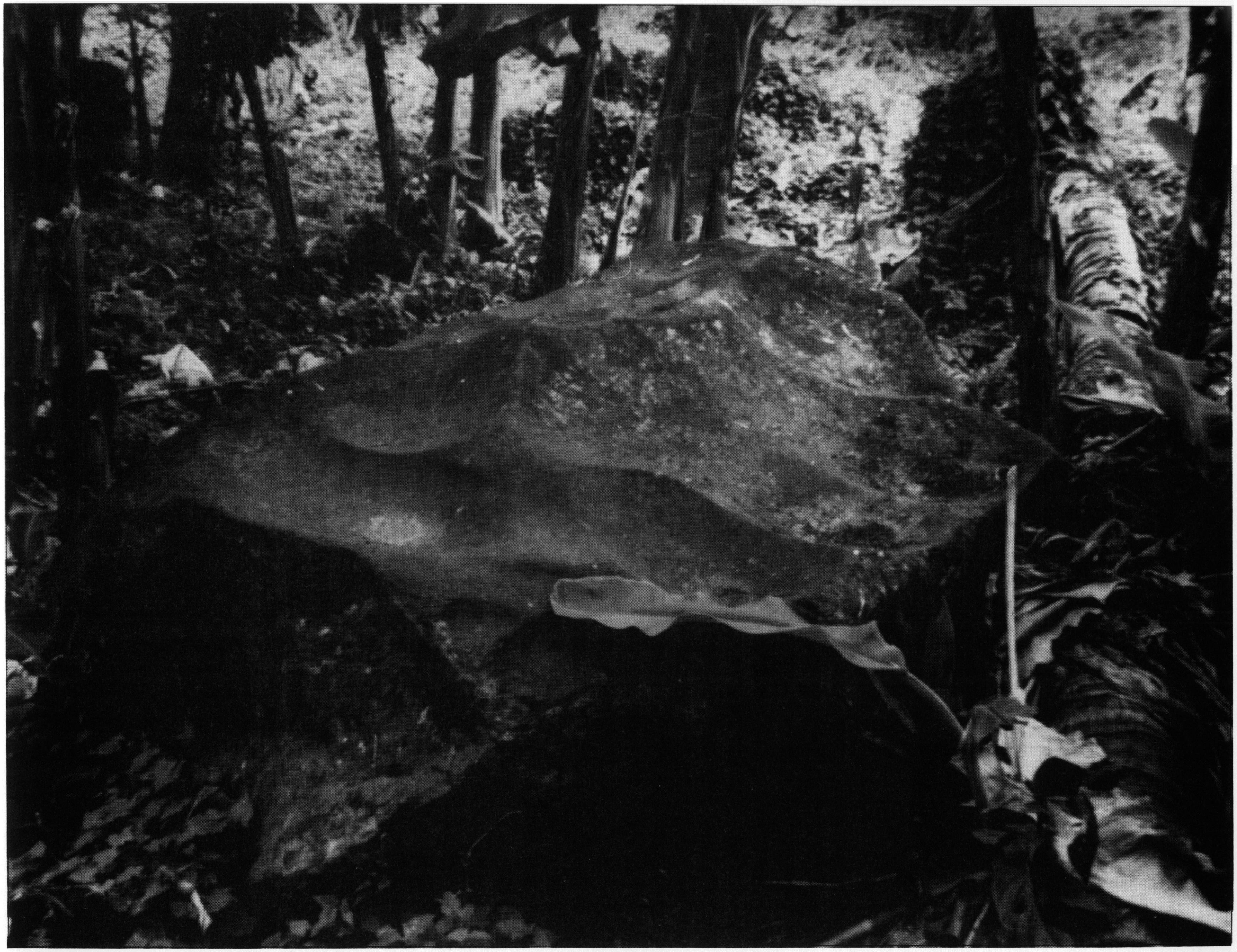

Figure 3.3 Large volcanic boulder at the base of the talus slope, with twelve artificial grinding facets (Feature 4).

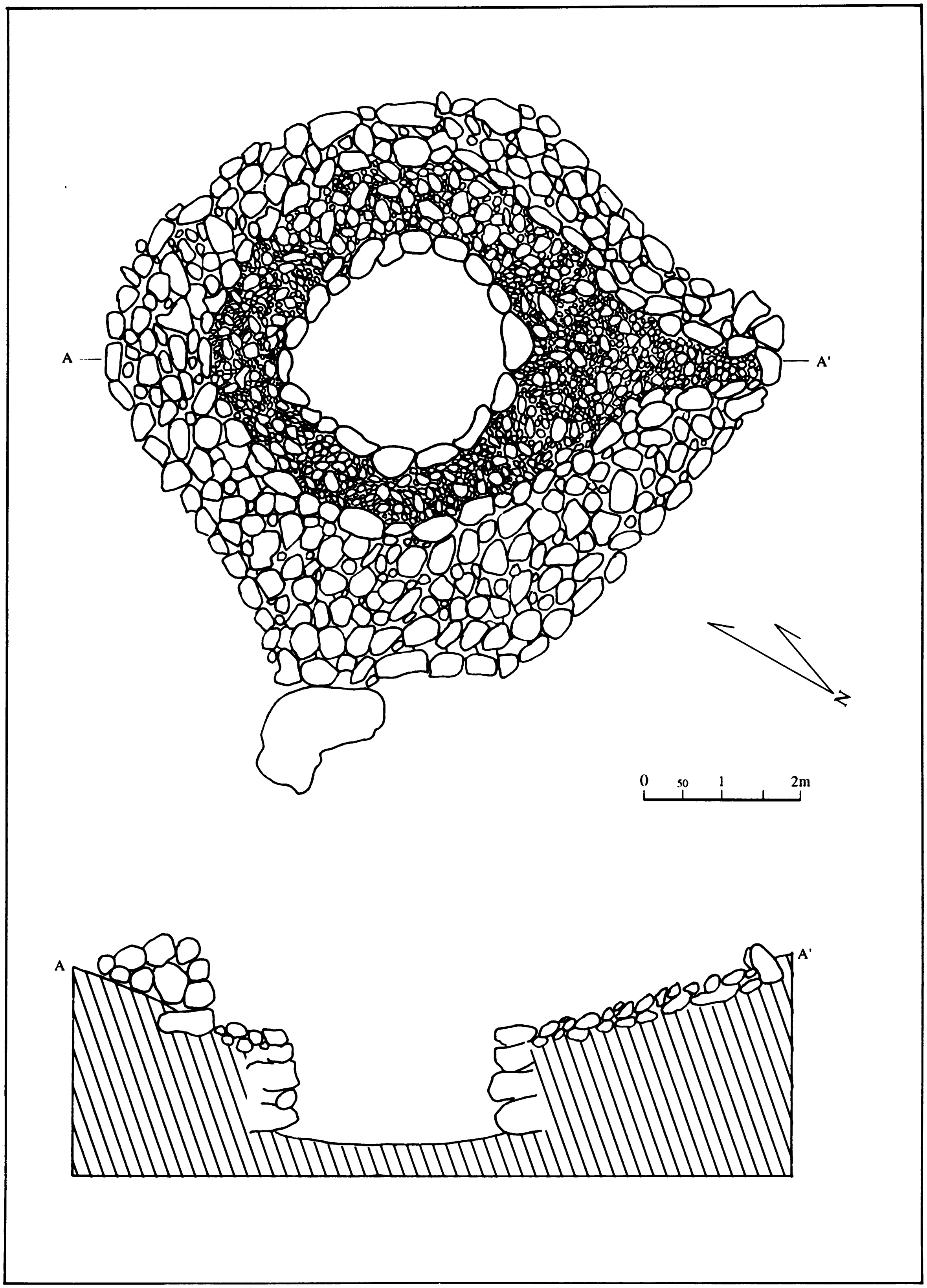

Figure 3.4 Plan and cross section of the Tui Ofu well at Muli'ulu.

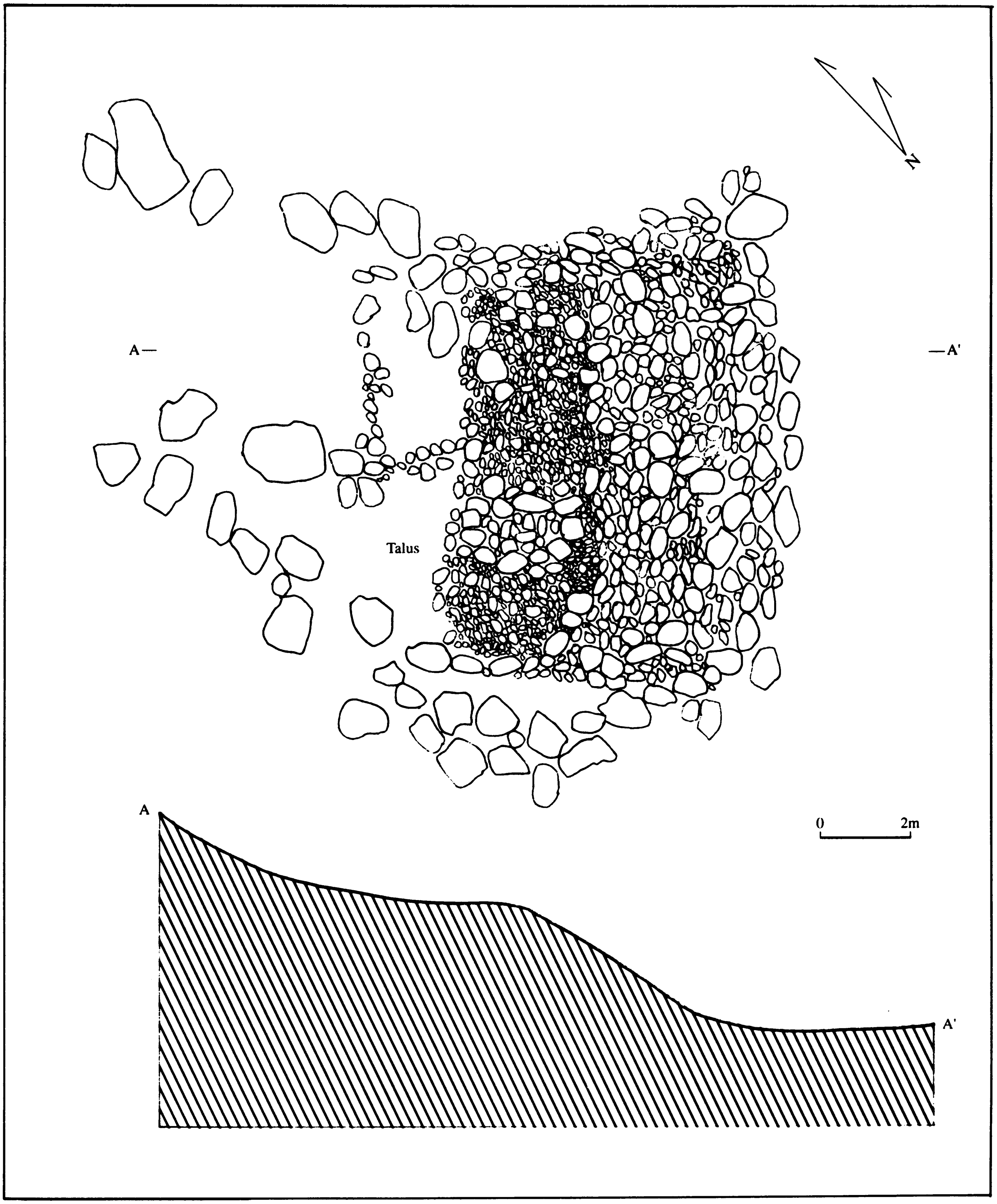

Figure 3.5 Plan and cross section of the the Tui Ofu Tia, stone mound/tomb at Muli'ulu.

Samoa but do include forms linked to domestic activities. Only the Tui Ofu Well and Tui Ofu Tia represent structures of specialized function, indeed those associated with social rank.

The available evidence suggests a redundant pattern of associated features which can be interpreted as the remains of domestic compounds. The distribution of such habitation suggests dispersed settlement organized on the basis of descent groups, as represented in Samoan socioeconomic organization documented ethnographically (Mead 1930).

The distribution of structural features also reveals late prehistoric and historic settlement situated primarily on the stabilized dune ridge. The surface and excavation evidence (Kirch and Hunt, chapter 5) suggests that occupation has centered on the high ground of stabilized sand dune ridges. As progradation of the To'aga coastal land occurred, settlements moved seaward. The archaeological evidence on today's relatively young surface reflects the last phase of habitation at To'aga. Thus, the settlement pattern marks continuity over To'aga's pre- and post-contact history.

The primary focus of fieldwork at To'aga has been the definition and sampling of the subsurface deposits of the coastal terrace. Additional intensive surface survey is necessary to complete the picture that has emerged so far.

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4

THE TO'AGA SITE: MODELLING THE MORPHODYNAMICS OF THE LAND-SEA INTERFACE

PATRICK V. KIRCH

IN CHAPTER 2 WE described the economic and cultural significance of the narrow coastal terrace of Ofu which—as the only flat land on the island—is thus the main locus of settlement and a major zone of subsistence production. This coastal terrace, which the To'aga site exemplifies well, must be understood as a dynamic geomorphological entity lying at the critical land-sea interface. McLean has aptly described the importance of such land-sea interfacial zones on small tropical islands:

> The attractiveness of the coastal lowlands for settlement purposes is obvious.... On many islands they comprise the only flat country. It is easy to move over and easy to build on. Soils, though naturally of low fertility and moisture status, are easily worked. The sandy substrate, beach sand and beachrock are readily available for such uses as building materials, graves and road 'metal.' That the coastal flats are multi-purpose and multi-utilized resources goes without saying. Moreover, their location at the land-sea edge permits optimal access to a complete range of terrestrial and marine environments and resources: hillslope, valley and forest; reef, lagoon and fish. They function as convenient bases to exploit the local environs. They also function as verandahs to the worlds outside (1980:129-30).

In their study of the prehistory and ecology of Tikopia, Kirch and Yen (1982) similarly argued for the importance of unraveling the morphodynamic histories of these interfacial environments:

> among these [environments] are the coastal/marine interface, with implications for access to resources of reef and sea, and that of calcareous plains and volcanic hills, with implications for erosion and agricultural development.... Both of these interfaces have been active zones of landscape change, with long-term implications for human adaptation (1982:17).

In particular, the Tikopia case revealed the agricultural significance of human-induced modifications to the coastal zone: "the plain and hill interface provides the opportunity for the mixing of volcanic and calcareous soils to form edaphic media, more favorable for the cultivation of root crops than either separate type" (Kirch and Yen 1982:17).

Prior experience in Tikopia (Kirch and Yen 1982), Niuatoputapu (Kirch 1988), and other small tropical islands had sensitized us to the necessity of a geomorphologically informed approach to the archaeological study of the To'aga site. This was critical both to an understanding of depositional and site-formation processes, as well as for contributing to our knowledge of the evolution of the island's larger settlement patterns and production systems. This chapter focuses on several aspects of the local environment at To'aga which played key roles in the morphodynamic evolution of the site. Chief among these are the changing configuration of sea level in the mid-Holocene, and the tectonic instability of the Manu'a Group. Equally significant, however, is the role of humans themselves in shaping the landscape through physical manipulation of soil and rock, forest clearance, the introduction of a "portmanteau" biota (cf. Crosby 1986), and the continual manipulation of the coastal environment to best suit human needs. My aim here is to outline a model of these morphodynamic processes that may then be tested against the empirical evidence revealed through our field and laboratory investigations.

GEOMORPHOLOGY OF THE TO'AGA COASTAL TERRACE

The key geomorphological features of the coastal terrace at To'aga can best be described along a generalized transect running from the reef inland across the flat up to the steep hillslope and cliff as in figure 4.1. (Particular, surveyed transects are illustrated and described in chapter 5, along with the stratigraphic evidence for temporal development.) At the seaward end is the reef flat, source of the calcareous sediment (composed of the detritus of coral, molluscs, and other reef-dwelling organisms) of which the coastal terrace is primarily constructed. This reef flat is a mosaic of microenvironments, including surge channels, the 'lithothamnium ridge' at the seaward edge, large coral heads, and sandy patches.

A careful examination of the beach slope reveals several clues as to the dynamic processes presently at work along the land-sea interface. At the foot of the beach slope in various places are exposed layers of 'beach rock' (Wiens 1962:64-67) made up of sand and coral rubble cemented with calcium carbonate ($CaCO_3$). Such beach rock deposits can form fairly quickly under tidal conditions of continual wetting and drying within active beach ridges. Their exposure along the To'aga beach front, however, signals a current phase of coastal erosion and net sediment loss (or lateral transfer). This evidence is reinforced by an examination of the vegetation line at the top of the present beach ridge crest, where large trees (such as *Cocos*, *Cordia*, and *Hernandia*) have been undercut and eroded by wave action.

Moving inland, one mounts the crest of the present beach ridge or berm, lying between the beach slope and the sandy road. This narrow zone is covered with a thick tangle of vegetation, dominated by *Pandanus tectorius*, *Barringtonia asiatica*, *Hernandia nymphaeifolia*, *Scaevola taccada*, *Messerschmidia argentia*, *Cocos nucifera*, and other species that anchor the loose, unconsolidated calcareous sands. Test pits dug into this beach ridge revealed only a thin (ca. 5 cm) organic A horizon directly overlying the young parent sands. The absence of archaeological deposits suggests that the present beach ridge is of no great antiquity.

Crossing the road and plunging through a narrow band of *Pandanus* and *Hibiscus tiliaceous* shrubs, one enters the main extent of the coastal terrace, a zone of intensive economic utilization through arboriculture and root crop gardening (see Kirch, chapter 2). The ground at first slopes down slightly from the beach ridge, levels out, and then begins to rise again gradually toward the talus slopes inland. As one moves inland from the road through this zone, the soil gradually becomes less sandy and more clayey, reflecting the increased contribution of volcanic colluvium which has been eroded from the hillslopes and added to the calcareous sands that form the main component of the substrate. The mixing of these calcareous and volcanic sediments—through the continual action of human cultivation—has made this zone of particular edaphic value for Samoan horticulture. This is also the main zone of archaeological features, both surface and subsurface, as described in chapters 3 and 5.

Moving farther inland toward the talus slope, one begins to note volcanic cobbles and boulders strewn over the land surface, signals of the dynamic instability of the 500-m-high cliffs that tower over the To'aga flat. Some of these boulders are several meters in diameter and can fall with considerable destructive force. The ground surface closest to the talus is entirely gravelley clay-loam with no calcareous component evident. Rather abruptly, one arrives at the base of the talus itself, an imposing and unstable jumble of boulders rising steeply toward the cliffs, over which grows a tangle of *Hibiscus tiliaceous* and scattered forest trees such as *Erythrina varigata*.

In sum, this geomorphological traverse across

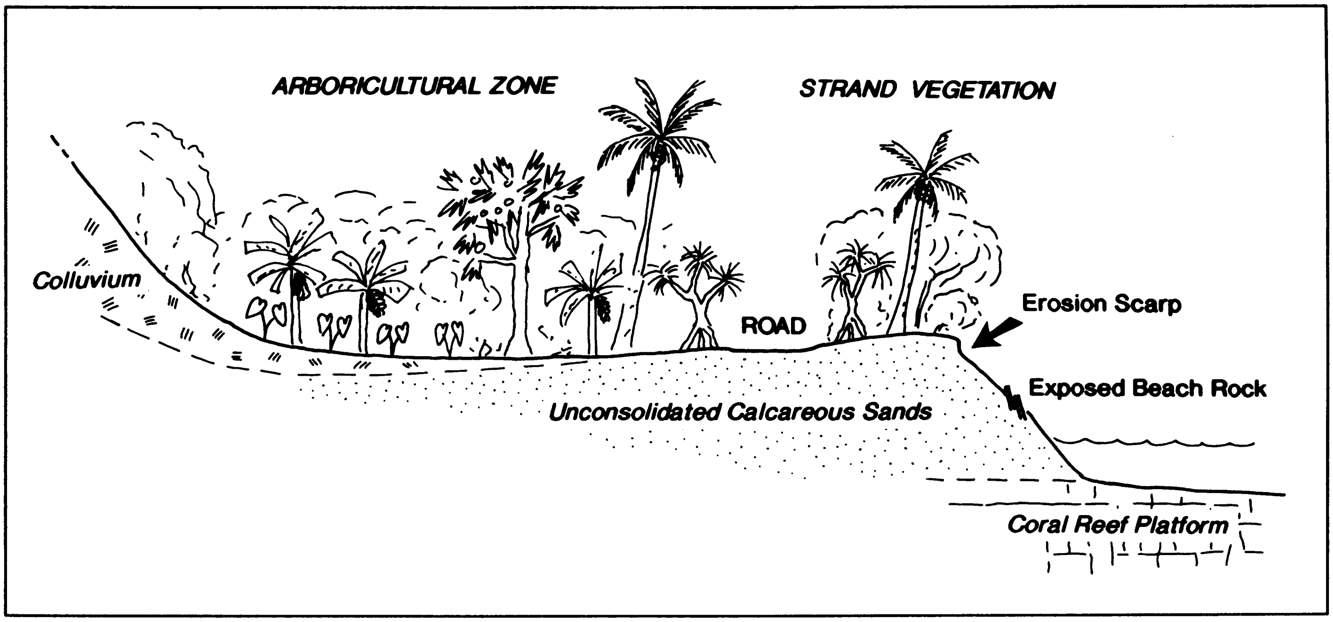

Figure 4.1 A generalized transect across the coastal plain at To'aga, showing the distribution of colluvial and calcareous sediments, major vegetation associations, and geormorphological features.

the To'aga coastal terrace reveals several key features: (1) the terrace is constructed primarily of marine biogenic sediments (calcareous sands and larger clastics); (2) one finds a progressively greater contribution of terrigenous sediments as one approaches the volcanic mass; and (3) there is some evidence for current coastal erosion and marine transgression at the present time. These are features that must be accounted for in any model of the morphodynamics of the To'aga site over the past several thousand years.

MORPHODYNAMIC PROCESSES: SEA LEVELS AND SUBSIDENCE

As the archaeological deposits of the To'aga site are integral sedimentary components of the coastal terrace, any model of site formation processes must first account for the geomorphological processes by which the terrace was formed. Lying at the critical and highly dynamic land-sea interface, any consideration of the morphodynamics of this zone must begin with an examination of controlling processes in shoreline formation. Among the most important of these are: (1) glacio-eustatic sea-level changes; and, (2) the local tectonic situation which—as we shall argue—is one of subsidence. The temporal period with which we are concerned is the mid- to late-Holocene, from about 6 kyr B.P. to the present. This time span covers some 3 kyr prior to the human colonization of Ofu as well as the subsequent interval during which humans have added their input to the development of the local landscape.

Before examining the evidence for relative sea-level change during this period, it is essential to introduce a few key concepts regarding coastal change on small islands. In this I have drawn primarily from Chappell (1982) and McLean (1980b). The construction of a coastal terrace such as that at To'aga results from *progradation*, the "progressive formation of new land by sedimentation irrespective of the tendency of sea level movement" (Chappell 1982:71). Sea-level changes themselves, whether due to glacio-eustacy or tectonic movements, or both, are important as controlling factors for the sediment budget, but alone they do not provide a sufficient model of progradation. As Chappell emphasizes, "... sea level changes alone cannot be used to account for coastal changes. In fact, for the last 6000 years, the sedimentary budget is the more important factor" (1982:71). The sediment budget can be thought of as the net sum of sediment input from both terrestrial (talus, colluvium, etc.) and marine biogenic (calcareous sands and coral detritus) sources, minus the loss of sediment from transport (fig. 4.2). In modelling the To'aga coastal terrace formation, therefore, we need to pay particular attention to changes that would either increase or decrease the production of sediment from terrestrial or marine sources.

Figure 4.3 graphically portrays the dynamic effects of changes in relative sea level (due either to glacio-eustatic or tectonic change), combined with increases or decreases in sediment budget. In this diagram, sediment budget is indicated along the *x* axis, and relative sea-level change along the *y* axis. The heavy diagonal line separates transgression or coastal retreat, from regression or coastal advance.

Holocene Sea Levels in the South Pacific

A rapid rise in sea levels following the end of the Pleistocene is a global phenomenon that has been widely recognized (Fairbridge 1961; Shepard 1963). More controversial—because they depend upon a complexity of local conditions and processes—have been the details of the eustatic sea-level curve in the mid- to late-Holocene, especially the matter of whether there have been higher-than-present stands. Bloom (1980, 1983) modelled some of the global diversity in these Holocene curves and suggested that a +1-2 m stand existed in the south Pacific region during this period. Substantial geomorphic and radiometric evidence from a variety of islands now supports this interpretation of a +1-2 m high sea level during the period between about 4-2 kyr B.P. In Fiji, for example, Nunn (1990:304) concluded that the coasts "experienced a middle to late Holocene sea-level maximum some 1-2 m above present mean sea level." Recent work by Miyata et al. (1990) also supports this finding. Similar results are presented by Ash (1987) for Viti Levu Island, and Yonekura et al. (1988) report evidence for a +1.7 m stand between 3400-2900 B.P. on Mangaia Island in the southern Cooks. In French Polynesia, Pirazzoli and Montaggioni (1986, 1988; Montaggioni and Pirazzoli 1984) describe evidence from various islands for a MSL between +0.8 and 1.0 m beginning about 6-5.5 kyr B.P. and lasting as late as 1.2 kyr B.P. In Western Samoa, Rodda and his colleagues (1986; Sugimura et al. 1988) summarize various evidence for Holocene higher stands. Isla (1989:361-63) discusses a comparable range of evidence for several Pacific Islands. In figure 4.4, the geographic distribution of mid- to late-Holocene higher sea-level stands is plotted along with associated radiometric ages. Figure 4.5 shows a time-elevation plot of sea levels in various Polynesian archipelagoes over the past 5 kyr B.P.

This widespread and consistent pattern of radiometrically dated shoreline features provides strong evidence for a higher sea level ranging between about +1-2 m over the southwestern Pacific, from at least 5 kyr B.P. and lasting until sometime between 2-1 kyr B.P. After about 2 kyr B.P., sea level fell (perhaps fairly rapidly) to its present position. This mid- to late-Holocene sea-level curve thus provides one important dimension for a model of coastal terrace formation at the To'aga site.

Subsidence in the Samoan Archipelago

Most of the volcanic archipelagoes of the central Pacific region are arrayed linearly along age-progression sequences emanating from a "hot spot" or magma plume on the floor of the Pacific Plate (Menard 1986). As the Pacific Plate gradually migrates west or northwest, active volcanic islands move off the hot spot, and a new island is formed. Thus, the islands in such an archipelago comprise a "plume trace" of increasing age from east to west. Classic instances of this pattern are the Hawaii-Emperor chain and the Society Islands. The Samoan archipelago presents a somewhat more complicated geological picture, primarily due to recent volcanism on Savai'i Island which, at the western end of the chain, theoretically should be the oldest island (Menard 1986:186-87). This unusual situation confounded geologists for many years (Dana 1849; Daly 1924; Stearns 1944; Natland 1980). Recently, however, K-Ar dating of rocks from various Samoan islands has confirmed the basic pattern of an east to west age progression; the mean K-Ar ages are 0.1 myr for Ta'u, 0.3 myr for Ofu-Olosega, 1.26 myr for Tutuila, and 2.2 myr for 'Upolu (McDougall 1985:318-19). Savai'i is presumably the oldest island but has had renewed volcanism in recent times. McDougall concluded that "Upolu, Tutuila, and the Manu'a Islands comprise a hot spot or plume trace on the Pacific plate, similar to the Hawaiian and Society Islands chains." Nevertheless, the

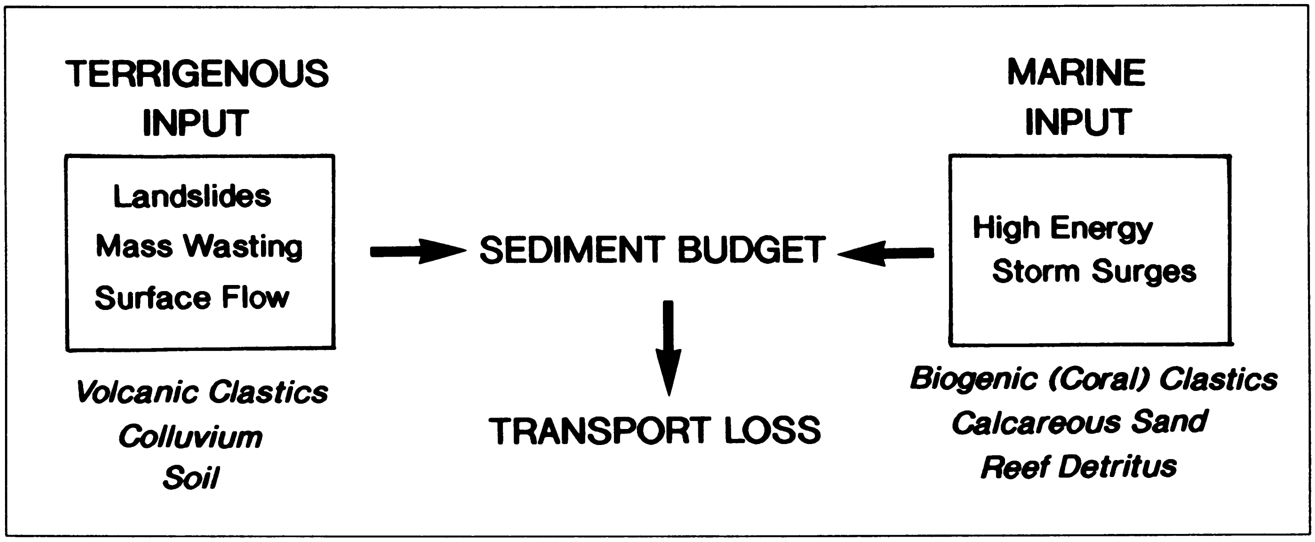

Figure 4.2 A model for the sediment budget at To'aga, showing terrestial and marine inputs.

dominance of youthful volcanism on Savai'i remains an enigma and may indeed reflect major rejuvenescence related to deformation of the Pacific Plate adjacent to the Tonga Trench (1985:319; see also Menard 1986:186-87).

This linear age-progression and the fact that the Manu'a Islands are still in a youthful stage of geological evolution are essential factors in understanding the local tectonic situation of Ofu Island. The rapid construction of a volcanic mass on the oceanic crust of the Pacific Plate results in a phase of subsidence, due to point loading on the thin and flexible crust (Menard 1986:165-69). Such subsidence and associated crustal deformation is well documented for the younger Hawaiian Islands. The island of Hawai'i appears to be subsiding at an average rate of about 4.8 mm/yr.

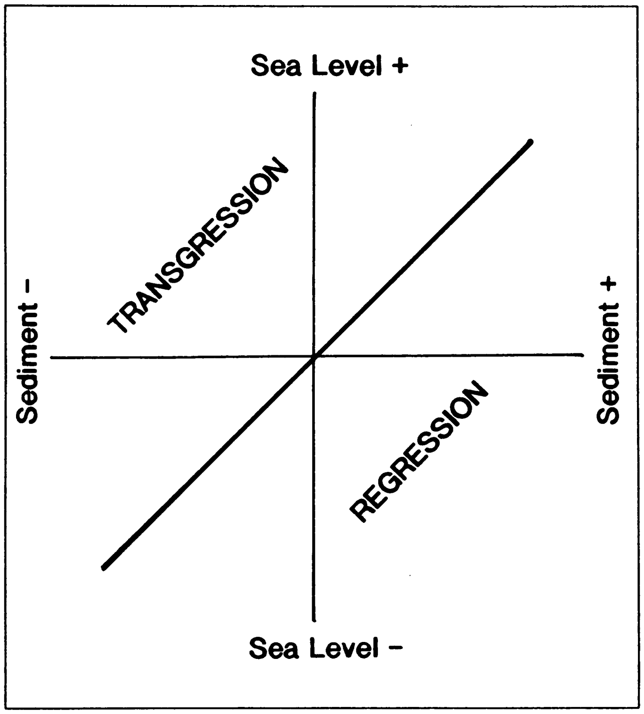

Figure 4.3 A model of shoreline transgression and regression as a function of relative changes in sea levels and in sediment budget (after Chappell 1982).

For Ofu Island itself, we are not aware of geological documentation of subsidence at the present time, although we have strong indirect reasons to believe that this is the case. The young age of the island (only 0.3 myr) would itself suggest that subsidence and crustal deformation (which lag behind volcanism) have not yet reached equilibrium. The evidence for active erosion of the island's coastline, described above, strongly supports this interpretation of active subsidence. Further evidence is provided by the reefs along the To'aga area which display active coral head growth and lack the solution-pitted and eroded reef platforms typical of islands that have been tectonically stable during the Holocene. These observations suggest that Ofu and Olosega islands are still in a phase of subsidence due to point loading on the oceanic crust resulting from their initial volcanic construction.

Elsewhere in Samoa, dramatic evidence for rapid subsidence was provided by the chance

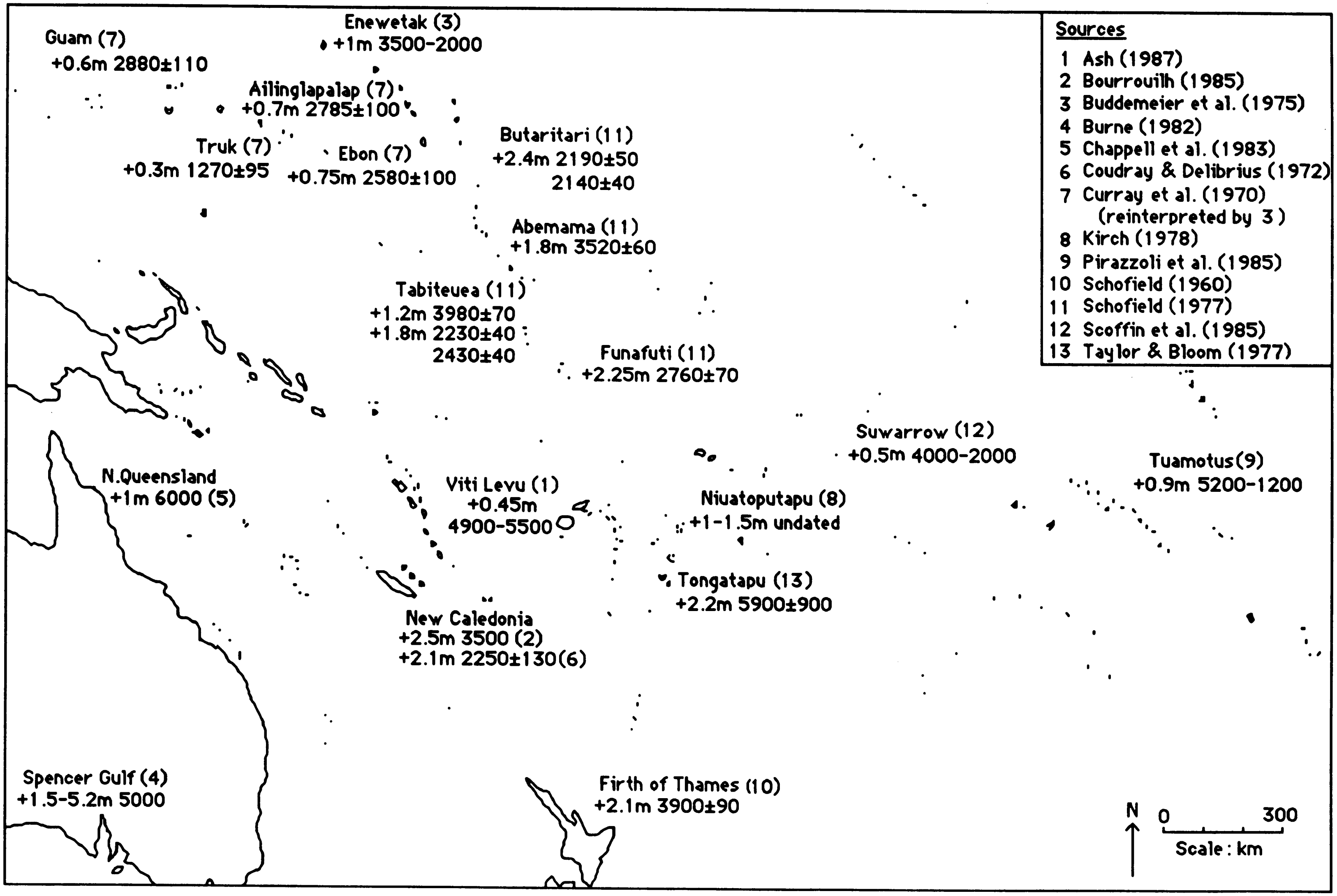

Figure 4.4 Map of the southwestern Pacific region, showing locations with evidence for mid- to late-Holocene higher sea-level stands, and associated radiocarbon ages. (Map courtesy of J. Ellison.)

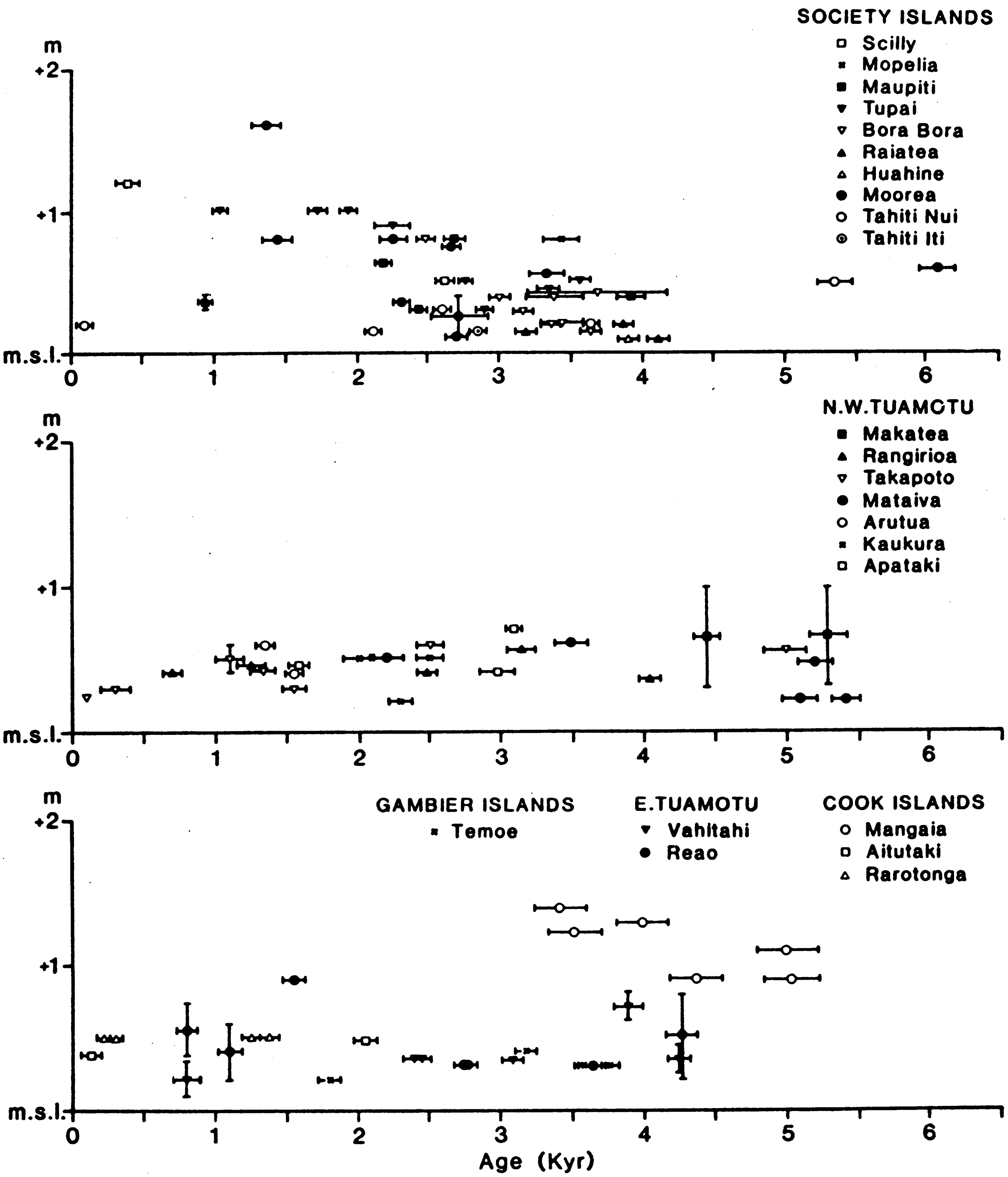

Figure 4.5 Time-elevation plot of sea levels in Polynesian archipelagoes (source: Spencer 1989, fig. 13).

discovery of the Mulifanua archaeological site (Green and Davidson 1974; Green and Richards 1975; Leach and Green 1989). Dating to 3251 ± 155 B.P., Mulifanua is a Lapita-pottery bearing deposit now situated -1.5 m below mean sea level, and further capped by 0.75 m of reef rock (Leach and Green 1989:324-26). The site was accidentally discovered by dredging for a ferry berth. Given that the site represents a village occupation on a former beach or coastal terrace, between 2.6-3 m of subsidence is indicated, or an approximate subsidence rate of 1 m/kyr. (Davis [1928:249-53] also discusses evidence for the submergence of Tutuila Island.)

In constructing a morphodynamic model for the development of the To'aga coastal terrace, we assume that Ofu has been undergoing continual subsidence throughout the Holocene. Although no precise rate can be empirically determined at this time, we may use a working rate of 1 m/kyr based on the Mulifanua situation. (It is possible that the actual rate of subsidence on Ofu could exceed this value.)

SEDIMENT BUDGETS: SOURCES AND MODES OF DEPOSITION

In addition to the relative changes in sea level resulting from a combination of glacio-eustatic and tectonic processes, we need to consider both the sources of sediment which contributed to the construction of the To'aga coastal terrace and the agents responsible for the deposition of these sediments. The bulk of the To'aga coastal terrace is constructed of calcareous sands and larger clastics (coral heads and chunks of reef conglomerate) of marine biogenic origin. These biogenic sediments are produced on the reef through a number of mechanisms, including wave action and biologic processes (such as the generation of sand by parrot fish and other species that rasp and grind coral to extract algae). These biogenic sediments are transported landward over the reef flat by wave action. Episodes of high-energy storm surges, associated with the cyclones that periodically lash the island, are extremely important for the rapid accumulation of large quantities of sand and of the larger size component of coral boulders and cobbles.

The contribution of terrigenous sediments to the coastal terrace appears to have been less significant, although this increases as one moves landward. The primary source of terrestrial sediment is the steep cliff which towers over the site, continually depositing talus and rockfall onto the coastal terrace. Some finer grained sediments wash over and down the cliff during heavy rains, but there is no major alluvial contribution of sediment. Thus mass wasting (principally landslides) and sheet erosion are the major agents of terrigenous sediment deposition.

The sediment budget of the To'aga geomorphic system would have fluctuated during the Holocene, as the generation of biogenic sediments in particular would vary with sea-level regimes. During periods of rapid sea-level rise, when corals are actively growing below mean sea level, the generation of sediment would be substantially reduced. When sea level dropped or was stable for a period of time, coral growth would have caught up with sea level and would have been exposed to wave action, resulting in erosion and the generation of calcareous sediment.

MODELLING THE MORPHODYNAMICS OF THE TO'AGA COASTAL TERRACE IN THE MID- TO LATE-HOLOCENE

The variables essential to a model of the formation of the coastal terrace at To'aga in the mid- to late-Holocene have been reviewed. In figure 4.6 these variables are diagrammed along the same temporal axis. Figure 4.6A shows the Holocene glacio-eustatic rise in sea level, reaching a +1-2 m maximum between about 4-2 kyr B.P. Prior to about 5 kyr B.P., the rapid rise in sea level would have continually drowned the shoreline, and the formation of a stable coastal terrace would not have been possible. Rather, the sea would have encroached directly against the island's volcanic mass, creating the dramatic sea cliff behind the To'aga site, as described by Stice and McCoy (1968). Only after a maximum sea level was achieved, between ca. 4-2 kyr B.P., could a coastal terrace have begun to have formed along the base of the cliffs. At the same time, we presume that Ofu has been subsiding at a rate of about 1 m/kyr, as depicted in figure 4.6B. Therefore one takes into account these two controlling processes to determine the probable net change in relative sea level as graphed in figure 4.6C. This

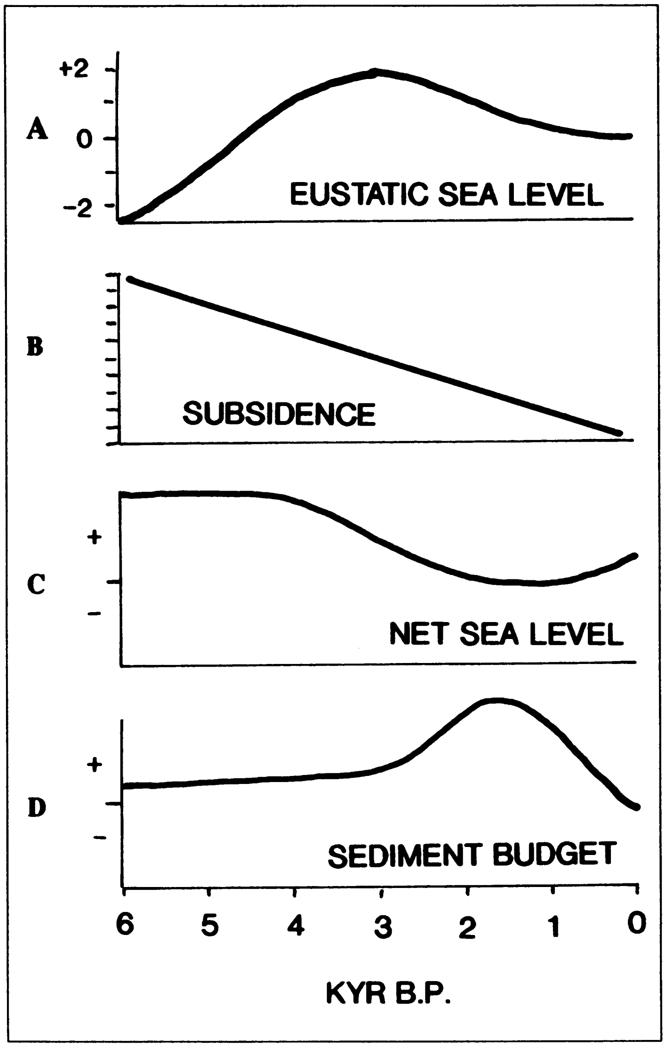

Figure 4.6 Time trends in four key variables affecting the morphodynamics of the To'aga coastal plain.

graph predicts that the most likely period during which the To'aga terrace could have prograded through the rapid deposition of biogenic sediments would have been between ca. 2-1 kyr B.P., when the eustatically controlled sea level dropped from its mid-Holocene maximum down to modem levels. Depending upon the extent of this drop (1-2 m), the actual sea level on Ofu would have been either stable, or there may have been a slight fall. This would have resulted from the eustatic sea-level fall, off-setting the continual effects of tectonic subsidence. As shown in figure 4.6D, the biogenic sediment budget would increase significantly during this period as the coral reef fronting the To'aga area was exposed to wave action, especially storm surges. During the past 1 kyr B.P., as sea levels again stabilized and local tectonic subsidence continued, the sediment budget would again have decreased, so that a phase of regression recommenced. This is consistent with our field observations of active shoreline erosion at the present time along the To'aga site.

This model of the formation of the To'aga site can also be diagrammed as a temporal trajectory along the two axes shown earlier in figure 4.3. In figure 4.7, we have plotted a retrodiction of the most probable transgression-regression sequence for the To'aga shoreline over the course of the past 6 kyr B.P. In this diagram, the *y*-axis represents the net sea-level change resulting from the combination of both glacio-eustatic and local tectonic effects, while the *x*-axis represents the changing sediment budget.

This model provides a working hypothesis for the formation of the To'aga coastal terrace and its archaeological deposits and may be tested against the stratigraphic and radiometric evidence derived from our program of transect excavations at various points along the site. Several predictions may be generated based on the model: (1) The earliest archaeological deposits should be located adjacent to the cliffs and should date no earlier than about 4 kyr B.P. (2) These early sediments are likely to have a higher component of volcanic clastics, because talus material would still have been readily available for erosion by wave action. (3) There should be a fairly rapid or even abrupt episode of coastal progradation beginning sometime after about 2 kyr B.P. and ending by about 1 kyr B.P. The sediments deposited during this interval would consist almost wholly of marine biogenics.

This model was not developed prior to the actual fieldwork, but evolved during the course of our investigations, as a dialectic between field observations and theoretical exercises. Nonetheless, it is crucial to stress that the model in no way depends on our archaeological data; it is wholly independent, deriving from current geological and geomorphological knowledge of coastal processes in the southwest Pacific. To briefly anticipate the results of our field and laboratory studies presented in chapters 5, 6, and 7, we shall see that the predictions of the model developed here are substantially borne out.

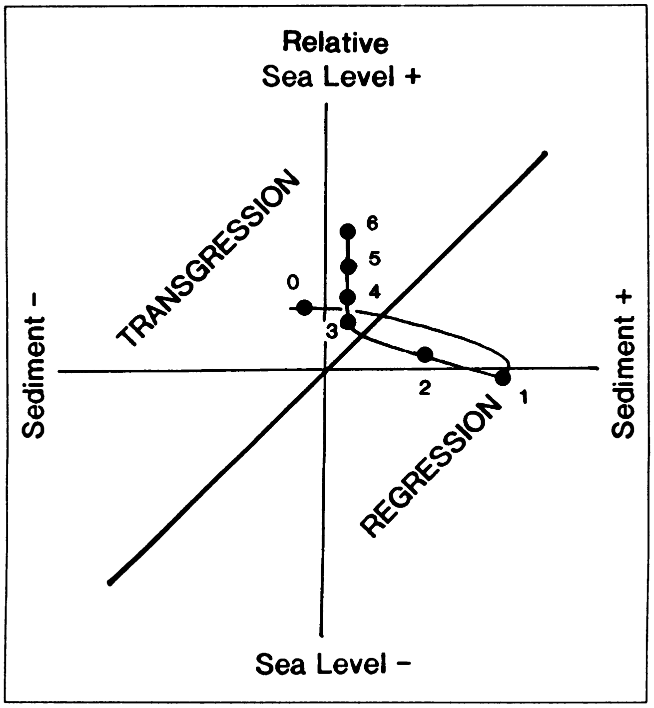

Figure 4.7 Retrodiction of the transgression-regression sequence along the To'aga coastline from 5 kyr B.P. to the present.

TO'AGA: SOME FURTHER EXPECTATIONS FOR ARCHAEOLOGICAL SITE FORMATION PROCESSES

Schiffer has averred that "during human occupation of regions, natural processes, influenced by cultural behavior, have created an ever-changing landscape that the investigator perceives at just one point in time. The contemporary region is a complex, three-dimensional mosaic consisting of natural sediments, vegetation, modern artifacts and settlements, and archaeological remains. In order to find sites and, especially, to understand how settlements functioned in regional systems, one must endeavor to infer or reconstruct changes in the landscape" (1987:261). In this chapter, I have endeavored to model some of the key processes which contributed to the formation and modification of archaeological deposits in the To'aga area. Lying at a fragile interface between land and sea, the To'aga coastal terrace is subject to environmental influences of several kinds, and can potentially undergo rapid changes if any of these inputs vary. This interfacial zone has also been subject to intensive human use which has implications for both the formation and modification of the archaeological record.

Among the most important implications of our model of morphodynamics of the coastal terrace is that the very existence of this interfacial microenvironment depends upon a sediment budget which has fluctuated highly during the mid- to late-Holocene. Since the archaeological deposits at To'aga are an integral part of the geomorphological structure of this zone, it is essential that we understand these processes of coastal terrace construction and erosion. To quote Schiffer again, "from the standpoint of survey [and excavation] design, the archaeologist needs to know where deposition and erosion are occurring and where they have occurred during the period of human occupation of the region" (1987:257). Our model of relative sea level and sedimentary budgets suggests that the To'aga coastal terrace could not have begun to form or stabilize until after the Holocene sea-level maximum of about 5-3 kyr B.P. Given that the Western Polynesian region was first colonized by the makers of Lapita pottery at about 3.4-3.2 kyr B.P. (Kirch and Green 1987; Kirch and Hunt 1988), the area of coastal terrace available for initial establishment of human habitations would have been very restricted, probably consisting of little more than a beach ridge lying directly under the steep cliff. As the coastal terrace began to rapidly prograde after about 2 kyr B.P., the area available for intensive land use would have increased substantially. Such progradation, however, combined with deposition of colluvium, probably would bury the earlier occupation deposits deeply. Thus, our morphodynamic model also implies that the earliest archaeological deposits will be the most difficult to locate, being situated farthest inland and possibly buried under substantial depths of colluvium. The model predicts, therefore, that archaeological deposits dating to the earliest phase of Samoan prehistory—the phase marked by the presence of ceramic assemblages—are not likely to be exposed on present ground surfaces or to be encountered by surface survey alone, no matter how intensive. Indeed, the initial archaeological reconnaissance of the island by Sinoto and Kikuchi [Emory and Sinoto 1963] failed to locate a single site of this early period.

The model also has implications for the longer-term management of archaeological sites or 'cultural resources' of the To'aga area. We explore these implications in more detail in chapter 15, but briefly note here that if, as our model predicts, the To'aga area is now undergoing a phase of active erosion and shoreline transgression, the archaeological sites of this area will in time be eroded away. How quickly these sites will be threatened by erosion depends on several factors, especially the rate of subsidence and of eustatic sea-level rise. The problem of 'global warming' and associated sea-level rises (Geophysics Study Committee 1990), however, could potentially result in an acceleration of coastal erosion in the To'aga area.

ACKNOWLEDGEMENTS

I am particularly grateful to Joanna Ellison of the Department of Geography, University of California at Berkeley, for kindly supplying me with various references on sea-level change in the southwest Pacific, for the use of figure 4.4, and for her comments on an earlier draft of this chapter.

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5

EXCAVATIONS AT THE TO'AGA SITE (AS-13-1)

PATRICK V. KIRCH AND T. L. HUNT

INTRODUCTION

PRIOR TO THE COMMENCEMENT of the Manu'a Project in 1986, our knowledge of the archaeology and prehistory of the Manu'a Islands was limited to a few late prehistoric architectural sites and to surface finds of stone adzes and flakes (Kikuchi 1963; Emory and Sinoto 1965; Clark 1980). No well-stratified occupation sites were known, and there was no established sequence of occupation phases extending back to the Ancestral Polynesian period, as had been developed for Western Samoa (Green and Davidson 1969, 1974). Indeed, previous archaeological reconnaissance in Manu'a had failed to locate any sites that contained prehistoric pottery and thus might date to the first millennium B.C., based on comparisons with the Samoan sequence as defined for 'Upolu Island. A major goal of our 1986 reconnaissance survey of Ta'u, Olosega, and Ofu islands was thus to determine whether the apparent absence of ceramic-bearing sites was simply an artifact of archaeological sampling, or whether such early period sites were truly absent in the Manu'a Group.

The surface find of a Polynesian Plain Ware sherd in Ta'u Village on the first day of our 1986 reconnaissance was followed up by test excavations, revealing the presence of subsurface occupation deposits dating to the Ancestral Polynesian period (Hunt and Kirch 1988). This discovery was sufficient to establish that the prehistory of the Manu'a Islands would in general terms parallel that of the larger and better known Western Samoan group. Moving from Ta'u to Ofu Island, we subsequently discovered a pottery-bearing site at To'aga on the southern coast, where the Public Works Department had bulldozed a landfill dump and thereby exposed subsurface deposits. This area was within the site AS-13-1 defined by Clark (1980). We carried out a limited test excavation at the To'aga landfill in 1986, recovering pottery and other artifacts *in situ* (see below). Because of the significance of the To'aga materials for elucidating Manu'a prehistory, we expanded our excavations in 1987, revealing that the site was far more extensive than originally thought. A third season of transect test excavations was carried out in 1989 to assess the full area of this extensive and deeply stratified site. In this chapter, we present the details of these three excavation seasons, including the specific excavation procedures used, as well as the stratigraphy and depositional sequences revealed. Subsequent chapters provide detailed analyses of the ceramics, other portable artifacts, and faunal materials, as well as discussions of radiocarbon chronology and site geomorphology.

Field Methods: General Comments

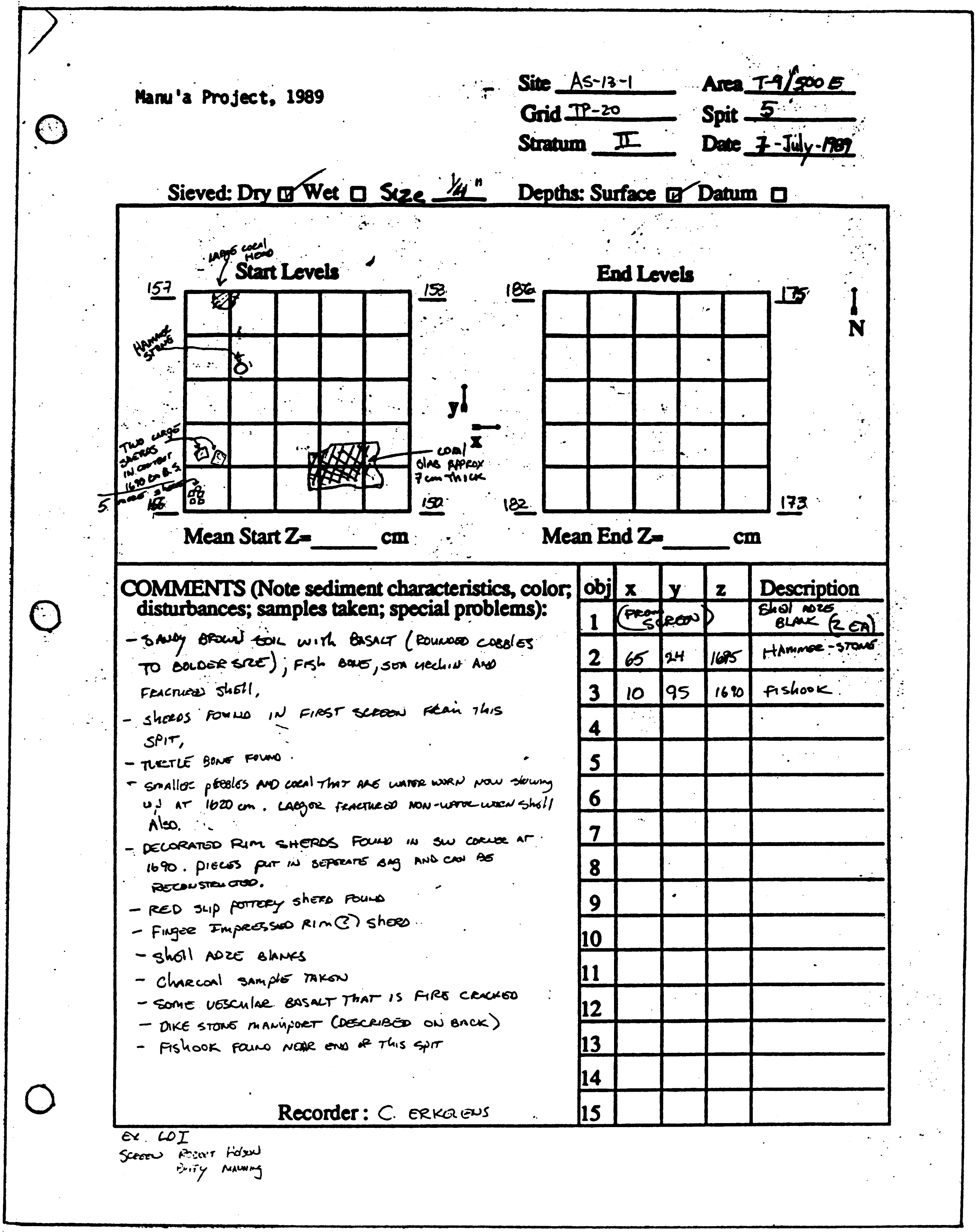
Some aspects of field methodology which were constant in all field seasons may be briefly summarized. The principal sampling strategy used was that of "systematic transects" (Redman 1974; Kirch and Yen 1982; Kirch 1988), with 1-m excavation units generally spaced at 10 m intervals. We oriented these transects perpendicularly to the coastline in order to provide geomorphic profiles across the coastal flat. All transect profiles were carried out to the reef flat and correlated to mean sea level. Using a telescopic level and stadia rod, a surface elevation profile was obtained for each transect. Observations were also made of soil variation and vegetation associations along the transect, as these data indicated current land use and provided important clues as to the geomorphic history of the site. This strategy of acquiring data (surface and excavation) along systematic transects has the advantage of producing results that can be mapped and interpolated.

Whenever possible, excavation proceeded according to natural stratigraphy, although arbitrary subdivisions were made within thick strata. Individual excavation blocks (referred to as "spits") were designated within strata, but never cross-cut stratigraphic boundaries. Detailed records were maintained on standardized recording forms (fig. 5.1), on which horizontal features were drawn to scale and all localized finds were plotted according to *x*, *y*, and *z* coordinates. After excavation, measured stratigraphic profiles were drawn for each excavation unit, and all strata were described in terms of thickness, boundary, morphology, color, lithology, cultural content, and other characteristics. Color designations are from the Munsell soil color charts (Munsell 1988). Most profile descriptions were done by Kirch to assure consistency (in 1989, Hunt described several units after Kirch left the field to initiate a project in the Cook Islands). Following the drawing and description of each profile, a series of sediment samples were taken; sediment samples were taken from within strata, never cross-cutting stratigraphic boundaries. These samples were subsequently analyzed in the University of California, Berkeley, geoarchaeology laboratory (see Kirch, Manning, and Tyler, chapter 7).

All excavated sediment was sieved through 0.25 inch mesh screens. Although smaller mesh (particularly 0.125 inch mesh) would have enhanced the recovery of minute faunal remains, we opted against this screening strategy in the interests of covering a greater area during this testing phase. Given our primary objective of determining the areal extent and nature of the subsurface deposits at To'aga, sufficient areal sampling was judged to be a more important consideration than complete faunal recovery. During screening, however, we made periodic checks of the small size fraction passing through the 0.25-inch mesh screens and were generally satisfied that the bulk of the faunal materials was being retained. In addition, bulk sediment samples were taken from strata in the areal excavation blocks, as well as from some of the individual test pits (see Nagaoka, chapter 13). These samples allowed us to assess the frequency of minute faunal remains. All vertebrate and invertebrate faunal materials caught in the sieves were bagged and shipped back to the laboratory for identification and analysis. Preliminary sorting of the vertebrate fauna, as well as detailed identifications of the avifaunal remains, were carried out by Dr. David Steadman of the New York State Museum (see chapter 14). Further analysis of the non-bird vertebrates and of the invertebrate fauna was undertaken by Lisa Nagaoka of the University of Washington (see chapter 13).

The numbering of stratigraphic units (distinguished by roman numerals) is based primarily on sedimentological (rather than cultural) criteria. Each sedimentological-lithological unit that was determined to have been deposited either as a single event, or as several events all representing the same source and mode of deposition, was designated as a "layer." Subunits within these sedimentological layers, including cultural occupations, are designated by letters. Hence, an occupation episode that is wholly incorporated within a calcareous sand beach ridge deposit, Layer III for example, might be designated as Layer IIIB, with the culturally sterile, but lithologically identical sands above and below designated Layers IIIA and IIIC. Thus, our layer designations emphasize the geomorphological site formation processes rather than simply the presence or absence of cultural materials.

In describing the lithology of beach ridge depositional units, we paid special attention to admixture of volcanic lithic grains with the dominant calcareous grains. When volcanic grains are present, these give the sediment a 'salt-and-pepper' appearance. The significance of this 'salt-and-pepper' lithology is that it reflects the availability of a volcanic sediment source from which sand grains



Manu'a Project, 1989

Site AS-13-1
Area T-9/500 E
Grid TP-20
Spit 5
Stratum II
Date 7-July-1989

Sieved: Dry ☑ Wet ☐ Size 1/4" **Depths:** Surface ☑ Datum ☐

Start Levels

End Levels

Mean Start Z=______ **cm** **Mean End Z=**______ **cm**

COMMENTS (Note sediment characteristics, color; disturbances; samples taken; special problems):

- SANDY BROWN SOIL WITH BASALT (ROUNDED COBBLES TO BOLDER SIZE); FISH BONE, SEA URCHIN AND FRACTURED SHELL,
- SHERDS FOUND IN FIRST SCREEN FROM THIS SPIT,
- TURTLE BONE FOUND
- SMALLER PEBBLES AND CORAL THAT ARE WATER WORN NOW SHOWING UP AT 1620 cm. LARGER FRACTURED NON-WATER-WORN SHELL ALSO.
- DECORATED RIM SHERDS FOUND IN SW CORNER AT 1690. PIECES PUT IN SEPERATE BAG AND CAN BE RECONSTRUCTED.
- RED SLIP POTTERY SHERD FOUND
- FINGER IMPRESSED RIM(?) SHERD
- SHELL ADZE BLANKS
- CHARCOAL SAMPLE TAKEN
- SOME VESCULAR BASALT THAT IS FIRE CRACKED
- DIKE STONE MANUPORT (DESCRIBED ON BACK)
- FISHOOK FOUND NEAR END OF THIS SPIT

Recorder: C. ERKELENS

obj	x	y	z	Description
1	(FROM SCREEN)			SHELL ADZE BLANK (2 EA)
2	65	24	1685	HAMMER-STONE
3	10	95	1690	FISHOOK
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

EX. LOI
SCREEN ROBERT HOLSON
BETTY MANNING

Figure 5.1 Example of the excavation recording form used in the 1987 and 1989 To'aga field seasons. This form is for level 5 of Unit 20 on Transect 9.

were produced by wave action along the former shoreline. Today, the sandy beaches fronting To'aga are almost purely calcareous. Volcanic grains are present only in a few spots, where volcanic headlands protrude through the coastal terrace and are exposed to wave action. The frequent presence of 'salt-and-pepper' lithologies in deeply buried deposits exposed by our excavations indicates a landform stage when the coastal terrace was much narrower (prior to progradation), and when substantially more volcanic material was available for incorporation into the sediment budget. Thus, along most transects, there is a transition from deeper, earlier 'salt-and-pepper' sand lithology to purely calcareous lithology, reflecting coastal progradation and removal of most volcanic source material from the sediment system. In chapter 7 we use point counting of sediment samples to further document the precise quantities of volcanic lithic grains in strata within various excavation units.

1986 TEST EXCAVATION

The To'aga site (AS-13-1) was initially discovered during the 1986 reconnaissance survey, when examination of a deep bulldozer cutting made by the Public Works Department for a sanitary landfill disturbed a buried cultural deposit containing Polynesian Plain Ware ceramics (Hunt and Kirch 1988:168). The bulldozer cutting lies at the edge of a fan of massive talus boulders. It appears that the landfill site is at the inland-most location possible on this particular section of the coastal flat. A single test pit (1 m^2) was placed directly adjacent (3 m west) to the bulldozed area of the To'aga landfill. This locale had remained undisturbed by the bulldozer activities.

Excavation of the test pit (designated Unit A) revealed the following major strata:

Layer I: This dark (2.5 Y 2/0) mucky sand mixed with colluvial clay is enriched with organic matter (contemporary A soil horizon). It contains coral pebbles, shell midden (mostly *Turbo* spp.), and waterworn basalt pebbles and cobbles. Layer I reached a maximum depth of 60-70 cm below surface. The contact with Layer II is diffuse over a 1-3 cm zone.

Layer II: This layer had mottled pale yellow to grayish brown (2.5 Y 7/2 & 5/2) calcareous sand containing coral and basalt pebbles and cobbles, shell midden (mostly *Turbo* spp.), and ceramics (four thickware sherds only). Layer II reached a maximum depth of 135 cm below surface. The contact with Layer III is very diffuse. A single radiocarbon date (Beta-19742) on *Turbo* shell yielded a conventional radiocarbon age of 2350 ± 50 B.P. (cal 28 B.C.-A.D. 108 at one standard deviation; see chapter 6).

Layer III: No cultural material was present in the white (10 YR 8/2) calcareous sand of this layer. Excavation of test Unit A reached a maximum depth of 160 cm below surface.

Subsequent work in 1987 revealed that these major stratigraphic zones fit well within the geomorphological sequence for the To'aga flat as a whole (see below). Artifacts collected from the bulldozed area of the To'aga landfill and from Unit A were described and illustrated by Hunt and Kirch (1988:169-76) and are included here in chapter 11.

THE 1987 EXCAVATIONS

The 1986 surface collections from the landfill site, combined with the limited results from the test excavation, revealed the presence of early Polynesian occupation deposits in the To'aga area. Along with the discovery of pottery at Ta'u Village on Ta'u Island (Hunt and Kirch 1988), this was the first record of an early phase of occupation in the Manu'a Islands. With the concurrence of the American Samoa Historic Preservation Officer, we therefore determined that a major objective for a second season of fieldwork in Manu'a should be more intensive investigation of the To'aga site, with the application of subsurface systematic transect testing in order to determine whether undisturbed pottery-bearing occupation deposits were present in the vicinity of the landfill site. This second phase of work was carried out in 1987.

Excavation Procedures

Returning to the To'aga site in 1987, we focused on the coastal flat immediately northeast of the landfill which had not been disturbed by bulldozing (fig. 5.3). As can be seen in the transect profile in figure 5.2, this flat is about 125 m wide from the base of the steep colluvial-talus slope to the

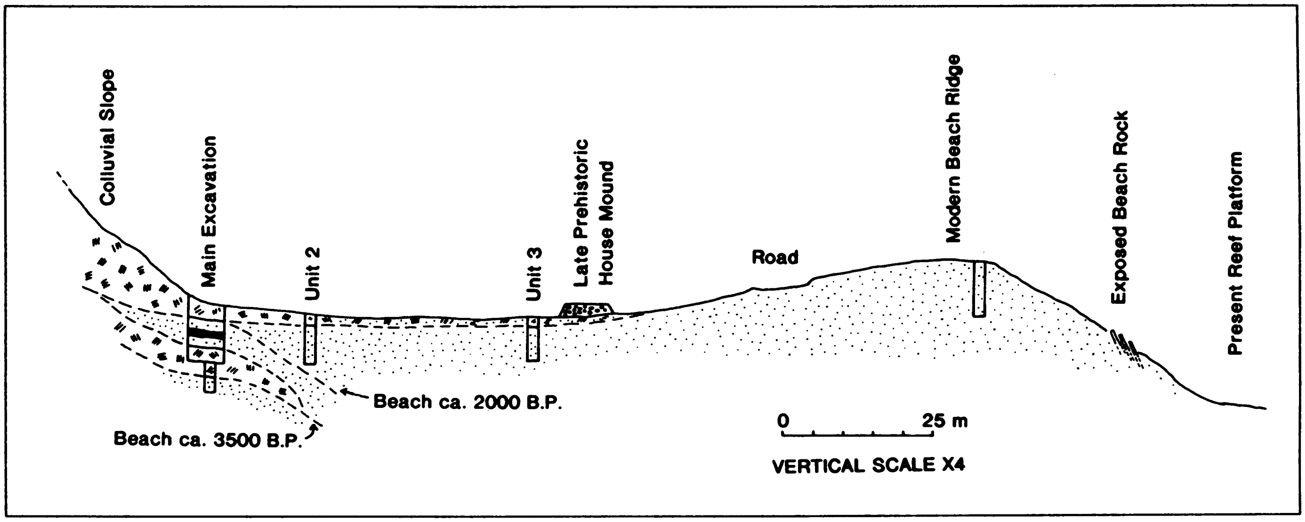


Figure 5.2 Elevation profile along the 1987 excavation transect, showing the positions of the main excavation and Units 2 and 3, in relation to geomorphic and pedologic features.

present shoreline. Using the systematic transect strategy developed by Kirch for sub-surface sampling in similar coastal settings in Tikopia and Niuatoputapu islands (Kirch and Yen 1982; Kirch 1988), we laid out a transect baseline extending across the To'aga coastal flat, at a location 60 m northeast of the Ofu landfill. The first three units excavated along the transect (at 0, 15, and 45 m from the base of the talus slope) revealed a complex and deep cultural stratigraphy in Unit 1, but only shallow cultural deposits overlying calcareous beach sands in the more seaward Units 2 and 3. A shovel test at 105 m farther seaward along this transect, near the crest of the modern beach ridge, revealed a total absence of cultural deposits, with only calcareous sand. These tests thus demonstrated that the oldest cultural deposits were to be found close to the base of the steep talus and volcanic cliff, and that most of the coastal flat consisted of culturally sterile coral sands and reef detritus, which had been deposited during seaward progradation during the past 2-3 kyr B.P.

Following these initial transect tests, Unit 1 was expanded into a larger excavation in order to effectively sample the deep stratigraphic sequence, including the *in-situ* deposits of Polynesian Plain Ware ceramics. Units 4-9 were excavated, joining with Unit 1 to form a T-shaped trench as shown in figures 5.3 and 5.4. All units were dug through the Layer II calcareous sand deposit containing pottery, while Units 1 and 6 were carried deeper into underlying Layers III and IV (see Stratigraphy, below).

The third stage of our 1987 excavation strategy was to determine the lateral extent of the early pottery-bearing deposits southwest and northeast of the main excavation, parallel to the base of the talus. Unit 10 was thus laid out 45 m southwest of the baseline transect, as close to the base of the talus as feasible (actually set in among several massive rockfall boulders). This revealed a stratigraphy similar to that in the main trench, including deeply buried cultural deposits with Polynesian Plain Ware and one fine, thin-ware sherd. Unit 11 was then laid out 45 m northeast of Unit 1. Unit 11 revealed ceramic-bearing deposits, but these were truncated by a large, deep pit (probably a late prehistoric *lua'i masi* or breadfruit-fermentation pit), and so an adjacent square, Unit 14, was opened to clarify the stratigraphy. In order to get as close as possible to the base of the talus, another test was laid out 15 m northwest of Unit 11, at the foot of the talus and designated Unit 12. In Unit 12, a massive deposit of colluvium and large angular boulders had to be penetrated to a depth of 1.8-1.9 m before we were able to reach a thin deposit of calcareous sand containing four thin, fine-tempered potsherds (one rim and four body sherds). These test units indicated that early, pottery-bearing cultural deposits at To'aga extend over a distance of at least 105 m northeast of the Ofu landfill, in a narrow zone at the base of the colluvial-talus slope.

A final test, Unit 13, was opened in the center of

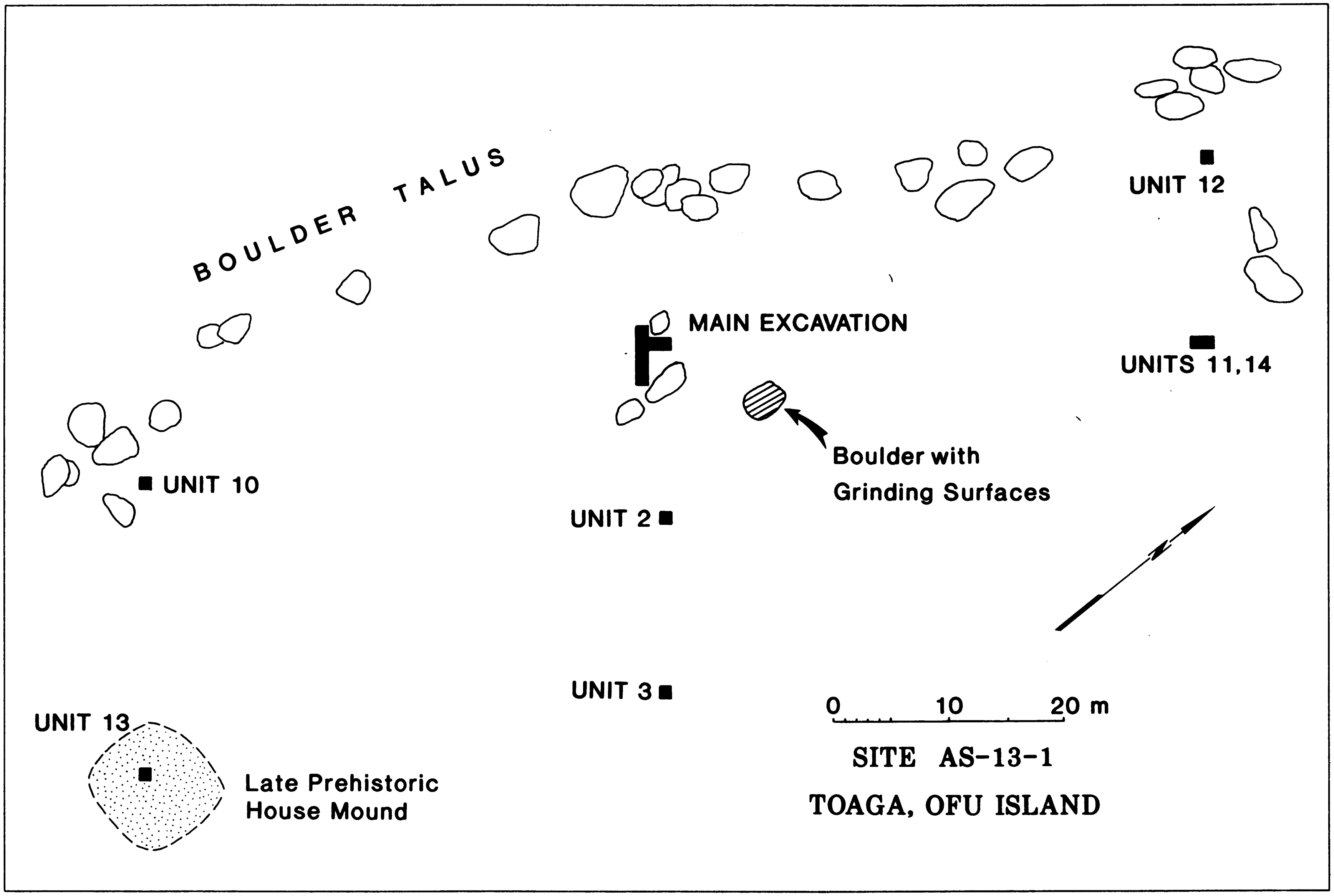


Figure 5.3 Map of the 1987 excavation area, showing the locations of excavations units. See figure 5.8 for the location of the area shown here in the larger To'aga study area.

Figure 5.4 Excavation in progress in the 1987 main trench. Note the large talus boulder on the left. P. Kirch is recording the stratigraphy of the south face of Unit 1.

a low pavement of waterworn pebbles (such pavements are called *'ili'ili* in Samoan) apparently marking a later prehistoric house floor. Our objective in excavating Unit 13 was to obtain a sample of this later prehistoric midden to contrast with the older, ceramic-associated assemblage.

Stratigraphy of the 1987 Main Excavation

Although the stratigraphy of the 1987 excavations varied from unit to unit, the most complete depositional sequence was revealed in the main trench excavations (Units 1, 4-9), but was reflected as well in Units 10, 11, 12, and 14. Seaward of the main trench, Units 2 and 3 displayed simpler stratigraphic profiles, resulting from the later progradation of calcareous beach sands.

The western profile of the 1987 main trench is shown in figure 5.5, in which all of the principal depositional units are represented. The stratigraphic units follow:

Layer IA: The upper 15-20 cm portion of the upper colluvium (10 YR 3/1.5) found here has been heavily reworked by gardening. Various planting pits or depressions are detectable in the section.

Layer IB: This is a massive deposit of reddish brown colluvium (10 YR 3/2), very compact, with no internal lensing or bedding evident. No charcoal flecking was observed. The deposit incorporates numerous angular to subangular weathered volcanic lithic fragments in the gravel-to-pebble size range. A small, lens-shaped pocket of slightly darker soil containing charcoal flecking was noted within Layer IB (designated Feature 1) and may represent a garden burn feature. This would suggest that Layer IB accumulated gradually and that the land surface was intermittently gardened during its deposition.

Layer IC: The basal 15-20 cm of the upper colluvium (10 YR 2/1) makes up this stratum. It is somewhat darker than the overlying Layer IB, containing dispersed flecks and chunks (5-10 mm) of charcoal. The deposit is associated with an earth oven feature in Unit 9, and the charcoal (which is concentrated in a zone around the oven) appears to

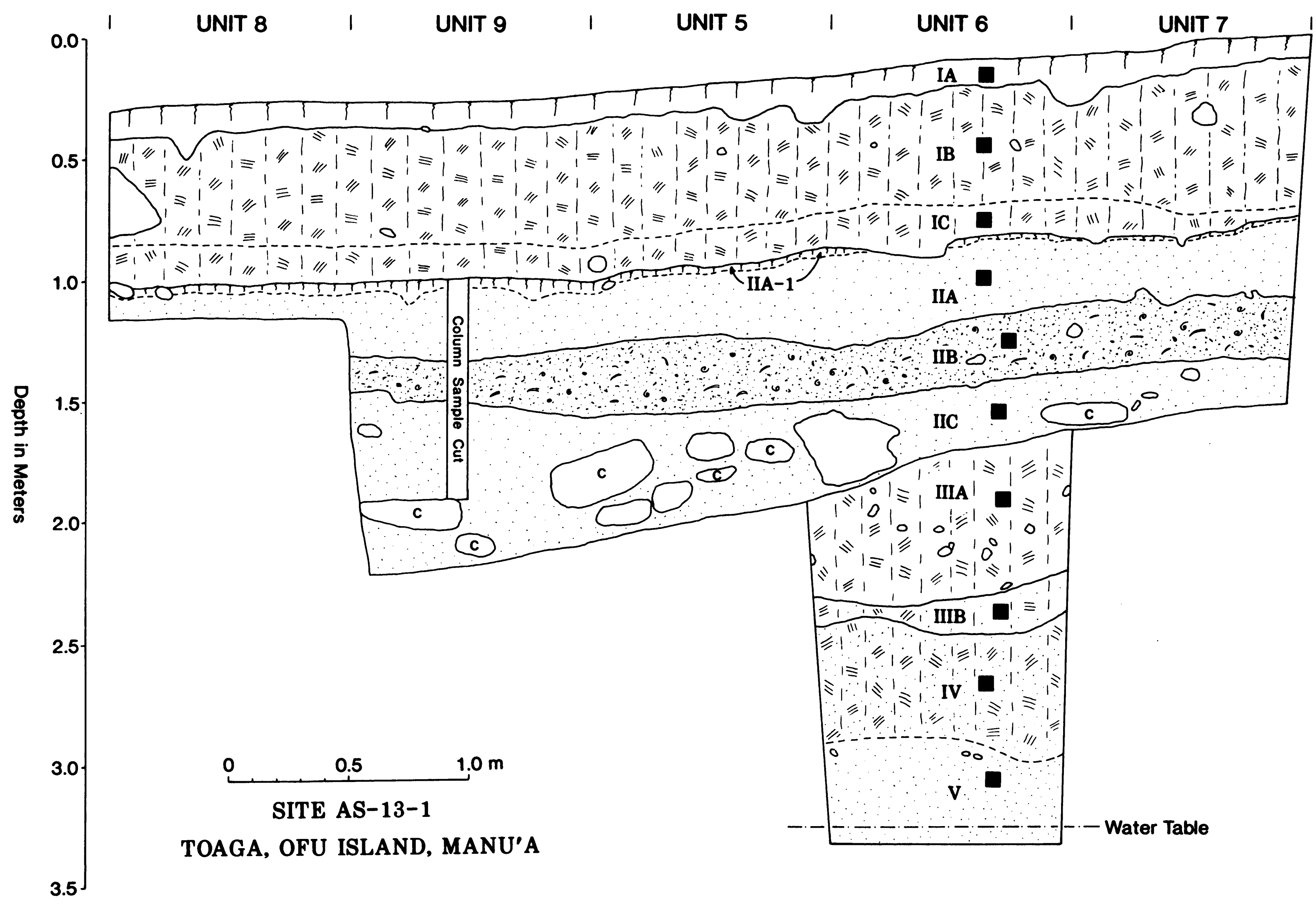


Figure 5.5 Stratigraphic section of the southwest face of the 1987 main excavation (Units 5-9). Black squares indicate the position of sediment samples; "C" indicates coral cobbles.

have derived from oven rake outs. Some thick, coarse-tempered pottery was also recovered from this deposit. It does not appear to have been a permanent occupation, however, and may represent a short-term or intermittent occupation such as a field shelter on a former land surface.

Layer II: This unit with its subdivisions represents a period of active deposition of a calcareous beach ridge.

Layer IIA-1: A thin zone at the top of Layer IIA, slightly darker and organically enriched (10 YR 5/2), this stratum contains anthropophilic land snails and represents a phase of stabilization and vegetation of the Layer II sandy beach ridge. Some occupation in the vicinity is suggested by the presence of a few thick, coarse-tempered sherds and a thin scatter of marine shell midden.

Layer IIA: This deposit contains loose, calcareous beach sand (10 YR 7/2), not compacted or cemented and lacking cultural materials. Although most of the sediment consists of calcareous materials, there is a subordinate quantity of basaltic lithic grains, giving the sand a distinct 'salt-and-pepper' appearance. This indicates that at the time of deposition there were exposed volcanic headlands in the vicinity of the beach, providing a source for the basaltic sand grains.

Layer IIB: This principal pottery-bearing deposit represents a period during which the surface of the actively accumulating sandy beach ridge was occupied. Lithologically, Layer IIB is similar to IIA and IIC, but with the addition of organic/cultural materials due to human occupation making it both darker (7.5 YR 4/2) and more compacted. The deposit contains shell and bone midden, large quantities of small sea urchin spines and test fragments, ceramic sherds (primarily of thick, coarse-tempered ware), and other artifacts. It also contains anthropophilic land snails. The deposit is non-concentrated and probably accumulated over a fairly brief span of time.

Layer IIC: This layer, the basal component of the Layer II beach ridge consists, as with IIA, of a 'salt-and-pepper' lithology with dominant calcareous grains and a subordinate quantity of volcanic lithic fragments (10 YR 5/2). Toward the base of this deposit are numerous large coral cobbles and some angular volcanic cobbles, along with branch coral fingers and coral rubble. This material indicates a relatively high energy depositional environment, such as storm activity along an exposed beach front. Thirteen sherds of thin, fine-tempered ware were present, although the deposit showed no evidence of being an *in-situ* occupation locale.

Layer III: Massive silty-clay colluvium (7.5 YR 3-4/2) with some incorporated subangular lithic fragments makes up this layer. Occasional charcoal flecks are present, particularly near the top of the deposit. Nine thin, fine-tempered potsherds were also incorporated in the deposit. It appears to represent a single depositional event, resulting from a combination of mass-wasting and fluvial transport of terrigenous sediment from the colluvial slope above the site. A lower zone, designated Layer IIIB, incorporates some sand mixed from Layer IV, presumably at the time of deposition. The presence of charcoal flecking indicates burning of this slope prior to the deposition of the sediment, perhaps due to gardening or other human disturbance.

Layer IV: Here one encounters a mixed deposit of fine-grained calcareous sand and reddish silt-clay (7.5 YR 5/4), apparently culturally sterile.

Layer V: This basal deposit of 'salt-and-pepper' sand (10 YR 8/2) includes marine shell and reef detritus; fairly compact, and showing the initial stages of cementation probably due to frequent ground-water wetting. The deposit represents an active beach ridge depositional environment. It yielded two sherds of thin, fine-tempered ware, which may have derived from a primary occupation locus behind the beach (which would now be buried under at least 10 m of colluvium).

Excavation Units 2 and 3

The stratigraphies of Units 2 and 3, seaward of the main excavation, were essentially identical; the section for Unit 3 (fig. 5.6) is typical:

Layer I: This organically enriched, silty-clay loam is presently under cultivation. Lithologically, the deposit is a mixture of calcareous sand (77%), silt, and clay-sized terrigenous grains, the latter deriving from sheet wash erosion from the colluvial slope. Various planting depressions filled with loose, reworked soil are visible in the section. The deposit also contains fragments of marine shell midden from occupation in the vicinity. An earth oven feature was exposed in the west face of the unit.

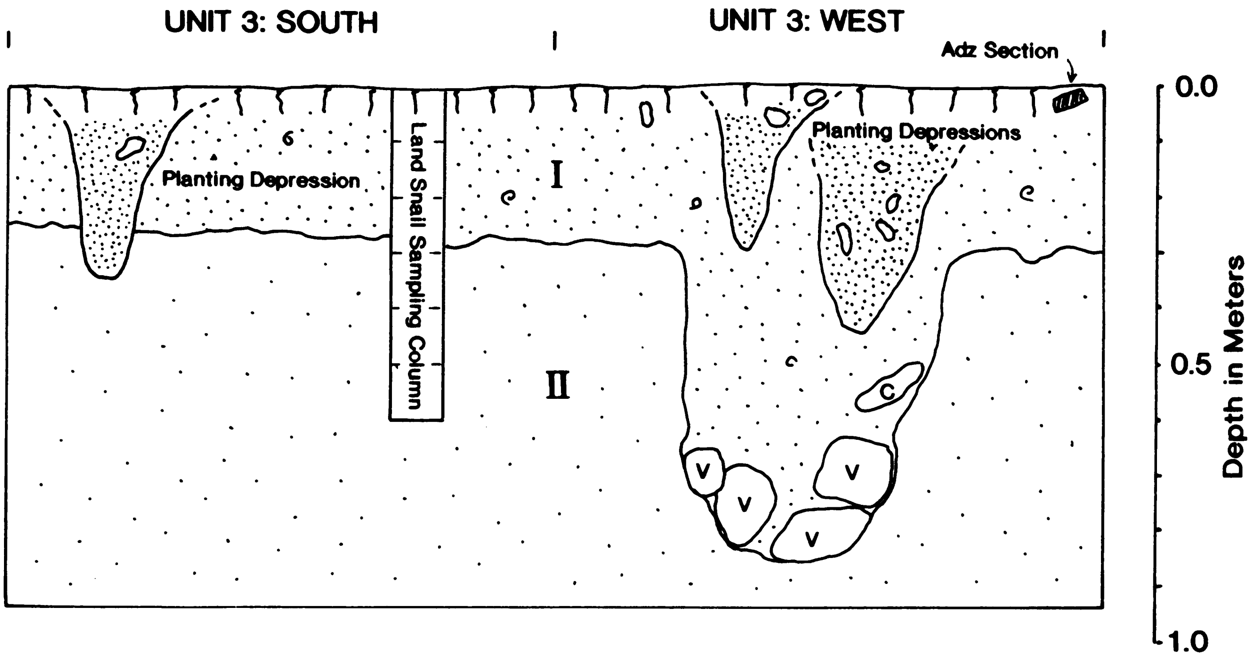


Figure 5.6 Stratigraphic section of the south and west faces of Unit 3. "C" indicates coral, and "V" indicates volcanic.

Layer II: Here one encounters loose, calcareous beach sand which is culturally sterile. This deposit is composed wholly of calcareous grains and lacks the 'salt-and-pepper' combination of calcareous and basaltic grains found in the Layer II deposit in the main excavation This absence indicates that by the time of deposition of Layer II in Unit 3, the coastline had prograded sufficiently to bury the volcanic headlands.

Excavation Unit 10

As shown in figure 5.3, Unit 10 was located 45 m southwest of the 1987 baseline transect. The pit was situated in a small clear space between several very large boulders, at the base of the steep talus. Our aim here was to get as close to the talus as possible, in the hope of exposing deeply buried cultural deposits. This unit revealed a stratigraphic sequence similar to that in the main excavation trench. The north and east faces of Unit 10 are shown in figure 5.7. The strata are described below:

Layer IA: This upper portion of the colluvium (5 YR 3/2) is presently gardened and thus loose and reworked. Its silty clay loam includes angular lithic gravel. The contact with Layer IB is diffuse over a 2-3 cm zone.

Layer IB: This very compact deposit of clayey colluvium (5 YR 4/4) contains subangular lithic fragments. Occasional charcoal flecks are present. There is no evidence that this zone had been reworked by gardening, and it probably represents a single depositional event. The contact with Layer IC is diffuse over a 2-3 cm zone.

Layer IC: The basal portion of the colluvium (5 YR 3/2), this deposit is similar to IA, and may represent an older land surface that was gardened. It is less compact than Layer IB and contains some anthropophilic land snails (e.g., *Lamellaxis gracilis*). Also, some disturbances penetrate down into Layer II. The contact with Layer II is distinct.

Layer IIA-1: This thin, discontinuous deposit of calcareous sand is enriched with organic matter and stained gray (color 5 YR 4/1). Land snails of several genera are present, indicating the former presence of a stable land surface with vegetative cover. This deposit is a former paleosol formed on the old beach ridge represented by Layer II. It reflects a phase of stability capping the earlier phase of beach ridge accumulation. This paleosol must have formed after progradation of the shoreline removed the source of calcareous sediment that had resulted in the deposition of the deeper Layer II deposits. The contact with Layer IIA is diffuse and gradational over a 3-4 cm zone.

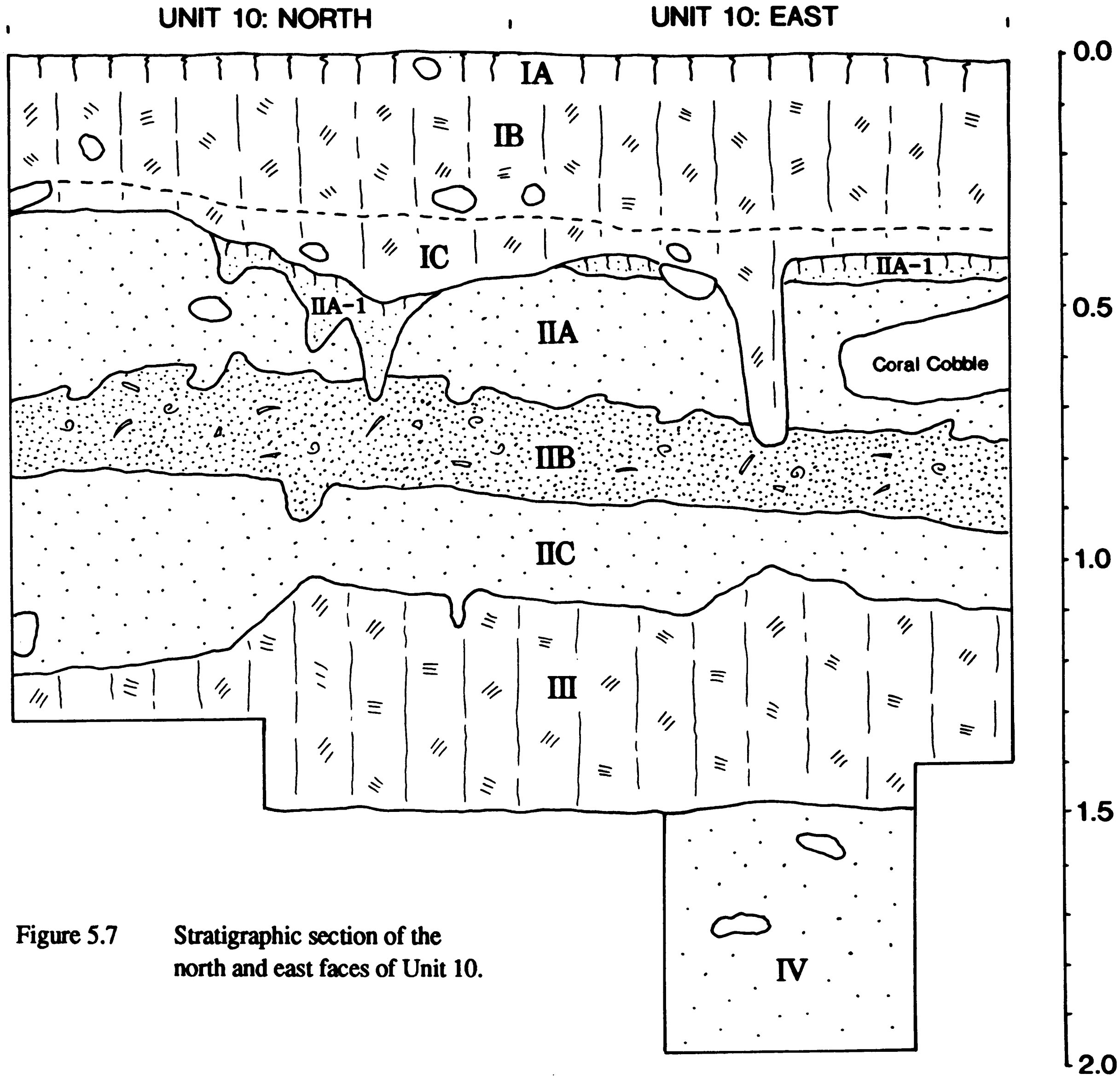


Figure 5.7 Stratigraphic section of the north and east faces of Unit 10.

Layer IIA: A culturally sterile deposit of 'salt-and-pepper' sand (7.5 YR 7/2), this stratum is predominantly calcareous but incorporates some volcanic grains indicating the exposure of volcanic headlands near the site at the time of deposition. The deposit is fairly loose and was probably developed rapidly after the abandonment of the underlying Layer IIB occupation. The contact with Layer IIB is very irregular but relatively sharp.

Layer IIB: This is a ceramic-bearing occupation deposit (7.5 YR 5/2). The parent lithology is essentially identical to Layer IIA. This layer represents a period of occupation on the beach ridge while the active deposition of sandy sediment continued, primarily through aeolian action. The deposit is stained grey with finely dispersed organic material but is very sparse in midden (not nearly so concentrated as Layer IIB in the main excavation trench). The contact with Layer IIC is diffuse.

Layer IIC: The mixture of calcareous sand and reddish clay (7.5 YR 5/4) found here probably results from fluvial/hydraulic transport of the clay from the talus upslope. It is culturally sterile. The contact with Layer III is sharp but irregular.

Layer III: This compacted deposit of reddish brown clay-silt (5 YR 3/4) includes no larger lithic fragments, suggesting a fluvial rather than mass-wasting mode of deposition. No charcoal flecks were observed. This deposit appears to represent a single depositional event, perhaps associated with a storm or cyclone. The contact with Layer IV is somewhat diffuse and mixed.

Layer IV: The 'salt-and-pepper' beach sand (10 YR 8/2) of this layer incorporates larger coral cobbles and waterworn branch coral fingers. The layer represents a fairly exposed, high-energy beach ridge depositional event.

Apart from shell and bone midden, Unit 10 yielded little artifactual material. A few small flakes of obsidian were recovered from Layer IIA-1, and a single thinware body sherd (5.7 mm thick) with an orange (5 YR 5/6) slipped exterior came from Layer IIB.

Excavation Units 11/14

As shown in figure 5.3, Units 11/14 were located 45 m east of the baseline transect. This location is among massive talus boulders where the ground surface is relatively level. Excavation of Unit 11 revealed a large pit feature over the entire unit which extended from the lower colluvium (ca. 55 cm below surface), cutting down through calcareous sand layers to 2.25 m below surface. The fill of this pit contained 181 thickware sherds and 4 thinware sherds (2 with red-slipped exteriors). Field observations indicated that pottery came from the lower deposits adjacent to the pit and not from the pit fill itself. As normal stratigraphy for this area could not be discerned with the intrusion of the deep pit, Unit 11 was expanded into a rectangular trench (1 by 2 m) with the excavation of Unit 14. Unit 14 exposed an undisturbed stratigraphic sequence, as follows:

Layer IA: The upper 20-30 cm of colluvium found here was dark brown (10 YR 3/2) and had been reworked by gardening. This layer contains some charcoal flecking (probably modern) and no pottery.

Layer IB: This massive lower colluvium is very poorly sorted and includes angular volcanic rock fragments with no evident bedding or lenses. No charcoal or other cultural materials were observed in this dark brown (10 YR 3/2) layer.

Layer IC: This stratum contained a dark grayish-brown (10 YR 3/1) mixture of clayey colluvium and calcareous sand with abundant midden, including shell, bone, pottery (309 sherds, with 304 [98%] thick-coarse, and 5 [2%] thinware), and charcoal. This deposit was the source of the fill of the large pit described for Unit 11, but in Unit 14, it made up a discrete area between 54-75 cm below surface. This layer appears to represent a depositional event contemporaneous with Layer IC in the main trench (see above).

Layer II: This calcareous sand deposit is enriched with organic matter and some eluviation of clay particles from the clay-rich Layer IC above. Layer II is brown (10 YR 5/3) and contains pottery (15 thickware sherds) and a relatively sparse amount of shell midden. This stratum is comparable to Layer II in the main area excavation.

Layer III: Calcareous sand (10 YR 7-8/2) with waterworn coral cobbles and unworn branch coral makes up this layer. It contains little cultural material and appears to represent a high energy depositional environment. Layer III compares in lithology and content to Layer IIC in the main trench.

Layer IV: This brown (7.5 YR 4/2) mixture of silty-clay colluvium and calcareous sand has some organic matter. Few larger lithic cobbles or boulders are present, suggesting a sediment that probably represents sorting with surficial flow of the terrigenous source, and wind (saltational) transport of the calcareous (beach ridge) source. A small hearth comprised of waterworn coral boulders surrounding a shallow ash concentration was excavated at the surface of this layer in Unit 14. Five thinware sherds were recovered from this stratigraphic boundary. Excavation was discontinued at the surface of Layer IV due to time constraints at the end of the 1987 season.

Excavation Unit 12

Unit 12 was located 16 m north and 45 m east of Unit 1 in the main trench (see figure 5.3). The unit is situated on the colluvial slope amidst huge talus boulders. Excavation of this unit (chosen to penetrate the subsurface deposits as close to the talus slope as possible) proved to be hazardous given the large boulders protruding from the unstable sidewalls of the pit, especially as the clayey sediment dried and became friable. The stratigraphy of Unit 12 was as follows:

Layer IA: The upper colluvium (0-20/30 cm below surface) consists of an organically enriched, A horizon soil. The layer is dark brown (10 YR 3/1) and has been reworked by recent gardening. No cultural material was observed.

Layer IB: The massive lower colluvium, dark brown (10 YR 3/2) in color, consists of very poorly sorted, large, angular rock fragments, with cobble- and boulder-sized clastics, in a clay-silt matrix. No bedding or lenses of finer-grained sediment were observed, nor was any cultural material noted.

Layer IC: This is the base of the colluvial deposit, distinguished by an increase in fine-grained sediment. The boundary with Layer IB is gradual, reflecting a continuous increase of clay and silt content toward the base of Layer I. This clay-loam contains some calcareous sand (thoroughly intermixed) and angular volcanic rock fragments, but these are restricted to cobble-sized. Charcoal flecks and waterworn coral gravel are present in small amounts. Small amounts of bone and shell were recovered from this layer, but pottery was absent. Layer I extends from the surface to 2 m below surface.

Layer IC-1: This is a brown (10 YR 3/3) clay-loam with calcareous sand thoroughly intermixed. Layer IC-1 can be distinguished by both its greater calcareous sand content and the presence of pottery. The pottery in this layer is predominantly thinware (25 sherds, with 2 thick-coarse and 23 thinware) and includes three direct rims, one of them with red slip and an impressed lip. Shell and charcoal were recovered in small quantities. The deepest (2.6 m) portions of this layer had no cultural materials.

The stratigraphy of Unit 12 was almost entirely colluvial in origin. The upper portions, free of cultural materials, represent one or more rapid depositional events, i.e., mass wasting of material from the nearby steep volcanic cliffs. The clay-loam of the lowest portions of the sequence represents gradual accumulation of colluvial sheet wash during a period of occupation. Calcareous sand entered the deposit through wind transport (saltation) from the active beach ridge, which was then much more closely adjacent to this location.

Excavation Unit 13

Located 45 m east and 37 m south from Unit 1 in the main trench, Unit 13 was near the center of a stone-faced, waterworn gravel-filled (*'ili'ili*) mound typical of Samoan house foundation construction. The gravel mound measures 15 by 16 m across its center and is nearly round in plan view. The mound is elevated approximately 25-30 cm above the surrounding organically enriched and stable sandy substrate. Excavation of Unit 13 revealed the following stratigraphy:

Layer I: This deposit of waterworn coral gravel (*'ili'ili*) is mixed with a small proportion of waterworn volcanic gravel and with a finer, dark, organically enriched, sandy loam matrix (7.5 YR 2/0). A bottle glass sherd was excavated from this layer, possibly indicating occupation of the house mound into the Historic period.

Layer IB: This is a lighter colored (10 YR 5/2) sediment of the same texture as Layer I. The color difference is due to a lower percentage of organic matter. Ash, shell, and numerous sea urchin spines were mixed into the gravel paving stones. Excavation of the lower part (30-48 cm below surface) of this stratum exposed a small portion of a human burial cut from the floor surface (Layer I) of the house mound and extending into Layer II below. Only bones from the feet were recovered, the remainder of the burial lying outside of the excavation unit.

Layer II: This stratum contains culturally sterile, white (10 YR 8/2), calcareous sand. Excavation was completed with the testing of this layer to 68 cm below surface.

Radiocarbon Chronology of the 1987 Excavations

Seven samples of charcoal and shell from the 1987 excavation units at To'aga provide the basis for a radiocarbon chronology of the deposits in the vicinity of the Ofu landfill. The 1987 dates were reported in full by Kirch, Hunt, and Tyler (1989) and are discussed in detail in chapter 6.

The oldest dates are those for samples Beta-25035 and -25673, both from Layer V of the main trench, the basal calcareous beach sand which yielded two thin, fine-tempered sherds. Both samples consisted of unweathered marine shell which were probably deposited at approximately the same time as the sherds (details of these samples are provided in Kirch, Hunt, and Tyler 1989:11-12; see also Kirch, chapter 6). The samples yielded overlapping ages at two standard deviations which indicates a calibrated time range of between 3700-3300 cal B.P. for the deposition of this beach sand which contained the thin, fine-tempered ware pottery sherds. While this age range is certainly early for human occupation in Western Polynesia, it is not out-of-line with the earliest known dates for Lapita sites in the region (Kirch and Hunt 1988; Kirch 1988, table 48).

Three samples are in direct association with the Polynesian Plain Ware assemblage (Beta-25034, -26464, and -25033), deriving from the Layer II occupation in the main trench and from its correlated deposit in Unit 10. All three samples agree well in age and indicate a calibrated time range of between 2500-1900 cal B.P. for the main Polynesian Plain Ware occupation.

A *terminus post quem* for the use of ceramics at the To'aga site is provided by sample Beta-26463, which derives from the base of an aceramic occupation deposit which stratigraphically postdates Layer II in the main trench. This sample yielded a calibrated age of 1389-1287 cal B.P.

The final sample (Beta-26465) was obtained from the base of the aceramic house mound tested by Unit 13 and yielded a calibrated age of 1122-950 cal B.P. Since the platform is constructed on the present land surface, it is evident that the sequence of coastal progradation and of colluvial deposition in the vicinity of the main excavation had stabilized by the beginning of the second millennium A.D.

The Depositional Sequence in the 1987 Main Trench

The depositional sequence in the 1987 main trench excavation at To'aga can be summarized as the following series of stages:

Stage 1 (3700-3300 cal B.P.): The calcareous sand beach represented by Layer V of the main trench was formed at a time when the island's shoreline was close to the base of the talus slope. Thus, volcanic headlands were exposed to active wave erosion, yielding mixed calcareous-basaltic lithology sands. Human occupation in the vicinity of the beach (presumably now buried under a considerable depth of colluvium and talus) is suggested by the presence of thin, fine-tempered ware sherds.

Stage 2 (> 2500 cal B.P.): The older beach ridge was buried at this time by terrigenous silt-clay from upslope, with erosion initiated in part by human clearance of the vegetation with fire, indicated by charcoal flecking in the erosional deposit.

Stage 3a (ca. 2500 cal B.P.): Accumulation of the calcareous beach ridge was renewed during this stage, while the shoreline was still close to the talus slope (revealed again by mixed calcareous-basaltic grain suites). Exposure to the active shoreline is indicated by the large coral cobbles and reef detritus, representing one or more storm events.

Stage 3b (2500-1900 cal B.P.): Humans inhabited the active beach ridge surface (Layer IIB of the main trench) during this time, resulting in the deposition of ceramics and midden.

Stage 4 (2500-1900 cal B.P.): In this stage, the beach ridge was abandoned as an occupation locus, and the accumulation of the beach ridge (Layer IIA) continued.

Stage 5 (ca. 1900 cal B.P.): The old beach ridge surface stabilized during this stage. This is indicated by the formation of an A soil horizon and the deposition of anthropophilic garden snails (Layer IIA-1 of the main trench). The stabilization presumably resulted from seaward progradation of the shoreline, thus removing the immediate source of calcareous sediment. At roughly this time, the basal sands represented by Layer II in Units 2 and 3 were deposited.

Stage 6 (< 1900 cal B.P.): During Stage 6 there was additional erosion and deposition of terrigenous sediments from upslope in the area of the main trench. The presence of ceramics and an earth oven indicate a brief occupation event.

Stage 7 (< 1900-1000 cal B.P.): The progradation of the shoreline continued to its present position about 125 m seaward of the main excavation locus. Gradual deposition of fine-grained terrigenous sediments over the surface of the newly formed coastal flat and the reworking of these deposits through gardening activities also occurred during this stage.

Stage 8 (ca. 1000-100 cal B.P.): Human habitation dispersed across the expanded coastal flat during Stage 8, represented by the *'ili'ili* pebble pavement tested by Unit 13 and by other surface cultural features.

In sum, the depositional sequence revealed in the 1987 excavations begins late in the second millennium B.C. with a coastal terrace only a few tens of meters wide, and with a reef platform substantially wider than at present. This geomorphic situation fits well with evidence for a +1-2 m higher stand of the sea in the southwest Pacific at ca. 3 kyr B.P., as argued in chapter 4. By about 1900 B.P., the shoreline had begun to rapidly prograde, associated with a drop in sea level to its present stand and with exposure of the reef crest leading to a higher rate of calcareous sediment production. The development of a coastal terrace more than 100 m wide was accompanied by the addition of fine terrigenous sediments due to erosion and sheet-wash of the higher colluvial slopes, forming a highly productive zone for intensive cultivation and habitation. Therefore, the morphodynamic model of coastal terrace formation outlined above in chapter 4 is closely supported by the stratigraphic and radiometric data from the 1987 excavations

Summary of the 1987 Excavations

The program of excavations carried out in 1987 was successful in establishing the presence of undisturbed, well-stratified prehistoric occupation deposits in the To'aga area. The basal occupation layers contained Polynesian Plain Ware ceramics, including a fine, thinware pottery dating to the mid-first millennium B.C. The 1987 excavations also established a sequence of geomorphological change in the To'aga area, indicating substantial coastal progradation and consequently deep burial of the pottery-bearing deposits under recent calcareous dune ridge and colluvial slope-wash deposits.

By the close of the 1987 season, it had become clear that the subsurface archaeological resources of the To'aga area—especially the deeply buried, pottery-bearing deposits—were far more extensive than originally thought. The 1987 excavation units had revealed the presence of cultural deposits over an area of at least 4,000 m^2, but without reaching the horizontal boundaries of these layers. Because of the great significance of the To'aga site for Samoan prehistory, it was clearly essential to establish the full areal extent of the subsurface archaeological features at this extensive and well-stratified site. A third phase of excavations was therefore required, applying the systematic transect strategy of subsurface testing over the whole extent of the southern coastal plain on Ofu Island, extending from the Ofu landfill site and adjacent 1987 excavations eastward towards Fa'ala'aga. Potentially, this entire coastal strip nearly 2 km long and varying between 50 to 100 m wide, might contain subsurface archaeological deposits; this could only be determined through subsurface testing. Such a testing program was proposed to the Historic Preservation Office of American Samoa in 1988 and implemented by a third field phase of the Manu'a Project in 1989.

THE 1989 TRANSECT EXCAVATIONS

1989 Excavation Procedures

The primary objectives of the 1989 field season at To'aga included—among other things—the areal definition of the full extent of subsurface archaeological deposits within the coastal terrace and the further elaboration of a morphodynamic model of site formation processes. These goals dictated the continued use of a systematic transect sampling strategy, with excavation transects spaced along the full extent of the coastal terrace (as far to the northeast as Fa'ala'aga). In order to maintain accurate spatial control on the test units to be excavated along these transects, our first task was to establish a baseline. This was staked out at 100 m intervals, following the course of the dirt road that parallels the shoreline throughout the To'aga area. A zero or origin point was established where this baseline bisected the 1987 transect (which was designated Transect 1); from this 0-point, the baseline extended 300 m to the southwest, and 1500 m to the northeast. Each 100-m interval along the baseline was identified as a potential transect-intersection point for subsurface testing, and transects were labeled from 1 to 19. Transects 2-3 extended southwest from the origin point (Transect 1), while transects 4-19 extended to the northeast.

Choice of specific transects for test excavation was dictated by several factors, including permission from local landowners, locations of gardens (we did not wish to disturb active *Alocasia* garden sites), presence of 'sacred' sites (in particular, the Tui Ofu tomb complex), as well as the usual constraints of time and budget. Over the course of the field season, we were able to excavate test units along six of the potential sampling transects: Transects 3 (200 m W), 5 (100 m E), 7 (300 m E), 9 (500 m E), 11 (700 m E), and 17 (1300 m E). The locations of these transects, and their relationship to the baseline, are diagrammed in figure 5.8. (Note that in this figure the scales for the baseline and the transects are different.) These transects thus cover a total area extending 1.5 km from southwest to northeast, and in every case across the lateral extent of the coastal terrace.

Prior to the commencement of excavation, each selected transect was cleared of obscuring vegetation, and a transect baseline staked out at 10-m intervals. A continuous elevation profile along the transect was then surveyed using a telescopic level and stadia rod. These surveyed profiles provided valuable information on the geomorphic structure of the coastal terrace. In order to ascertain the relationships between surface and subsurface geomorphic features and modern sea level, each transect profile was also surveyed down to the shoreline, and out onto the reef flat.

A total of 16 1-m^2 units were excavated along the six transects listed above. Virtually all units extended to at least 1.5 m below surface, and some units reached depths as great as 2.9 m before culturally sterile sediments were exposed. Thus the total excavated volume was approximately 32 m^3. Excavation units were numbered sequentially in the order that they were initiated, beginning with Unit 15 and ending with Unit 30.

In the following pages, the 1989 excavations are described by transect, beginning with Transect 3 at the southwestern end of the coastal terrace and progressing towards the northeast to Transect 17.

Transect 3

Transect 3 is situated 200 m to the west of the 1987 excavation area (Transect 1); between Transect 3 and Transect 1 lies the bulldozed landfill site where pottery was first discovered during the 1986 reconnaissance survey. The surveyed elevation profile of Transect 3 is shown in figure 5.9, with the location of the single test, Unit 27, excavated along this transect. The ground surface along Transect 3 is composed of clayey colluvium with numerous volcanic cobbles and boulders scattered over the surface. The vegetation consists predominantly of cultivated bananas.

Excavation Unit 27

This test excavation is situated 42 m inland of the road. The profile of the east face is shown in figure 5.10. The following strata were identified:

Layer I: This dark brown colluvial clay contains angular and subangular basalt cobbles. Charcoal flecks were present throughout in low frequency.

Layer II: An orange-brown-stained calcareous sand makes up this layer. The lower part of this stratum contains many coral and basalt pebbles and cobbles. The distribution of these larger clastics suggests a storm or other high-energy depositional event, followed by a more gradual accumulation of the finer-grained sands in the upper portion of the deposit.

Layer IIIA: The brown-to-tan calcareous sand in this stratum exhibits some "peppering" of volcanic grains. The stratum also contains many angular and subangular basalt cobbles and boulders, shell, and coral rubble.

Layer IIIB: This layer is composed of brown sandy clay with angular to subangular basalt cobbles, rounded coral cobbles, and shell. The clay component of this sand is higher than in Layer IIIA, although the boundary separating the two strata is diffuse and unclear. Layer IIIB produced the bulk of the cultural material in Unit 27, between about 175-214 cm below surface. This cultural material included more than 6 kg of shell midden, 120 fish bones, and some turtle (see Nagaoka, chapter 13). The lower part of Layer IIIB was sterile, and excavation was discontinued at 225 cm below surface.

Unit 27 yielded a variety of prehistoric artifacts. These include pottery, pieces of obsidian (probably natural), basalt (from Layers II and IIA), and an adz butt fragment from Layer IIIA. Layer I did not contain any artifacts. A total of 95 sherds was recovered, with the following stratigraphic distribution: Layer II, 5 thickware sherds; Layer IIA, 80 sherds (5 [23%] thinware, 57 [71%] thickware); Layer IIIB, 10 sherds (3 [30%] thinware, 7 [70%] thickware).

No radiocarbon dates were processed from Unit 27. On the basis of the ceramics recovered, however, the occupation in Layer IIIB could date to

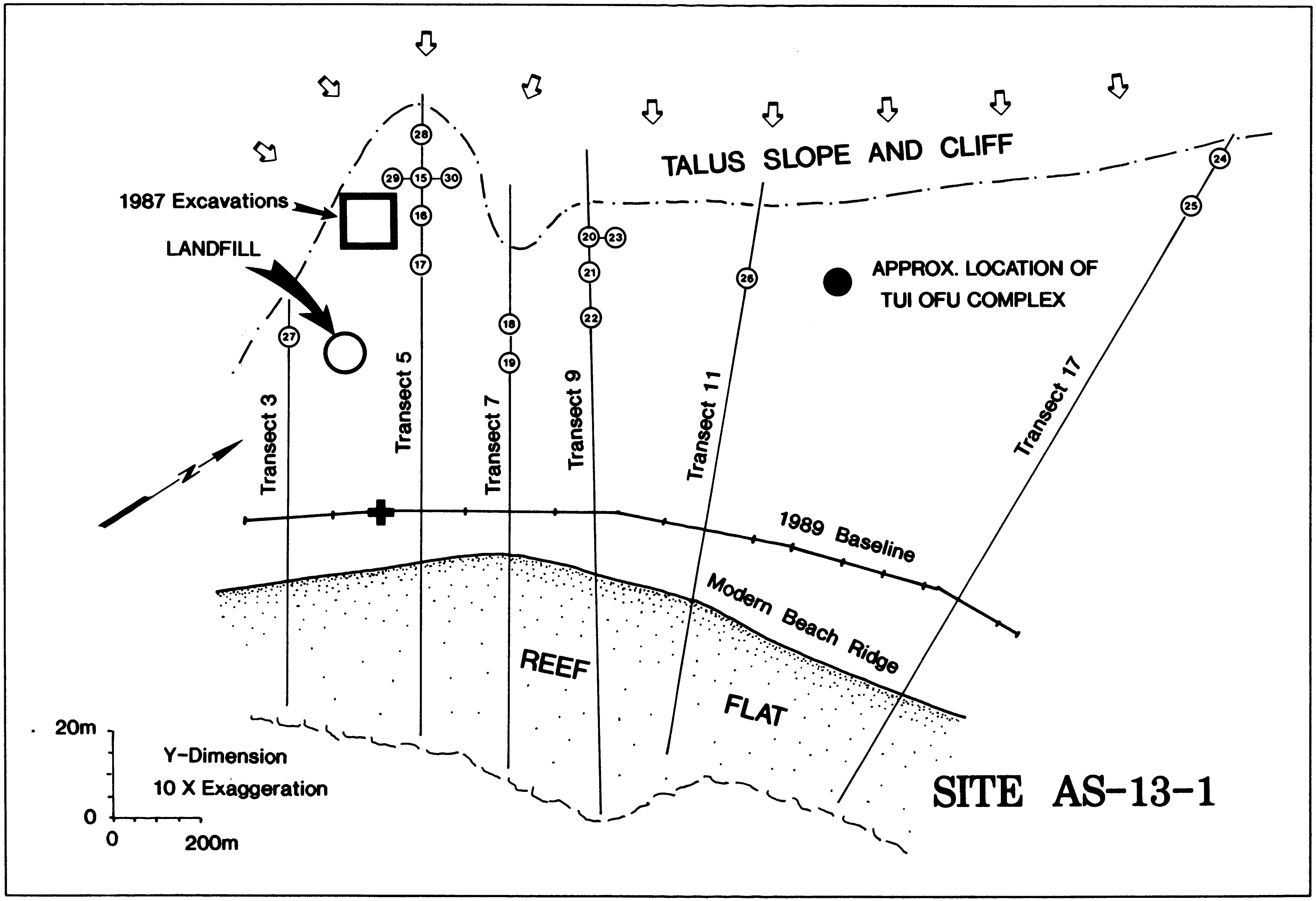


Figure 5.8 Schematic map of the southeastern coastal flat of Ofu Island, from To'aga to Fa'ala'aga. Note that the Y-dimension (seaward-landward) has been exaggerated by 10X in order to display the locations of transect test units (indicated by numbers within circles). The 1989 baseline follows the course of the coastal road.

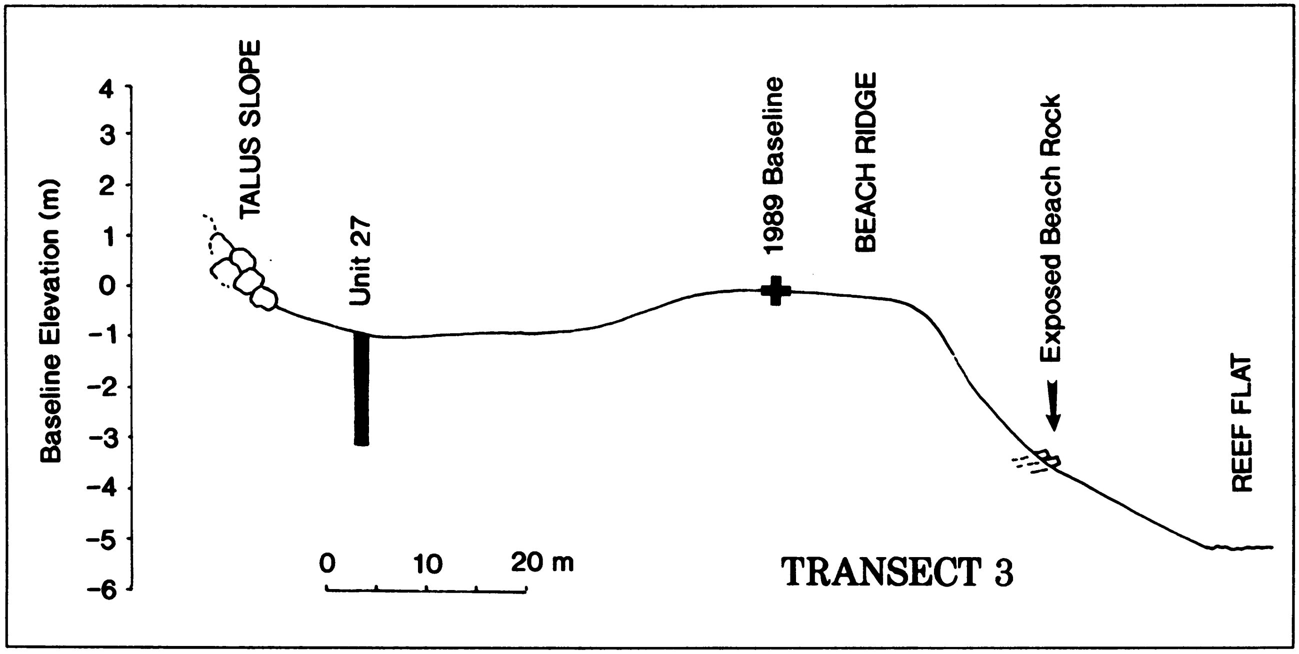


Figure 5.9 Elevation profile along Transect 3, showing the location of Unit 27 in relation to geomorphic features.

approximately 1000 B.C. Only a single occupation phase is indicated (in Layers IIIA and IIIB), followed by the accumulation of calcareous sands, mixed with increasing quantities of terrigenous, clay-silt sediment in the higher parts of the stratigraphic column. The concentration of large clastics in the lower part of Layer II is probably the result of a high-energy storm event. In the most recent depositional phase, the locality has been capped by 60-70 cm of colluvium.

Transect 5

Transect 5 lies 100 m east of the 1987 baseline which incorporates the main excavation trench (Units 1, 4-9) and Units 2 and 3. In 1989, Transect 5 was largely in second growth vegetation, with some *Alocasia* and bananas near the talus slope. The elevation profile along Transect 5 is shown in figure 5.11.

Excavations along Transect 5 commenced with three units, designated Units 15, 16, and 17, spaced 10 m apart. After these units had been completed and their stratigraphic profiles correlated, it became apparent that the most inland test, Unit 15, had exposed a deeply buried, thin cultural deposit containing a few sherds of thin, orange-slipped pottery. Seeking to sample more of this early deposit, another excavation (Unit 28) was opened 10 m farther inland, where the talus slope began to rise steeply. However, in this pit the massive upper colluvial deposit extended fully 2.4 m deep, making exposure of the underlying calcareous sandy strata that contained cultural materials exceedingly difficult. (Nonetheless, we did manage to carry the excavation down to 3.6 m, a risky matter in an unreinforced 1x1 m pit!) We therefore returned to the Unit 15 excavation, and expanded it with 1-m extensions north (Unit 29) and west (Unit 30). The excavation of these extensions was complicated by the partial collapse of the expanded pit walls at one point. Notwithstanding this setback, we carried the excavation of these extensions down to 2.5 m, thereby exposing a larger sample of the early cultural deposits. Our persistence in seeking an enlarged sample of this deeply buried material was justified subsequently by the results of ^{14}C dating of a charcoal sample from Layer II of Unit 28. The result of 3257-2879 cal B.P. is the oldest date for unquestionably *in-situ* cultural material obtained from the To'aga site. Indeed, this sample is penecontemporaneous with the submerged Lapita site of Mulifanua on 'Upolu Island.

Excavation Unit 17

Unit 17 was the most seaward excavation along Transect 5, situated 56 m inland from the baseline

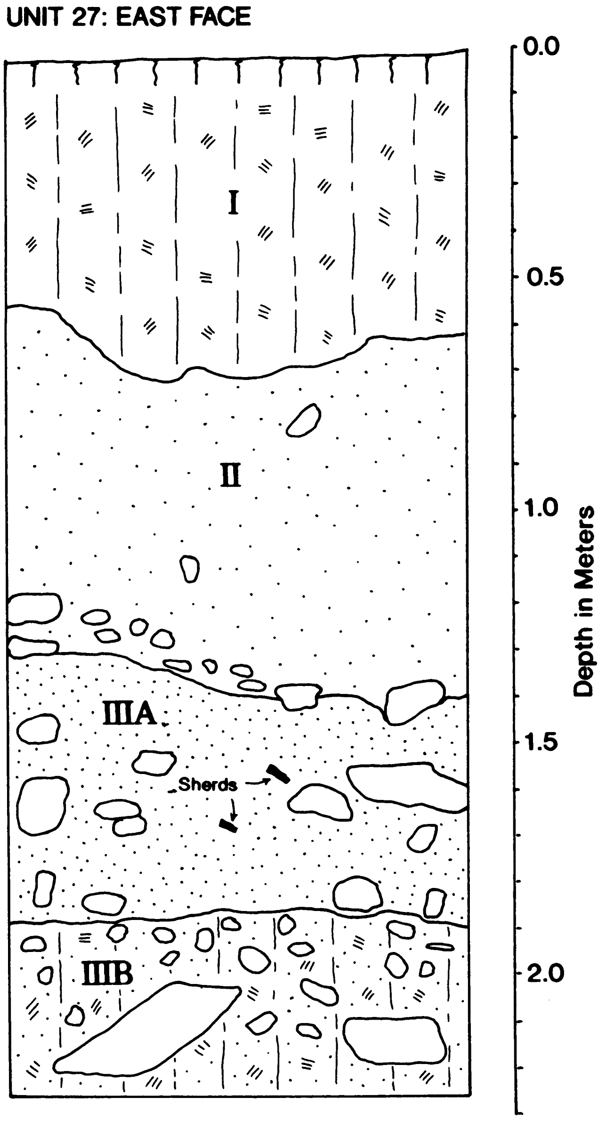


Figure 5.10 Stratigraphic profile of the east face of Unit 27.

along the road. A detailed profile of the west face is shown in figure 5.12, and an 'exploded' profile of the entire unit in figure 5.13. This unit was of particular note because of the exposure of a sequence of gravel house floor pavements (*'ili'ili*) in Layer III, associated with several post molds and a hearth. The stratigraphy as recorded on the west face was as follows:

Layer I: This 'greasy' midden deposit of sandy clay loam contains much dispersed coral *'ili'ili* gravel and shell midden. It has a very dark gray color (10 YR 3/1). The contact with Layer II is gradational over 2-3 cm.

Layer II: A compact deposit of *'ili'ili* gravel occurs here in an ashy, brown (10 YR 5/3), sandy matrix. This appears to be a thick, artificially laid house floor deposit and contains well-preserved shell midden. Four post molds visible in the exploded section (fig. 5.13) are filled with Layer II material and were cut through the underlying Layer III pavements. In addition, a hearth visible in the east and south profiles lies at the contact of Layers II and III.

Layer III: This thick deposit is made up of three successive *'ili'ili* pavements, laid directly over each other. The paving materials range from small waterworn coral pebbles (ca 0.5-1 cm diameter) down to very coarse coral sand (1-2 mm diameter). There are discontinuous bands of black ash and fine charcoal throughout the deposit as well, probably deriving from hearth rake-out events. The lowest pavement (Layer IIIC) lies directly on Layer IVA, with a very sharp, abrupt, flat contact. All of the pavements were pale brown (10 YR 7/3). The individual sub-components were: IIIA, fairly clean coral gravel; IIIB, coral gravel mixed with sand and ashy beds; and IIIC, coarse coral sand and gravel in fine beds. These three gravel deposits presumably represent successive repavements of a house floor. Buck (1930:68) describes the traditional Samoan practice of "levelling off the upper surface of the platform within the house and covering it with small stones (*'ili'ili*). . . . The larger coral gravel was picked out on the beach and carried up in baskets. It often took some time to get a sufficient quantity. A Samoan woman picking over the coral gravel might remind one of a woman of a higher culture selecting a carpet."

Layer IVA: This deposit consists of strong brown (7.5 YR 5/6) calcareous sand with a mixture of fine volcanic silt-clay. The admixture of silt-clay suggests surficial alluvial deposition of fine-grained sediment emanating from one of the colluvial fans inland, perhaps after a torrential rain. Some charcoal flecking is also present.

Layer IVB: The grayish brown (10 YR 5/2) calcareous sand of this deposit has small dispersed charcoal flecks. The deposit had been disturbed by the deposition of Layer IVA, and is therefore discontinuous. It represents an old paleosol horizon on top of the beach ridge following stabilization. The contact with Layer V is irregular and diffuse.

Layer V: This is a massive, structureless deposit of

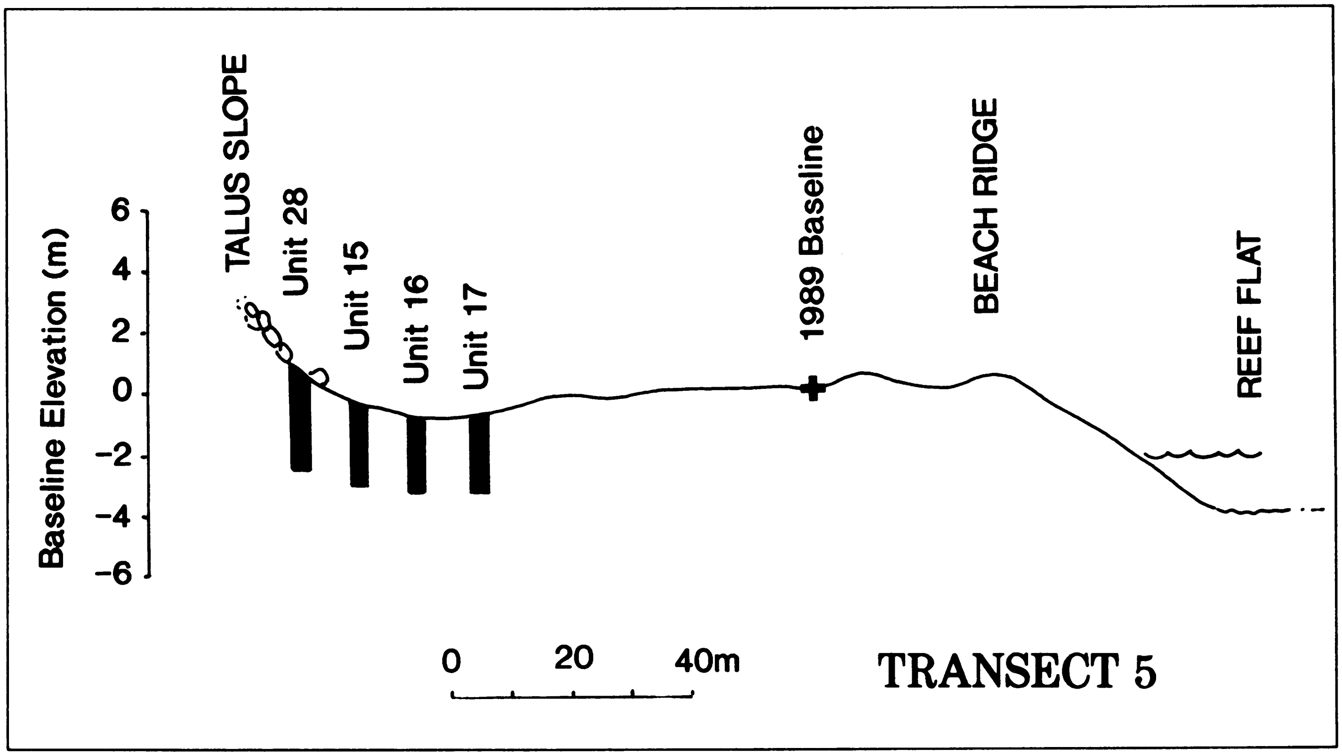


Figure 5.11 Elevation profile along Transect 5, showing the locations of Units 28, 15, 16, and 17 in relation to geomophic features.

fine to medium-grained calcareous sand (white, 10 YR 8/2) with a minor component of volcanic lithic fragments. It is culturally sterile. The contact with Layer VI is gradational.

Layer VI: This layer contains coarse-grained calcareous sand (white, 10 YR 8/2) with a greater frequency of volcanic lithic grains. The deposit also incorporates two distinct bands of fist-sized coral cobbles.

Layer VII: Composed of fine-grained sand with a distinctly 'salt-and-pepper' mixture of calcareous and volcanic grains, this layer marked the base of the excavation which was reached at 225 cm below surface.

Unit 17 did not produce a large quantity of cultural materials. One bone of *Sus scrofa* from Layer I was the only identifiable vertebrate faunal specimen. Shell midden was present in Layers I-III, with the highest concentration in Layer III (see chapter 13 for details).

Unit 17 yielded a single fishhook fragment (the point of a jabbing hook) from Layer II. No pottery was recovered from this unit, suggesting deposition of these strata after the abandonment of pottery production in Manu'a.

Excavation Unit 16

Unit 16 was positioned 10 m farther inland along Transect 5 from Unit 17. The stratigraphic profile of the west face, shown in figure 5.14, follows:

Layer IA: This is the A horizon-garden soil. On the surface one finds much leaf litter with numerous anthropophilic snails in the genera *Subulina*, *Lamellaxis*, *Succinea*, and *Pleuropoma*.

Layer IB: The very dark gray (10 YR 3/1) sandy loam here is a cultural midden deposit. Parent material consists primarily of calcareous sand, with a minor component of fine clay-silt. The dark gray color results from the inclusion of much finely dispersed charcoal and other organic material. The layer contains much shell midden (9.4 kg) and some dispersed *'ili'ili* gravel. The contact with Layer IC is gradational.

Layer IC: The very dark grayish brown (10 YR 3/2) calcareous sand in this stratum has some fine charcoal flecking. The layer appears to represent an

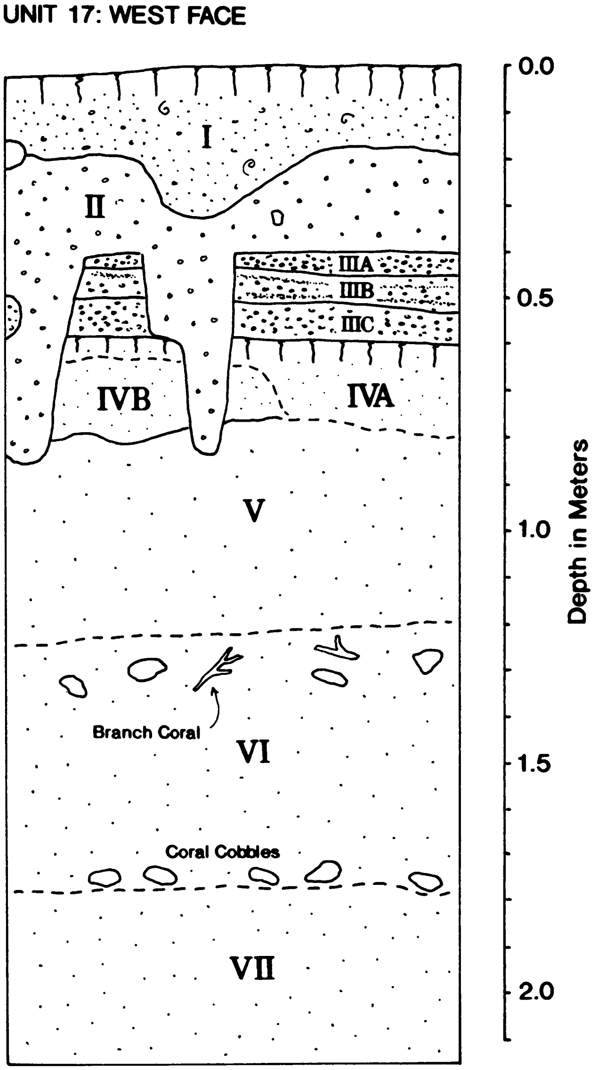


Figure 5.12 Stratigraphic section of the west face of Unit 17.

old stable surface (paleosol A horizon) of the former beach ridge. The surface is somewhat disturbed and reworked by the overlying Layer IB occupation. The contact with Layer II is irregular, and root casts penetrate from Layer IC into Layer II, indicative of vegetation on the former stable surface.

Layer II: This white (10 YR 8/2), massive, structureless deposit of very fine-grained calcareous sand incorporates some fine volcanic lithic fragments. At the base of Layer II is a zone of fist- to head-sized, waterworn coral cobbles indicative of a high-energy storm event. The contact with Layer III is very unclear and gradational.

Layer III: This is a very pale brown (10 YR 7/3), extremely non-concentrated cultural deposit. It yielded a few sherds during excavation, and one sherd was visible *in situ* in the west wall during profile recording (see figure 5.14). Several volcanic fire-altered oven stones were also noted in this layer. Except for its slightly darker color, this deposit is lithologically hardly distinguishable from Layer II. It probably represents the old beach slope fronting either the Layer IIB or Layer IID occupations in Unit 15. The lower contact with Layer IV is gradational and unclear.

Layer IV: The white (10 YR 8/2) fine grained calcareous sand in this deposit contains volcanic lithic grains ('salt-and-pepper' sand).

Unit 16 produced considerable cultural material, including 741 fish bones, as well as rat, turtle, and bird bones. Shell midden was most heavily concentrated in Layer I (9.4 kg), with lesser quantities in the deeper layers. Full details of the faunal analysis are presented in chapter 13.

Unit 16 yielded a worked *Tridacna* shell (possibly an adz preform) and a shell scraper from Layer IB. Artifacts from Layer III include a shell bracelet fragment, a *Turbo* shell fishhook fragment, obsidian (including a red and black banded specimen), and basalt flakes. In all, forty-four sherds was recovered from Unit 16. These include twelve thickware sherds in Layers I and II, one of which (in Layer I) has a parallel-rib, paddle-impressed exterior surface. Layer III yielded twelve (37%) thinware sherds and twenty (63%) thickware sherds.

Excavation Units 15/29/30

As indicated above, Unit 15 was excavated along with Units 16 and 17 on Transect 5. When a deeply buried, thin cultural deposit containing thin, red-slipped pottery was encountered, we decided to expand Unit 15 by excavating two adjacent squares, designated Units 29 and 30. The stratigraphy described below, and shown in figure 5.15, is that of the west face of Unit 15.

Layer IA: The upper 10 cm of Layer I is composed of dark reddish brown (2.5 YR 3/4) colluvium. This upper zone is slightly humic, with an A soil horizon at the surface. The deposit is a poorly sorted, very rubbly mixture of volcanic sand and clay, full of angular to subangular gravel and small cobbles. This deposit is the tongue of a colluvial fan emanating

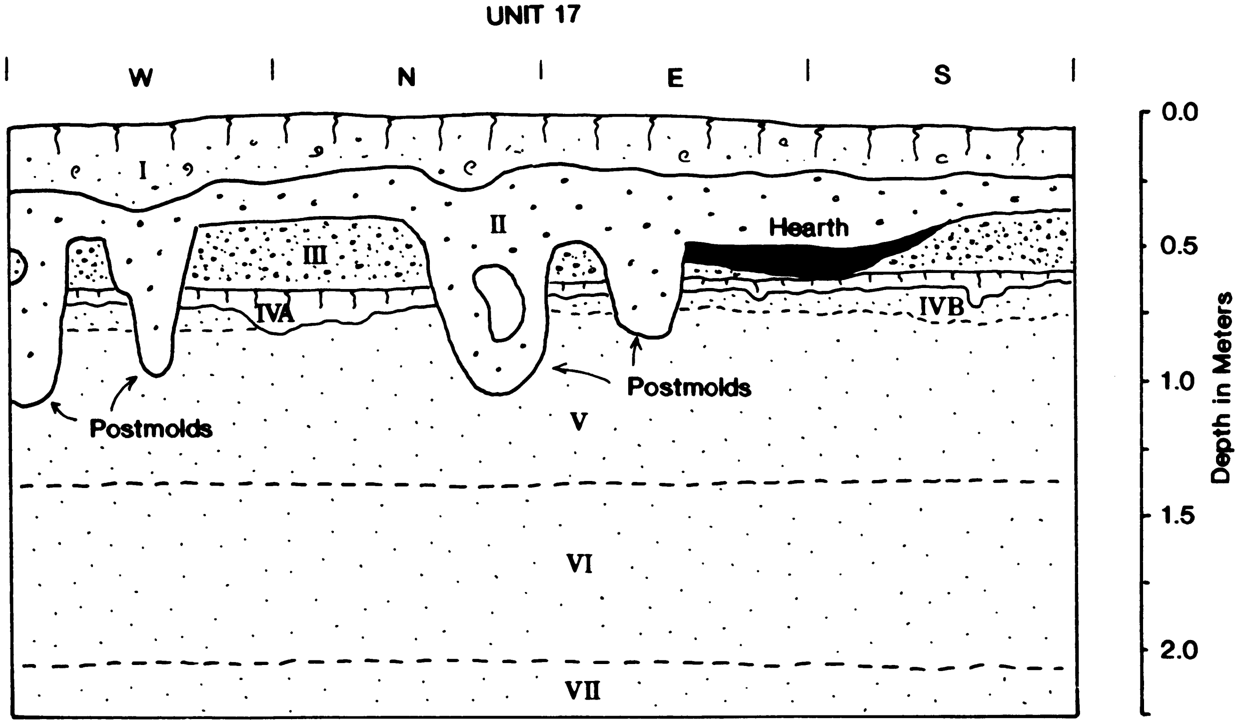


Figure 5.13 Exploded stratigraphic section of all faces of Unit 17, showing postmolds and hearth associated with Layer II.

from a small hanging valley above the Le'olo cliff. Layer IA grades into IB.

Layer IB: Although almost identical to Layer IA, this layer lacks the organic, humic component. The lower 5-10 cm of IB is noticeably more clayey, with a lower frequency of larger clastics.

Layer II: This 'greasy' midden deposit is a very dark gray (5 YR 3/1). The parent material is primarily calcareous sand with some silt-clay admixture. The dark color and greasy texture result from the incorporation of much finely dispersed ash, charcoal, and other organic material. The deposit contains abundant fist-sized, volcanic, fire-altered oven stones. Shell midden is also present (3 kg) but is somewhat chalky and chemically degraded. The contact with Layer IB is straight and abrupt; that with Layer IIIA-1 is irregular, varying from abrupt to gradational. The high carbon content and the presence of oven stones suggest that this layer represents a cookhouse activity area.

Layer IIIA-1: The reddish-yellow (7.5 YR 6/6) calcareous sand of this deposit has pockets of pinkish-gray sand (7.5 YR 6/2). In addition to considerable mottling, various irregularities and disturbances apparently resulted from the Layer II occupation on an old, stabilized beach ridge surface represented by this layer. Root casts extend from IIIA-1 into IIIA. The contact with Layer IIIA is sharp but highly irregular. This layer is interpreted as a formerly vegetated, stabilized dune surface (paleosol).

Layer IIIA: This sterile deposit of white (10 YR 8/2) calcareous sand is well-sorted with a medium-sized (2 phi) mode and has a minor admixture of volcanic lithic grains ('salt-and-pepper'). The contact with Layer IIIB is very sharp but highly irregular ('wiggly').

Layer IIIB: This pale brown (10 YR 6/3), very non-concentrated occupation deposit is indicated primarily by its slightly darker color and the

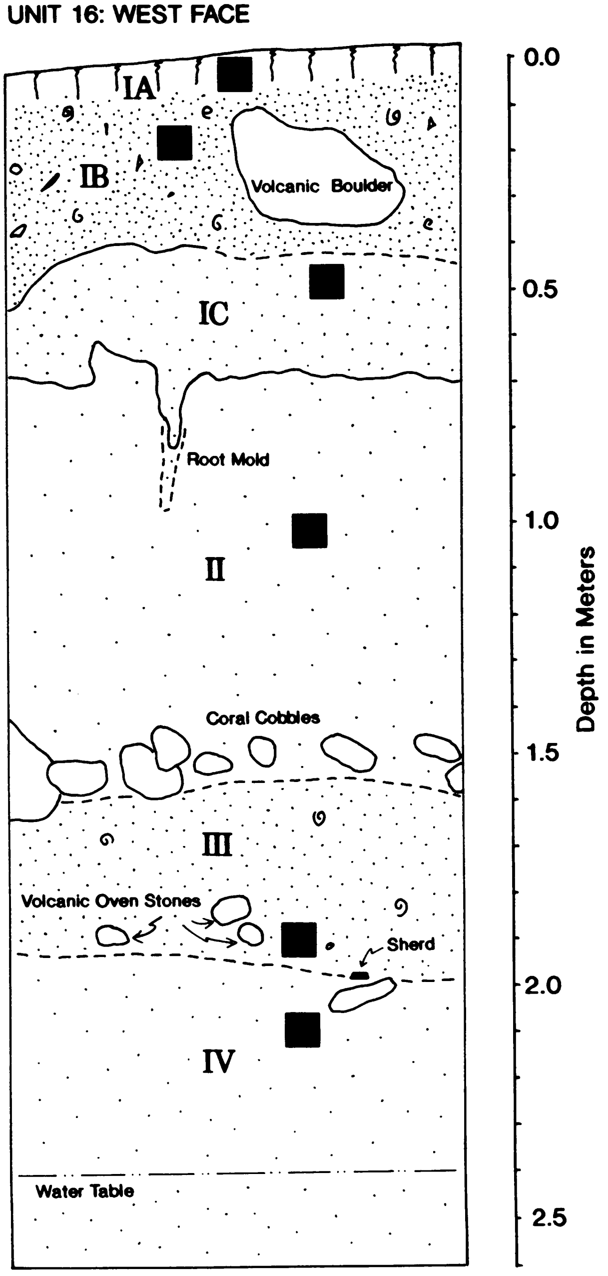


Figure 5.14 Stratigraphic section of the west face of Unit 16. Black squares indicate sediment sampling locations.

presence of some marine shell midden. The deposit is medium- to coarse-grained, and less well-sorted than Layer IIIA. The lower contact with Layer IIIC is irregular and slightly more gradational than the top contact. Lithologically, this is the same as Layer IIIA.

Layer IIIC: The white (10 YR 8/2), calcareous sand of this stratum is essentially identical to Layer IIIA but contains a higher frequency of coarse grains (1 phi).

Layer IIID: In Unit 15, this deposit appeared only discontinuously, as pockets in the west face of the section. These were pale brown (10 YR 6/3), very similar to the Layer IIIB deposit. In the east face of Unit 15, the zone was continuous. This is the deposit that yielded thin, fine-tempered, red-slipped pottery, together with thickware, during excavation.

Layer IV: The coarse- to very coarse-grained, white (10 YR 8/2) calcareous sand that is found here is poorly sorted, having a considerable mixture of volcanic lithic grains ('salt-and-pepper' appearance) and some small volcanic pebbles. The deposit also contains considerable quantities of branch coral fingers (water rolled) and coral pebbles. The presence of these larger grained sediments and the lack of sorting suggest that this was a relatively high energy, exposed beach depositional environment.

Excavation of Units 15/29/30 yielded an array of artifacts that include two shell fishhook tabs (Layers II and IIID), cut pearlshell (Layer II), a shell bracelet fragment (Layer IIIB), an unfinished fishhook (Layer IIIB), and numerous flakes of basalt and obsidian (Layers II, IIIB, and IIID).

A total of 200 sherds was recovered from these units. The distribution of these sherds by layer was as follows:

	Thinware		*Thickware*		*Total*
Layer II	3	5%	58	95%	61
Layer IIIA	8	24%	26	76%	34
Layer IIIB	7	13%	48	87%	55
Layer IIID	19	38%	31	62%	50

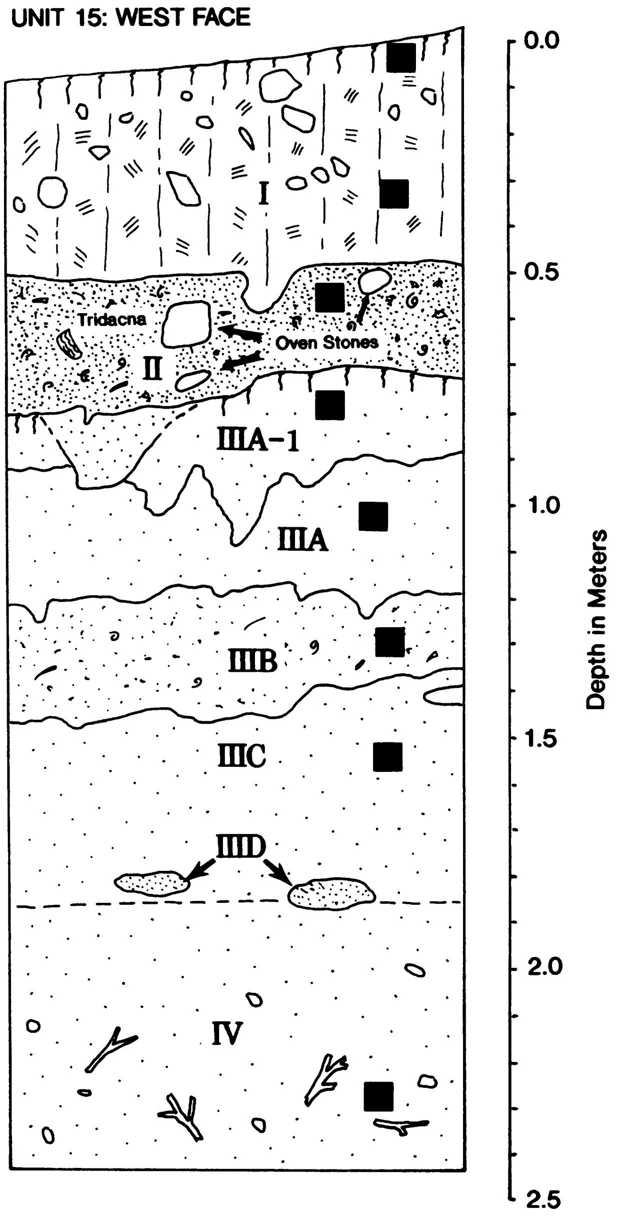


Figure 5.15 Stratigraphic section of the west face of Unit 15. Black squares indicate sediment sampling locations.

Two thickware direct rims from Layer IIIA have impressed lips, which appear to have been made with a carved paddle. Red slip is restricted to thinware (2 sherds only) from Layer IIID. As the frequencies above indicate, there is a general trend toward increasing relative frequency of thickware in proportion to thinware over time in this unit.

Excavation Unit 28

Unit 28 was excavated 10 m farther inland from Unit 15 in an effort to trace the deep Layer IIID occupation in Unit 15, inland under the steeply rising colluvial fan. Clearly, the depth of colluvial overburden which would have to be removed was substantial, making this the most inland position in which excavation could be attempted without the use of heavy machinery. The stratigraphy described below is that of the north face.

Layer I: This massive deposit of dark reddish-brown (2.5 YR 3/2) clayey colluvium is between 2.2-2.4 m thick and contains numerous, large, angular volcanic cobbles and boulders. No bedding or lenses were present, although clay content increases toward the base of the stratum. Free of cultural material, this colluvial deposit represents one or more events of mass wasting (landslides) from the adjacent volcanic cliffs.

Layer IIA: This discontinuous zone (pockets) of calcareous sand has been discolored (7.5 YR 6/6) by eluviation of clay from the colluvium above (Layer I). A small amount of cultural material was recovered, including pottery, shell and bone midden, and charcoal.

Layer IIB: The white (10 YR 8/2) calcareous sand in this stratum has waterworn coral cobbles and a few coral boulders. This layer contains a minor admixture of volcanic sand grains ('salt-and-pepper' lithology) as well as cultural material.

Layer IIC: The pale brown (10 YR 6/3) calcareous sand of Layer IIC is similar to IIB in origin, but is distinguished by a darker color explained by the addition of organic matter and some clay, resulting from human occupation. Its relatively abundant cultural material includes midden and pottery (see below). Layer IIC of Unit 28 is comparable to Layer IIID of Units 15/29/30.

Layer III: This layer is a white (10 YR 8/2), coarse-grained calcareous sand with abundant waterworn coral cobbles and fresh (unworn) branch coral fingers. Layer III yielded less cultural material than IIC and clearly is culturally sterile at its lower depths (3.3-3.4 m below surface).

Artifacts from Unit 28 came primarily from Layer IIC. These include worked shell, basalt flakes, obsidian flakes, an echinoid-spine abrader, and three *Cypraea* shell dorsa found artificially nested together, which may be parts of an octopus lure apparatus (see Kirch, chapter 11).

A total of 127 sherds was recovered, with the following stratigraphic distribution:

	Thinware		*Thickware*		*Total*
Layer IIA			1	100%	1
Layer IIB	7	30%	16	70%	23
Layer IIC	51	49%	52	51%	103

The decline in thinware in proportion to thickware over time is notable, as is the overall decrease in density of ceramics. Included in the above sherd counts are two thinware rims from Layer IIB, and nine thinware and five thickware rims from IIC. One of the thickware rims has an impressed lip. Eight thinware sherds, all from Layer IIC, carry a red or orange slip. Since the ceramic assemblage from Layer IIB dates to 1308-930 cal B.C. (Beta-35601), Layer IIC must be of equal or possibly greater antiquity. This suggests that in the Manu'a Islands, the ceramic transition from Early Eastern Lapita (carrying dentate-stamped decoration) to thin, plainware must have occurred relatively rapidly at the end of the second millennium B.C.

Radiocarbon Dates from Transect 5

Three ^{14}C age determinations were obtained from Transect 5 samples. The oldest date (Beta-35601) comes from charcoal at the Layer II/III interface in Unit 28, associated with the early, thin, red-slipped pottery. This sample has an age of 3257-2879 cal B.P. at one standard deviation. A sample of marine shell midden (*Turbo setosus*) from a cookhouse activity zone, Layer II in Unit 15, is associated with thick, coarse-tempered pottery. This yielded an age of 1631-1477 cal B.P. at one standard deviation (Beta-35924). The third sample (Beta-35600) was obtained from the Layer III *'ili'ili* pavement in Unit 17. This sample, which had no ceramics associated, yielded an age of 1256-1007 cal B.P. at one standard deviation. Further details of these radiocarbon dates and their implications are provided in chapter 6.

Transect 5: Summary of the Depositional Sequence

The correlation diagram of the Transect 5 excavation units (fig. 5.16) also shows the relationship of these units to contemporary shoreline and sea level features. The general depositional sequence along Transect 5 can be reconstructed as follows:

Stage 1 (> 3200-2800 cal B.P.): A narrow coastal bench at the base of the steep talus was formed. The active shoreline at this time would have been in the vicinity of Units 16-17, considerably inland of the modern shoreline. The 'salt-and-pepper' lithology of the beach ridge sediments indicates exposure of volcanic headlands along the coastline, providing a source of volcanic lithic grains. In addition, the presence of larger clastics (coral cobbles, branch coral fingers) indicates a fairly high energy shoreline.

Stage 2 (ca. 3200-2800 cal B.P.): Humans began to occupy the narrow bench formed during Stage 1, resulting in non-concentrated midden deposits that contain thin, fine-tempered, orange- or red-slipped pottery in Units 28 and 15/29/30. The main area of occupation was probably farther inland from Unit 28, and thus is now deeply buried under talus rockfall and colluvium. The deposits exposed in Units 28 and 15/29/30 appear to represent the seaward periphery of such an occupation, down the slope of the former beach ridge toward the old shoreline. Archaeological exposure of the putative main occupation zone would require the use of heavy machinery, since as much as 5-15 m overburden of boulder talus and colluvium would probably have to be removed.

Stage 3 (ca. 2800-2000 cal B.P.?): Deposition of calcareous sands onto the beach ridge continued, with significant seaward progradation of the shoreline occurring late in this phase which resulted in the deposition of the basal deposits in Units 16 and 17. During this stage, a second occupation phase resulted in the midden deposit of Layer IIIB in Units 15/29/30.

Stage 4 (ca. 2000-1600 cal B.P. ?): A stabilized land surface formed during these four centuries over the now wider and prograded coastal terrace, marked by the paleosol horizon (Layer IIIA-1 in Units 15/29/30; Layer IC in Unit 16; Layer IVB in Unit 17).

Stage 5A (ca. 1600-1400 cal B.P.): The stabilized coastal terrace in the vicinity of Units 16 and 15/29/30 was occupied during this terminal phase of ceramic manufacture and use on Ofu Island. The

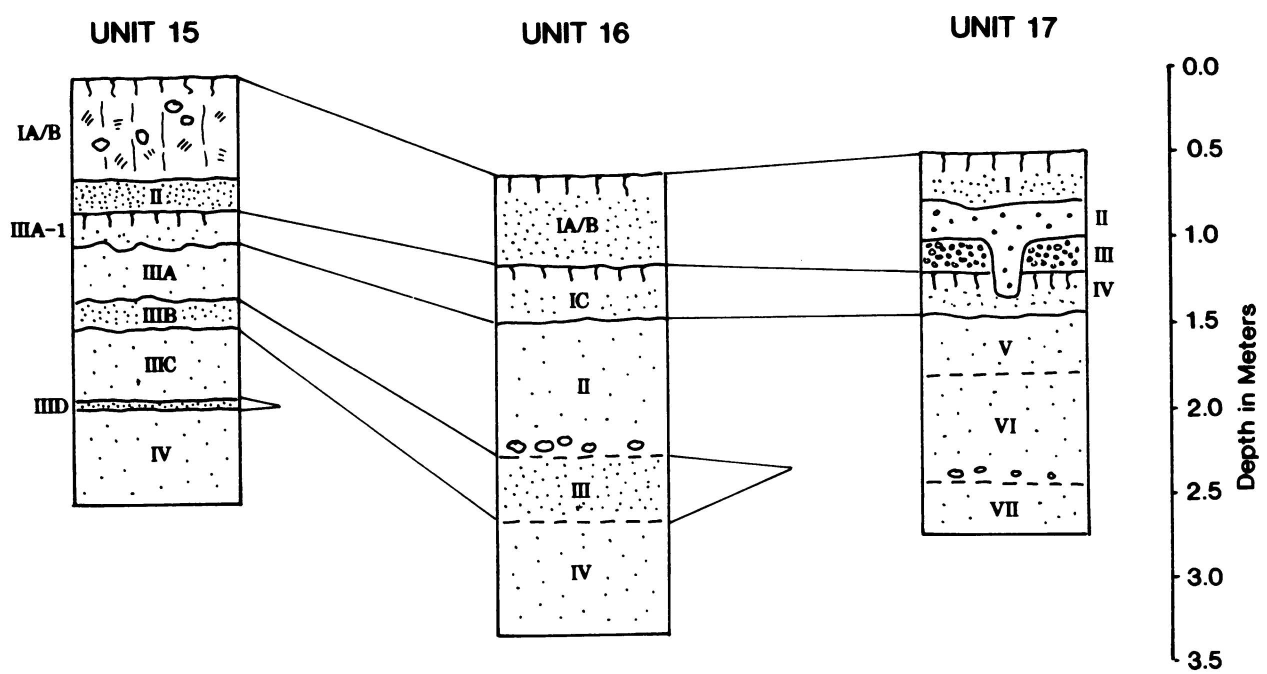


Figure 5.16 Stratigraphic correlations between Units 15, 16, and 17 on Transect 5.

Layer II deposit in Units 15/29/30 is interpreted as a cookhouse activity area, while the contemporaneous Layer IB in Unit 16 is a concentrated midden.

Stage 5B (ca. 1300-1000 cal B.P.): Aceramic occupation on the coastal terrace in the vicinity of Unit 17 resulted in the construction of a low house mound formed by several successive gravel (*'ili'ili*) pavements.

Stage 6 (< 1000 cal B.P.): A tongue of clay-silt colluvium was deposited out onto the coastal terrace, probably due to increased up-slope forest clearance, agricultural activity, and subsequent erosion. At this time the coastal terrace was used for tree-cropping and shifting cultivation, continuing into the present era.

The stratigraphic sequence along Transect 5 and its correlation to modern sea level, as well as the key topographic features of the contemporary coastline (reef flat, active beach ridge) also provide key evidence for testing the morphodynamic model developed in chapter 4. As indicated in figure 5.16, the oldest cultural deposit at Transect 5 is the Layer IIID occupation in Unit 15, yielding thin, fine-tempered, orange-slipped pottery, between 180-200 cm below surface. In Unit 28, this occupation appeared at the base of Layer II, between 290-300 cm below surface, and was ^{14}C dated to 3257-2879 cal B.P. When correlated to modern sea level, this occupation zone lies at virtually the same elevation as mean high tide and about 1.8 m above the reef flat. These elevation relationships provide incontrovertible evidence for tectonic subsidence, as the *in situ* cultural materials in Units 15 and 28 were clearly deposited on a narrow terrace or beach ridge that must have been at least 1 m, and more likely 2 m, above the sea level at 3 kyr B.P. Given a +1-2 m high sea level stand at 3 kyr B.P., this means that the To'aga site has undergone between 2-3 m of tectonic subsidence over the past three thousand years, as suggested by the morphodynamic model developed in chapter 4. In other words, if we retrodict the elevation of the early beach-ridge occupation at 3 kyr B.P. to +3 m (based on our hypothesized subsidence rate of 1 m/kyr), this would put the occupation surface between 1-2 m above the 3 kyr B.P. sea level (which itself was +1-2 m above the present level). The alternative hypothesis—that there was no tectonic subsidence—would require the deposition of the occupation deposit under water, a physical impossibility given the sedimentological evidence. In short, the Transect 5 stratigraphic profile strongly confirms several key elements of the morphodynamic model of coastal terrace formation developed in chapter 4.

Transect 7

Transect 7 is situated 300 m east of the 1987 excavation area. The coastal terrace here is fairly narrow, only about 65 m from the crest of the active beach ridge to the base of the steep talus slope. The elevation profile along Transect 7 is shown in figure 5.17 (a vegetation transect is given in chapter 2, fig. 2.5). The area was primarily in banana gardens under coconut and breadfruit trees in 1989.

Two tests were excavated along this transect, 10 m apart. Unit 18 was located at the base of the talus slope, while Unit 19 was situated on the flat depression in the center of the arboricultural zone. Unit 18 was excavated to 1.4 m below surface, at which depth the presence of large basalt boulders forced us to terminate the excavation. Unit 19, on the other hand, was taken to a depth of 2.2 m, and a thin, non-concentrated cultural deposit was exposed near the base.

Excavation Unit 18

The following strata were discernible in Unit 18:

Layer IA: This massive deposit of colluvial clay has numerous inclusions of subangular to angular gravel and pebbles. It is weak red to dusky red (2.5 YR 3-4/2) and very compact and sticky.

Layer IB: This layer contains the same material as Layer IA, but with an admixture of small quantities of calcareous sand grains. Some charcoal flecking (large chunks) was observed in a 10 cm thick zone between Layers IA and IB. The boundary between IA and IB is gradational over this zone of charcoal flecking. The contact with underlying Layer II is diffuse and irregular, over a 2-3 cm zone.

Layer II: Fine-grained calcareous sand with some clay admixture due to eluviation from Layer IB makes up Layer II. This pale brown (10 YR 6/3) layer incorporates massive volcanic cobbles and boulders which forced a termination of the excavation.

Excavation Unit 19

Unit 19 was positioned 45 m inland of the coastal road, in a relatively level area, surrounded by a few large talus boulders. The stratigraphy of the west face is described below and is illustrated in figure 5.18:

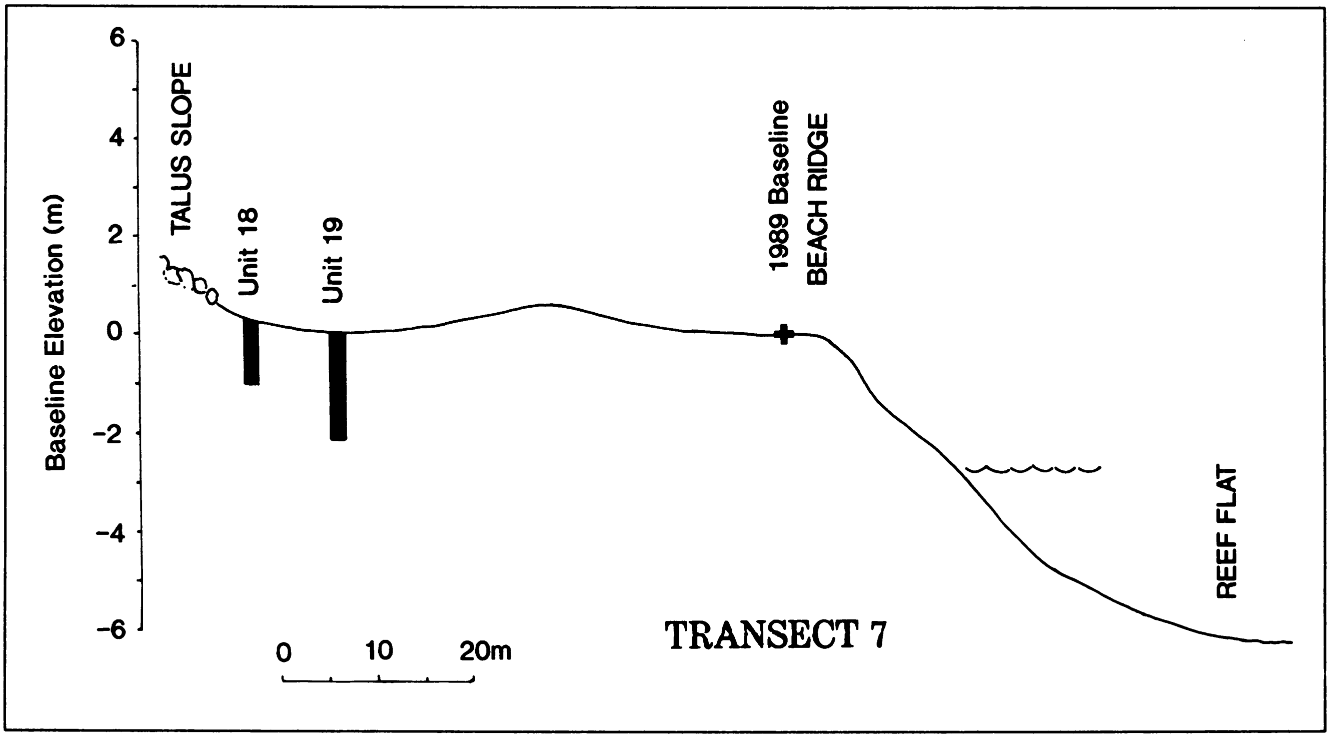


Figure 5.17 Elevation profile along Transect 7, showing the locations of Units 18 and 19 in relation to geomorphic features.

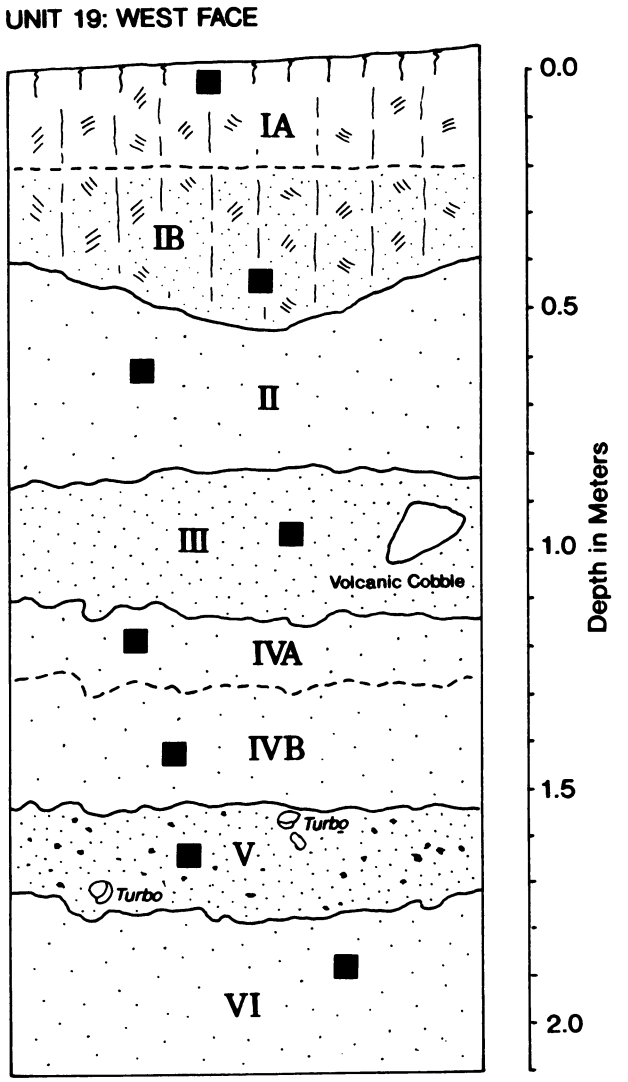


Figure 5.18 Stratigraphic section of the west face of Unit 19. Black squares indicate sediment sampling locations.

Layer IA: This dark reddish brown (5 YR 3/2), poorly sorted colluvial deposit has some subangular volcanic pebbles, but the general absence of gravel suggests deposition of the sand to clay-sized particles by sheet wash at the margin of a colluvial fan. Layer IA grades into IB over a 5 cm zone.

Layer IB: This stratum contains reddish-brown (5 YR 5/3), fine clay mixed with calcareous sand. The calcareous sand component increases with depth. The contact with Layer II is sharp and only slightly irregular.

Layer II: The very pale brown (10 YR 7/3), very fine-grained calcareous sand of this layer is culturally sterile. This deposit appears to represent a fairly long period of beach ridge stability, probably under vegetation. (The very pale brown color is virtually identical to that of beach ridge deposits under *Pandanus* and *Hibiscus* just inland of the modern beach.) The contact with Layer III is diffuse and irregular.

Layer III: This stratum is composed of pale brown (10 YR 6/3), medium- to fine-grained calcareous sand which is well-sorted with scattered coral and volcanic pebbles and cobbles. Layer III is barely distinguishable from Layers II and IVA. The contact with Layer IVA is very irregular. Layer III appears to represent another phase of beach ridge stability.

Layer IVA: The white (10 YR 8/2), medium- to fine-grained calcareous sand of this layer is well-sorted, lacks larger inclusions, and is culturally sterile.

Layer IVB: This layer with its very pale brown (10 YR 7/3), medium- to fine-grained calcareous sand, probably represents a period of beach ridge stability.

Layer V: The color of this cultural deposit ranges from dark grayish-brown (10 YR 4/2) to grayish-brown (10 YR 5/2). This non-concentrated midden consists of medium- to fine-grained calcareous sand stained with charcoal and ash. There are considerable quantities of dispersed charcoal flecks and charred wood fragments, some quite large (5-10 cm diameter). A *Turbo* shell fishhook was excavated from Layer V at 164 cm below surface. No pottery was present. The contacts with Layer IVB and with VI are both quite irregular but fairly distinct.

Layer VI: This layer contains white (10 YR 8/2), coarse- to fine-grained calcareous sand and is culturally sterile. Excavation was terminated at 220 cm below surface. An auger was then used to core to a depth of 385 cm below surface, at which point the water table was encountered. No cultural materials were observed in the augured sediments.

Unit 19 was notable also for the presence of a large pit, sectioned in the east and south faces of the square, as shown in figure 5.19. The pit, which was cut from Layer I down through Layers II and III into Layer IV, has a mixed fill incorporating Layer IB sediment. The pit is straight-sided, with a flat base. There is no evidence of burning or use as an oven pit, nor was the feature filled with midden or trash. In shape and size, the pit is consistent with *lua'i masi*, subterranean silos for the fermentation and

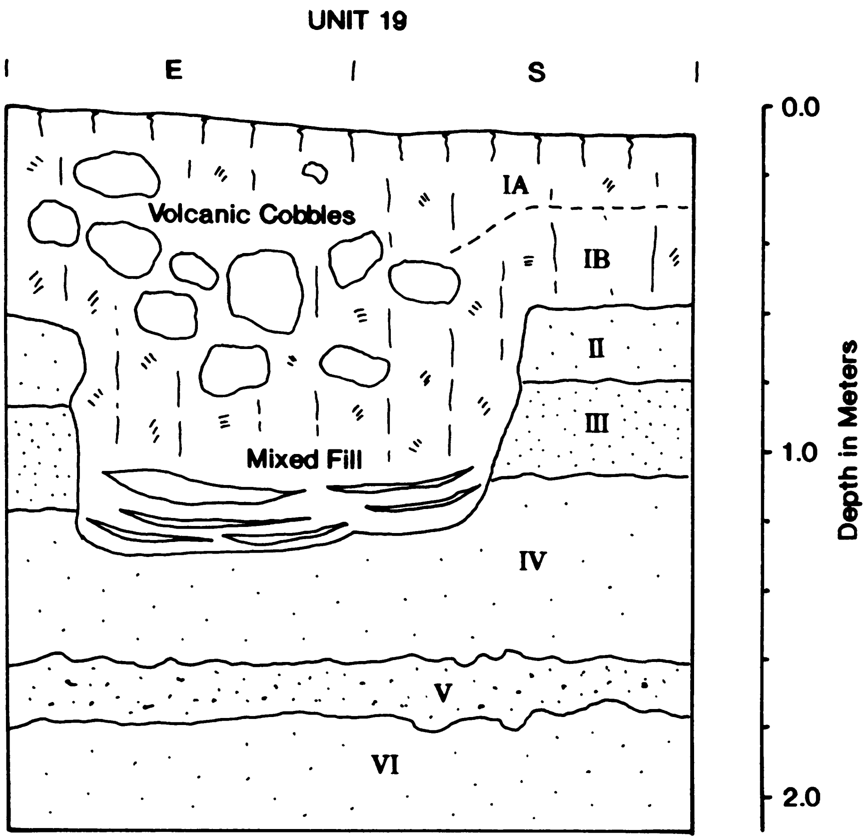


Figure 5.19

Stratigraphic section of the east and south faces of Unit 19, showing the large pit cut from Layer I into Layers II-IV.

storage of breadfruit paste or *masi* (Buck 1930:132-33; Kirch 1984:132-35; Cox 1980). This function is also suggested by the presence of large volcanic cobbles in the pit fill; such cobbles are used to cap *lua'i masi* pits after filling with breadfruit. The To'aga area is dotted with shallow circular depressions, ranging from 1-2 m in diameter, which our informants described as former *masi* pits.

Unit 19 produced a modest faunal sample (see Nagaoka, chapter 13), and a *Turbo* shell fishhook from Layer V. No other artifacts or pottery were present. Although charcoal and *Turbo* shell samples were collected from Layer V for radiocarbon dating, these have not been processed due to budgetary limitations. We are thus uncertain whether the absence of pottery in Layer V reflects sampling error, or whether this deposit post-dates the cessation of pottery use on Ofu (i.e., after about 1500 cal B.P.).

Transect 9

Transect 9 was positioned 500 m east of the baseline origin point. Inland of the road, the coastal terrace here was in dense banana plantations under breadfruit and coconut. No surface archaeological features were evident, other than a filled-in *lua'i masi* pit (1.5 m diameter; 30 cm deep depression) between Units 21 and 22. The elevation profile along Transect 9 is shown in figure 5.20.

We initially laid out three units for subsurface sampling along Transect 9: Units 20, 21, and 22, situated at 10 m intervals. Unit 20 was positioned at the base of the talus slope, with Units 21 and 22 on the flat between the talus and the road. Unit 20 penetrated a thick series of cultural deposits between about 1-2.6 m below surface, yielding an array of thin, fine-tempered ceramics (some with notched rims) and thickware, as well as fishhooks, ornaments, and other artifacts. We therefore decided to expand this test in order to enlarge our sample of the comparatively rare cultural materials recovered from these deposits. Unit 23 was therefore opened adjacent to Unit 20 on the north (inland) side (fig. 5.21). Thus a total of 4 m^2 was excavated along Transect 9.

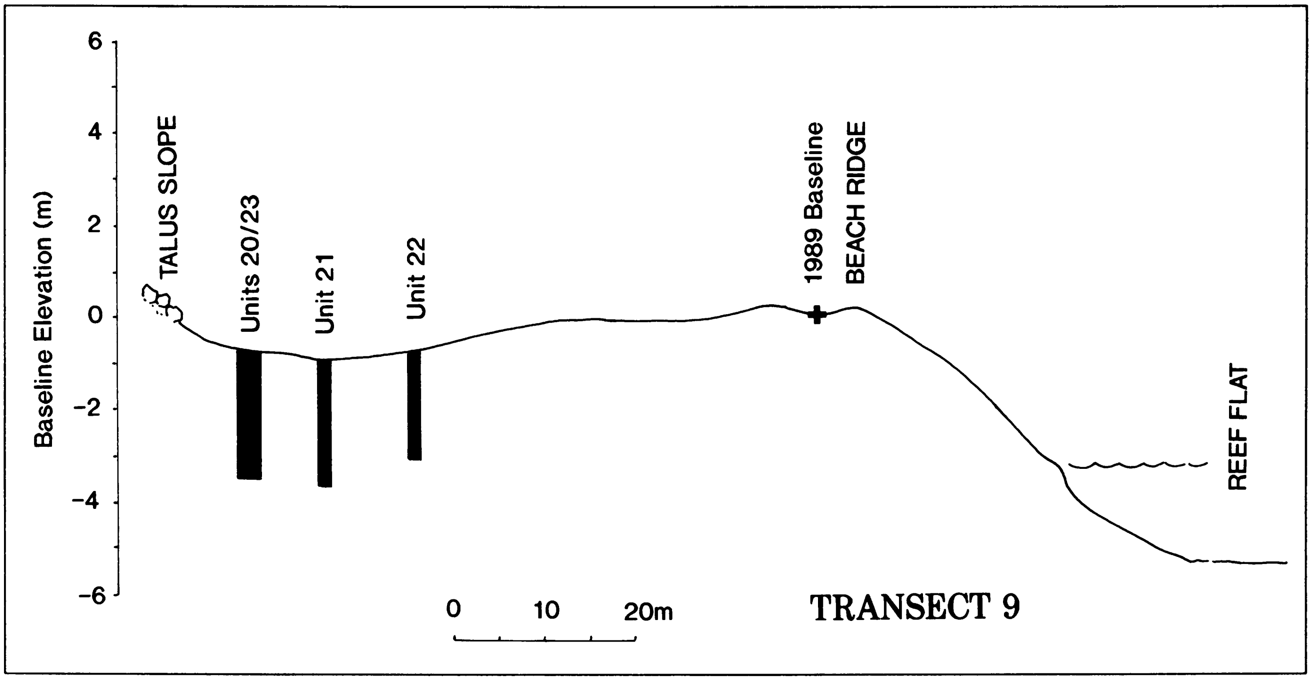


Figure 5.20 Elevation profile along Transect 9, showing the locations of Units 20/23, 21, and 22 in relation to geomorphic features.

Excavation Units 20/23

The stratigraphy of this 1x2 m excavation was recorded along the west and north faces, as depicted in figure 5.22, and described below:

Layer IA: This stratum consists of dusky red (2.5 YR 3/2) colluvium; the upper 10 cm is humic garden soil. The very poorly sorted, compact, sticky, very plastic sand-to-clay material has abundant subangular volcanic gravel- to cobble-sized inclusions. The contact with Layer IB is gradational.

Layer IB: This dark reddish-brown (5 YR 3/2) massive colluvial deposit is poorly sorted and has abundant larger volcanic clastics. Calcareous sand grains and occasional charcoal flecks are dispersed throughout. The deposit also contains a low frequency of dispersed, chalky shell midden (due to chemical decomposition in the humic soil matrix) and occasional waterworn *'ili'ili* coral pebbles. These cultural materials suggest some low intensity use of the area during the period of colluvial deposition. This deposition was presumably gradual and incremental, and not a single event. The contact with Layer IC is gradational over a 2 cm zone.

Layer IC: The dark reddish-brown (5 YR 3/3), compact, sticky silty-clay of this stratum lacks larger pebble-sized inclusions. The clay appears to represent a single depositional event, presumably resulting from sheet wash (fluvial mode of deposition) following heavy rains. The contact with Layer IIA is abrupt and slightly irregular.

Layer IIA: This stratum is composed of dark reddish-brown to reddish-brown (5 YR 3-4/4), coarse- to fine-grained, poorly sorted, calcareous sand mixed with fine clay-silt and is marked by abundant charcoal flecking. This appears to represent a paleosol or former stable surface of the beach ridge. The contact with Layer IIB is gradational.

Layer IIB: This layer contains yellowish-red (5 YR 5/6) to reddish-yellow (7.5 YR 7/6) well-sorted, medium- to coarse-grained, structureless calcareous sand mixed with reddish clay and is culturally sterile. The clay content decreases with depth, with the base of the layer consisting of nearly pure, medium-grained sand. The contact with Layer IIIA is abrupt and irregular.

Layer IIIA: This cultural midden deposit is very dark gray to very dark grayish-brown (10 YR 3/1-2) and has a sandy loam texture. The dark coloration of the calcareous sand matrix results from a high carbon and organic content. This layer was associated with a large earth oven feature, from which a ^{14}C sample was obtained (see below). The oven and adjacent sediment contained heavy concentrations (more than 2 kg) of the spines of the large slate-pencil sea urchin (*Heterocentrotus mammillatus*) and

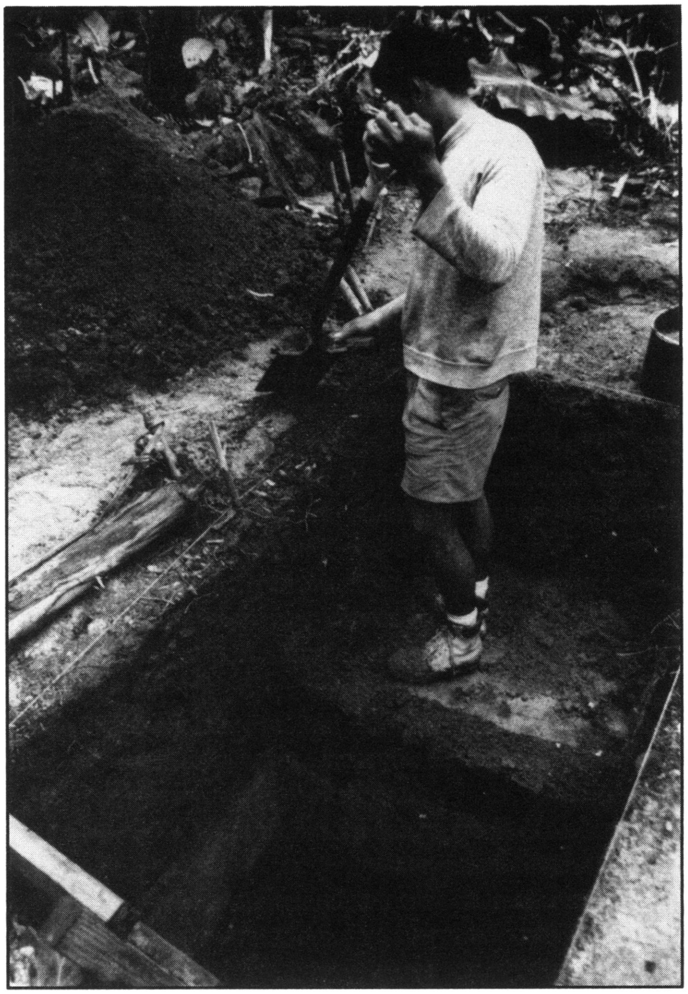


Figure 5.21 Expansion of Unit 20 into Unit 23; removal of the thick colluvial deposit in progress.

of fire-altered volcanic oven stones. This stratum clearly represents a cookhouse or food preparation activity area. The contact with Layer IIIB is gradational.

Layer IIIB: In this layer, a dark brown to brown (10 YR 4/3), thick, cultural midden deposit of calcareous sandy loam incorporates numerous, large, subangular, volcanic cobbles. Near the top of the layer is a distinct lens of compact grayish-white ash, about 1 cm thick. This ash lens was discontinuous over the 1x 2m excavation unit. The ash lens is capped by 1-2 cm of clean white beach sand, probably an artificially deposited house floor. Layer IIIB contained a heavy concentration of shell and bone midden, ceramics, and other portable artifacts. The contact with Layer IIIC is gradational over 5-10 cm.

Layer IIIC: Subangular volcanic pebbles and cobbles are contained in the light yellowish-brown (10 YR 6/4) calcareous sand midden of this stratum. The matrix consists of coarse- to medium-grained calcareous sand. This layer is essentially a lower facies of Layer IIIB, distinguished primarily by a lower concentration of midden and organic staining. The contact with Layer IV is gradational.

Layer IV: The white (10 YR 8/2), coarse- to medium-grained, 'salt-and-pepper' sand (calcareous grains with an admixture of volcanic lithic grains) of Layer IV contains abundant large clastics consisting of branch coral fingers, and waterworn volcanic pebbles and gravel. It is culturally sterile.

An earth oven was exposed in Layer IIIA of Unit 23, as noted above, and is illustrated in figure

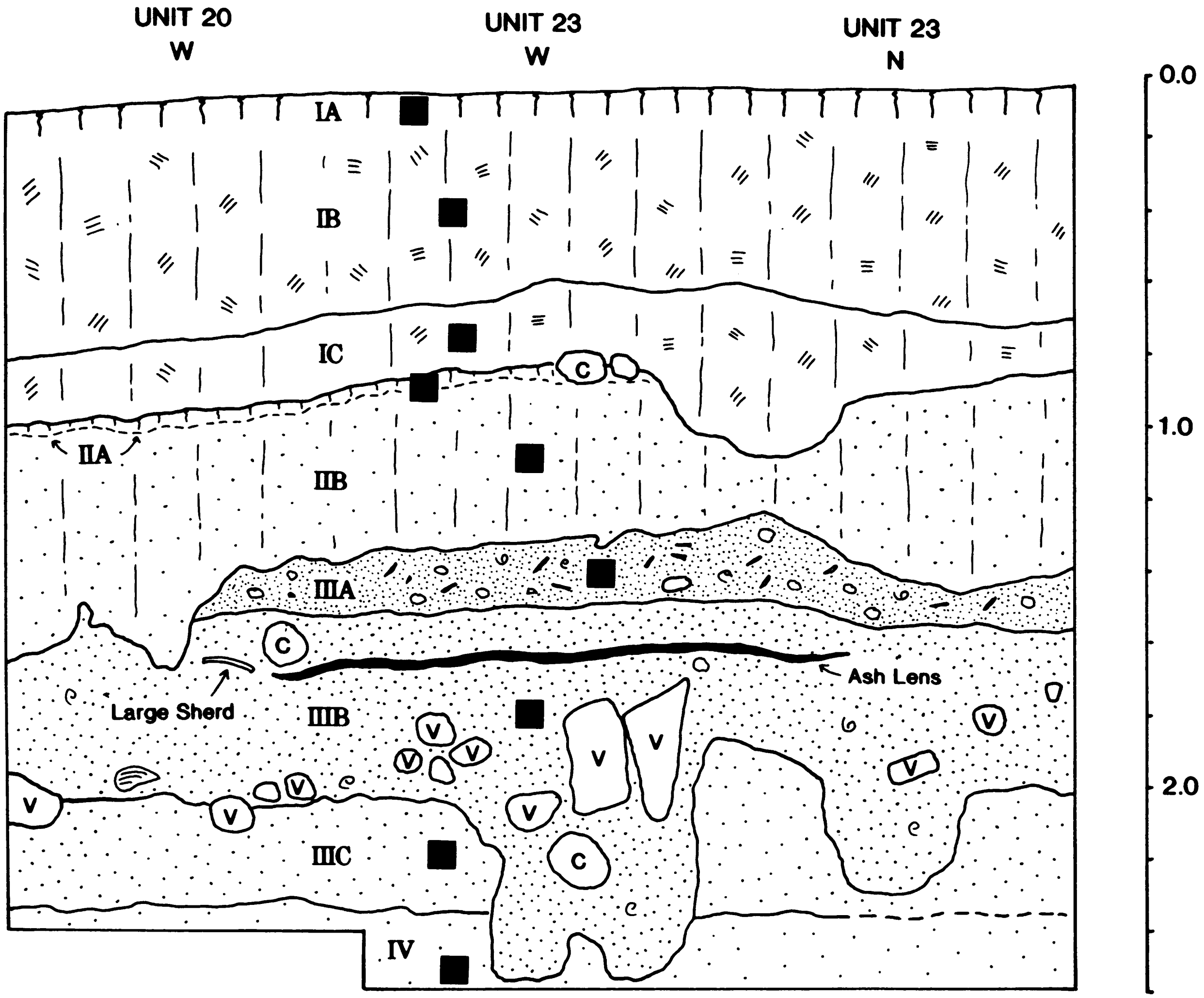


Figure 5.22 Stratigraphic section of the west and north faces of Units 20/23. Black squares indicate sediment sampling locations. "C" indicates coral; "V" indicates volcanic.

5.23. The oven consisted of a circular pit, with a diameter in excess of 80 cm, and a depth of 38 cm from the rim to the base. The oven pit fill consisted of fire-cracked volcanic oven stones (fist-sized) with a few larger stones at the base, charcoal, and ash. Both the oven fill and the surrounding midden contained large quantities of echinoderm spines and test fragments, particularly of the slate-pencil sea urchin (*Heterocentrotus mammillatus*), and several smaller echinoid species.

Units 20/23 yielded a large sample of pottery and a number of noteworthy portable artifacts. A total of 499 sherds was recovered, with the following stratigraphic distribution:

	Thinware		*Thickware*		*Total*
Layer IIB	5	10%	45	90%	50
Layer IIIA	8	8%	87	92%	95
Layer IIIB	50	21%	191	79%	241
Layer IIIC	32	28%	81	72%	113

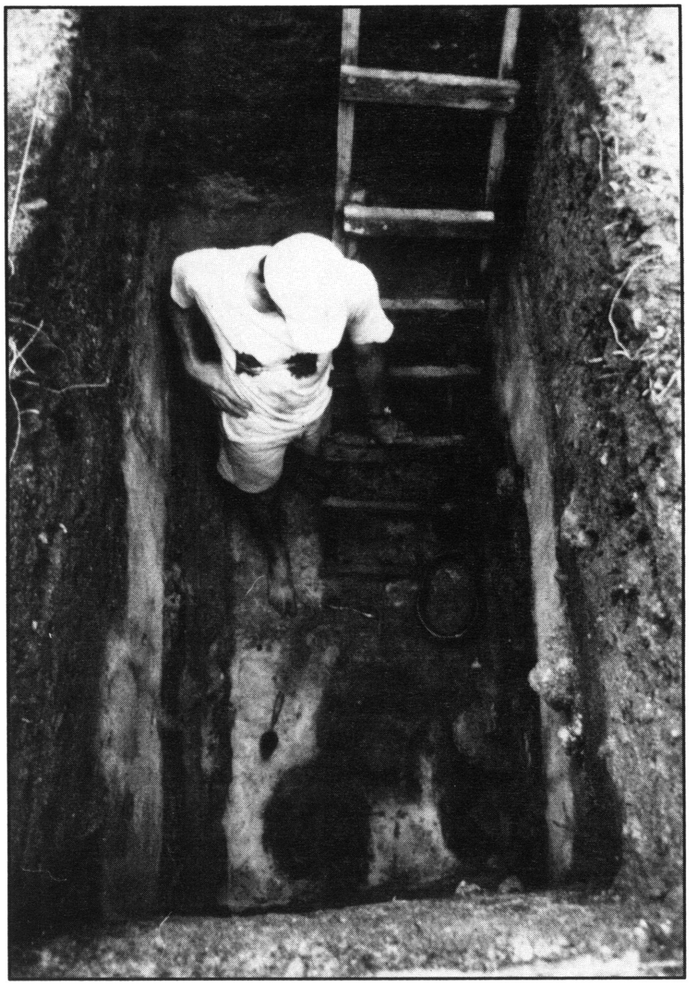


Figure 5.23 View into Units 20/23, showing circular pit or postmold features filled with Layer IIB sediment, exposed at the contact with Layer IIIC.

These frequencies confirm a decrease in thinware relative to thickware also noted from other transects (see above). The sherd assemblage from Units 20/23 includes one thickware rim from Layer IIB, six thickware rims and one thinware rim from Layer IIIA, twelve thickware and six thinware rims from Layer IIIB, and five thinware rims from Layer IIIC. None of the thickware rims have impressed lips, and all were recovered from Layer IIIB. Of 499 sherds, 15 are red-slipped (on thinware only) and were recovered from Layers IIIA, IIIB, and IIIC. One small thinware body sherd from Layer IIIC has incised lines on the exterior, but no pattern is discernible.

Several *Turbo*-shell fishhooks were recovered from Layer III, including one with a distinctly bent shank similar to early Eastern Polynesian forms (see Kirch, chapter 11 for further discussion). The butt of a plano-convex section adz (Samoan Type V) was excavated from Layer IIIB. Layer IIIC produced an unfinished ring of *Tridacna* shell which evidently broke in half during the process of manufacture. At the contact of Layers IIIB and IIIC, we also recovered an abrading stone designed for the manufacture of small *Conus*-shell beads. All of these finds are further described and illustrated in chapter 11.

Excavation Unit 21

Unit 21 was positioned 10 m seaward of Units 20/23, at essentially the same elevation above sea level. The profile of the south face is illustrated in figure 5.24, and described below:

Layer IA: This dusky red to weak red (2.5 YR 3-4/2) massive colluvial deposit is primarily clay with some large volcanic cobbles and talus boulders and some smaller subangular volcanic inclusions. It is very sticky and plastic. Small quantities of chalky shell midden are dispersed throughout the deposit. The contact with Layer IB is very gradational over 10-15 cm.

Layer IB: In this mixture of fine clay and calcareous sand, the sand content increases with depth. Some shell midden was noted near the top of the deposit, but the layer becomes culturally sterile near the bottom. There are many discretely dispersed flecks and chunks of wood charcoal, probably deposited with the clay, and suggestive of forest clearance/burning up slope. The contact with Layer IIA is quite irregular and somewhat diffuse.

Layer IIA: This stratum is composed of very pale brown (10 YR 7/3) calcareous sand. There is a minor lithological component of volcanic lithic grains.

Layer IIB: The sandy midden deposit of Layer IIB is grayish-brown to dark grayish-brown (10 YR 4-5/2). Contacts with both Layers IIA and IIC are irregular (wavy) but fairly distinct. This deposit contains large quantities of *Heterocentrotus mammillatus* spines, some fire-altered volcanic stones, shell midden, bone, and ceramic sherds. This layer appears to correlate with the thick Layer III midden deposit in Units 20/23, being a seaward 'pinching out' of this occupation zone in the direction of the former beach slope.

Layer IIC: The white (10 YR 8/2), fine-grained, calcareous sand of this stratum has a minor component of volcanic lithic grains. The layer is culturally sterile and represents a beach slope depositional environment.

The Layer IIB midden yielded a large faunal assemblage, including 13.1 kg of marine shell, 1,803 fish bones (including a large number of spines of the puffer fish *Diodon hystrix*), rat, bird, and turtle (see Nagaoka, chapter 13 for further details).

Unit 21 yielded several artifacts of worked shell and a shell ornament (see Kirch, chapter 11), all from Layer IIB. Pottery from IIB includes three (15%) thinware and 17 (85%) thickware sherds. No rims, decorated sherds, or red-slipped sherds were present.

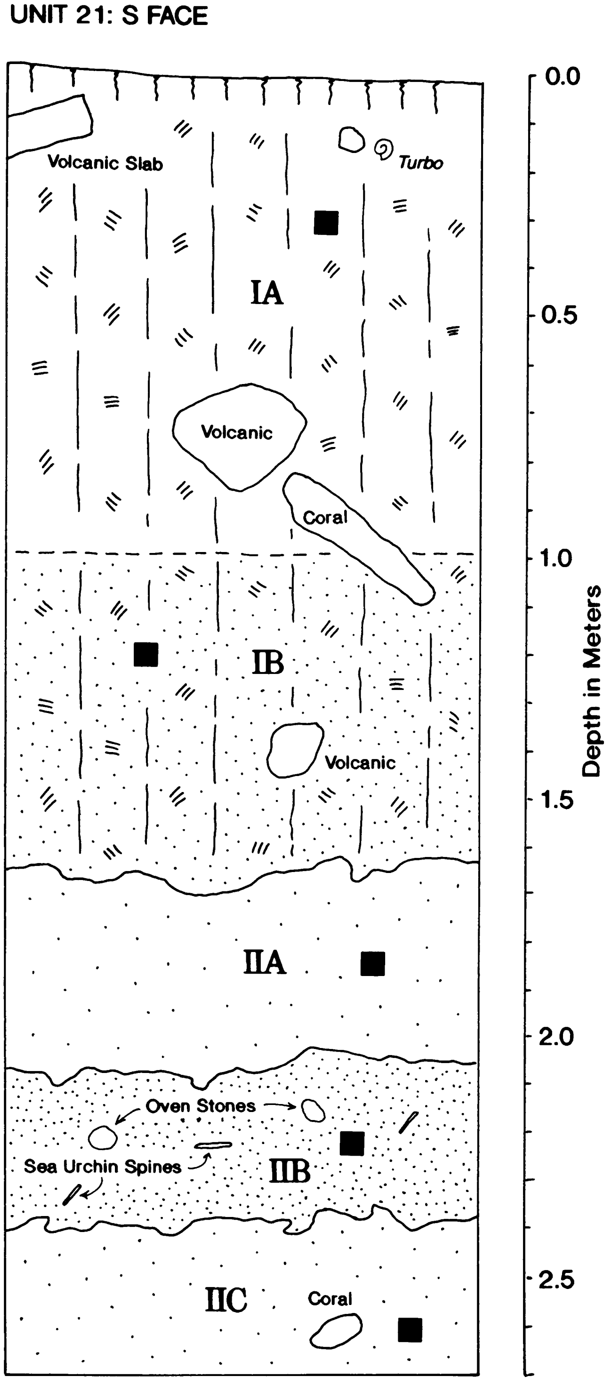


Figure 5.24 Stratigraphic section of the south face of Unit 21. Black squares indicate sediment sampling locations.

Excavation Unit 22

Unit 22 was positioned 10 m further seaward from Unit 21, and at a slightly higher ground elevation (on the inland slope of the present beach ridge). The north face of Unit 22 is illustrated in figure 5.25 and described below:

Layer I: The very dark grayish-brown (10 YR 3/2), sandy loam of this stratum has a 'greasy' texture. The deposit consists primarily of calcareous sand with a minor component of fine silt-clay. Dispersed throughout is chalky shell midden and some *'ili'ili* gravel. The deposit becomes darker toward the base, with increasing charcoal and ash content. The contact with Layer II is diffuse and irregular.

Layer II: Considerable coral and basalt waterworn *'ili'ili* gravel is dispersed throughout this brown (7.5 YR 5/4) sandy midden. There is some charcoal flecking, especially in the bottom of a shallow pit feature at the base of the deposit. The contact with Layer III is sharp but irregular.

Layer III: The white (10 YR 8/2), medium-grained, calcareous beach sand of this stratum with its minor component of volcanic lithic grains is culturally sterile.

UNIT 22: N FACE

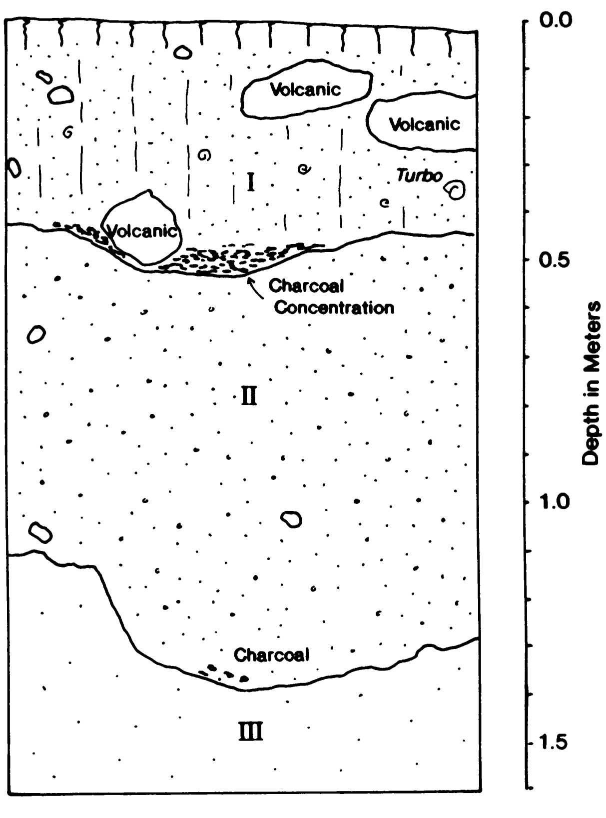


Figure 5.25 Stratigraphic section of the north face of Unit 22.

No ceramics were present in this unit.

Radiocarbon Dates from Transect 9

Three ^{14}C age determinations were obtained from Transect 9, all on samples excavated from Unit 23. Charcoal from the large earth oven in Layer IIIA (Beta-35602) yielded an age range of 2845-2612 cal B.P. at one standard deviation. This sample was in direct association with a ceramic assemblage composed of 8% thinware and 92% thickware. A second sample (Beta-35603) of dispersed charcoal flecks from the stratigraphically older Layer IIIB cultural deposit yielded an age range of 2917-2382 cal B.P. at one standard deviation. A large single valve of *Tridacna maxima* shell (Beta-35604) from Layer IIIB was also dated, yielding an age range of 2444-2289 cal B.P. at one standard deviation. All three samples from Unit 23 overlap at one standard deviation, suggesting that the deposition of Layers IIIB and IIIA occurred fairly rapidly, possibly over a span of only one or two hundred years. Further details on all samples are provided in chapter 6.

Summary of the Transect 9 Depositional Sequence

Figure 5.26 is a correlation diagram of the strata exposed in the Transect 9 excavation units. This diagram also shows the elevational relationships between these strata and the modern sea level and reef-shoreline features. Evidence from the Transect 9 excavation data suggests the following depositional sequence:

Stage 1 (> 2800 cal B.P.): A narrow coastal terrace or bench with a mixed calcareous-volcanic lithic sand lithology was formed. At this time the active shoreline was probably in the vicinity of Units 21-22.

Stage 2 (ca 2800-2300 cal B.P.): The occupation of the narrow coastal terrace formed in Stage 1 resulted in the accumulation of the thick pottery-bearing Layer III strata in Units 20/23. The Layer IIB deposit in Unit 21 represents a seaward diminution of this occupation down the former beach slope. The shoreline itself was presumably no more than 10-20 m further seaward of Unit 21 at this stage.

Stage 3 (ca 2300-1900 cal B.P. ?): The rapid progradation of the coastal terrace was initiated by an increase in the biogenic/calcareous sediment

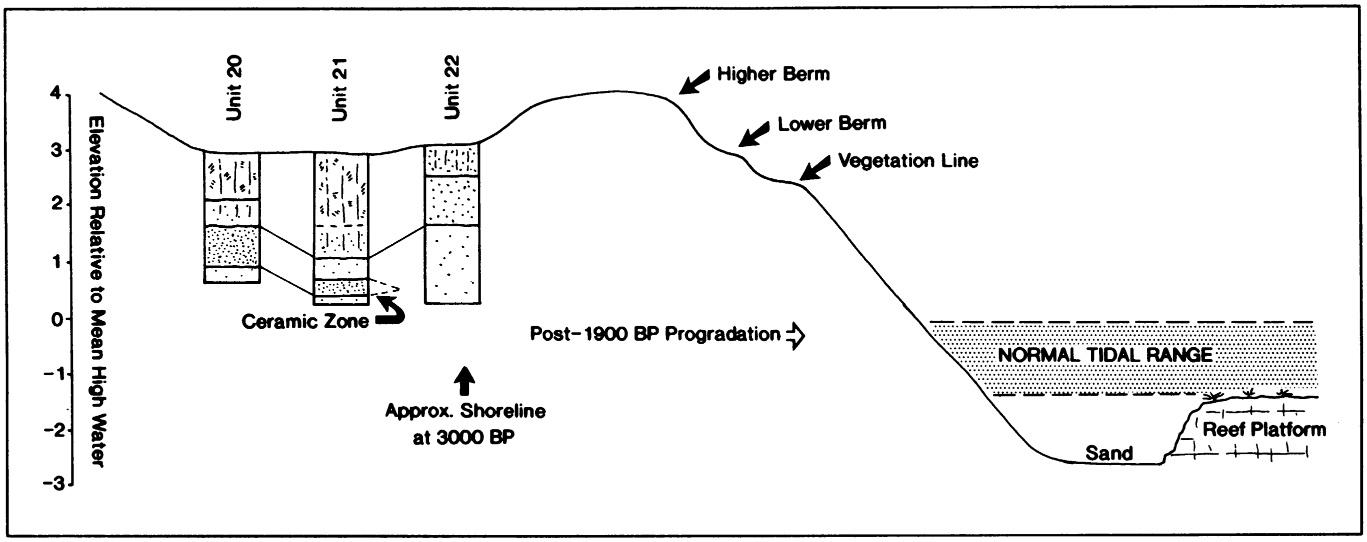


Figure 5.26 Stratigraphic correlations between Units 20/23, 21, and 22 shown in relation to a schematic elevation profile of Transect 9. The horizontal dimension along this transect is schematic and arbitrary, while the vertical dimension is expressed in meters above and below mean high water.

budget. This resulted in the sterile calcareous Layer IIB sand deposit in Units 20/23 (correlated with Layer IIA in Unit 21 and Layer III in Unit 22), capping the earlier pottery-bearing occupation. During this stage, the shoreline prograded substantially, and active accumulation of calcareous sediments in the vicinity of Units 20-21-22 subsequently ceased.

Stage 4 (ca. 1900 cal B.P. ?): Following progradation of the shoreline, the coastal terrace in the vicinity of the excavation units was stabilized, with the surface covered by vegetation. This is indicated by the stable paleosol surface represented by Layer IIA in Units 20/23.

Stage 5 (< 1900 cal B.P.): At this time colluvial clays and larger volcanic clastics were deposited onto the coastal terrace. The presence of charcoal in these clays suggests forest clearance and burning on the talus slope inland of the site. These human activities thus initiated increased rates of erosion.

Stage 6 (< 1900 cal B.P.): The mixed colluvial-calcareous soil of the coastal terrace was used for subsistence gardening and for dispersed habitation during Stage 6.

In sum, the depositional sequence of Transect 9 closely replicates that of the 1987 excavation locality, and that of Transect 5, as described above.

The elevational data from Transect 9 also fully support the morphodynamic model outlined in chapter 4, and argued above for Transect 5. As can be seen in the correlation diagram (fig. 5.26), the Stage 2 occupation is no more than 1 m above the modern high water mark, and some 3.5 m below the modern beach ridge. Given a + 1-2 m higher sea level stand at 2-3 kyr B.P., the Stage 2 habitations would have been awash if they were not at a higher elevation than at present. Retrodicting a subsidence rate of about 1 m/kyr puts these habitation surfaces at 1-2 m above the then sea level, which also fits the lithological-sedimentological data (see Kirch, Manning, and Tyler, chapter 7). Thus, the incorporation into our morphodynamic model of a tectonically induced subsidence rate for Ofu Island of ca. 1 m/kyr is supported by the Transect 9 stratigraphic data.

Transect 11

Transect 11 lies 700 m east of the baseline origin-point (the 1987 excavation locality). Here the coastal terrace is quite broad and flat, nearly 100 m wide from the present shoreline to the base of the talus slope. The elevation profile is depicted in figure 5.27. Only a single excavation, Unit 26, was located here, some 60 m inland from the baseline. The soil along Transect 11 is more sandy than at Transects 9 or 5, lacking the colluvial clay component except very close to the talus slope. The vegetation consists of tree crops (coconut and

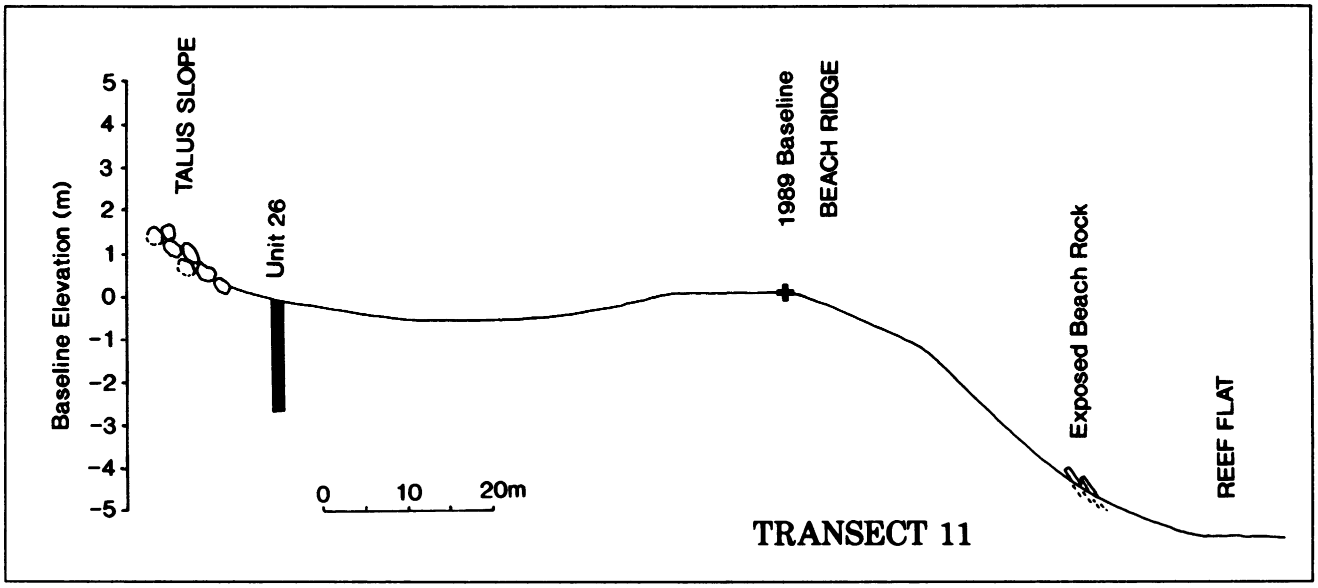


Figure 5.27 Elevation profile along Transect 11, showing the location of Unit 26 in relation to geomorphic features.

breadfruit) with bananas, but aroids are absent, reflecting the sandy, edaphic conditions.

The stratigraphy of the west face of Unit 26, shown in figure 5.28, follows:

Layer IA: The dark grayish-brown (10 YR 3/2) sandy loam in this layer is culturally sterile. A thick root mass was present in the upper 5 cm. This zone contains abundant shells of several terrestrial molluscs, including *Subulina*, *Lamellaxis*, and *Pleuropoma*. The contact with Layer IB is gradational over 3-4 cm.

Layer IB: This very dark gray (10 YR 3/1), non-concentrated midden deposit is lithologically identical to Layer IA. There is some charcoal flecking, and the texture is slightly 'greasier' than Layer IA due to carbon and organic material. Some fist-sized, volcanic fire-altered stones were noted. The contact with Layer IIA is irregular but distinct.

Layer IIA: This stratum contains a white (10 YR 8/2), massive, structureless deposit of culturally sterile calcareous, medium-grained sand. There is an irregular, diffuse contact with Layer IIB.

Layer IIB: The pale brown (10 YR 6/3), faintly darker calcareous sand in this zone is apparently an old, stabilized A horizon paleosol within the beach ridge depositional sequence represented by Layer II.

Layer IIC: The white (10 YR 8/2), coarse-grained, culturally sterile sand of this layer has a 'salt-and-pepper' lithology (mixture of calcareous and volcanic grains).

Little cultural material was recovered during the excavation of Unit 26. Layer IB, the major source, yielded slightly more than 2 kg of shell midden. No pottery was present in any of the layers. One broken *Turbo* shell fishhook was recovered at the Layer IB/IIA contact. No radiocarbon dates were obtained from this unit. The Layer IIB deposit may possibly correlate with the phase of progradation and subsequent coastal terrace stability at ca. 1900 cal B.P. identified from other transects. This could not be verified in the absence of radiometric dates, however. If a ceramic period occupation were ever present in the vicinity of Transect 11, it would have had to have been inland of Unit 26, and therefore now deeply buried beneath the steep talus rockfall.

Transect 17

This was the most easterly of our 1989 excavation transects, situated 1300 m east of the baseline origin-point. Transect 17 runs just slightly west of the low gap over the island's central ridge at Fa'ala'aga. At this easterly end of the To'aga coastal terrace, the reef flat is quite narrow; thus the coastline is exposed to greater wave energy, particularly during storms and cyclones. The beach fronting Transect 17 consists of coarse sand and gravel, rather than the finer-grained sands typical of locations farther to the west. Also, the modern beach sediments at Fa'ala'aga contain a high percentage of

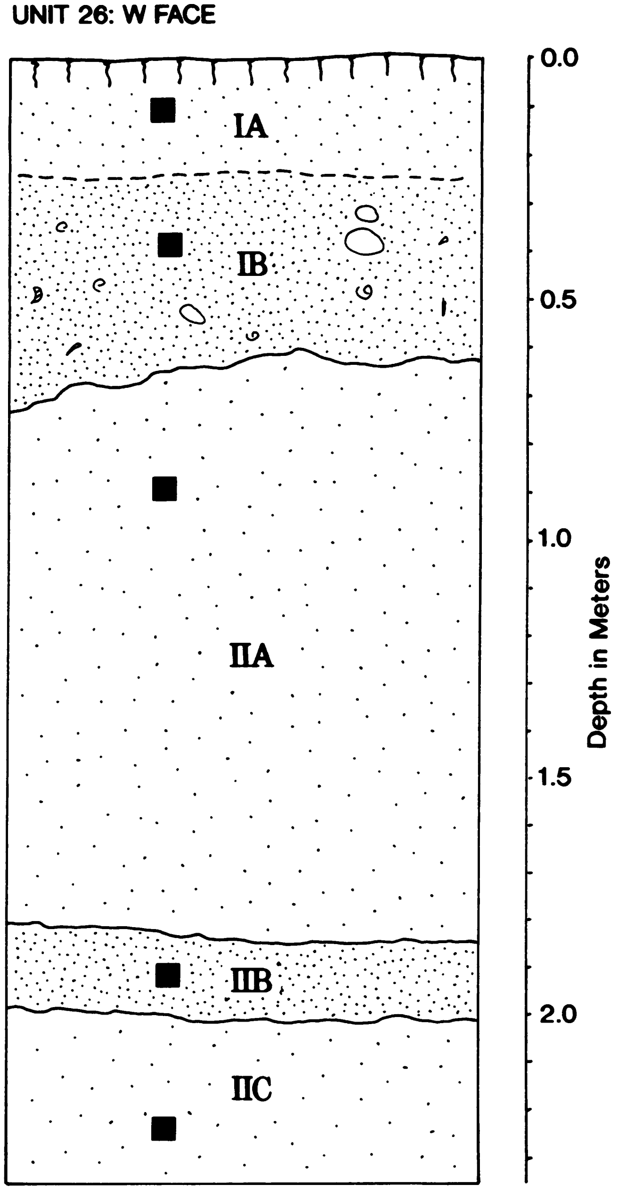


Figure 5.28 Stratigraphic section of the west fact of Unit 26. Black squares indicate sediment sampling locations.

volcanic clastics, derived from the exposed volcanic headland at the eastern tip of Ofu (a control sample of this modern beach sediment is described in chapter 7). These particular geomorphological features are likewise reflected in the lithology of the two units, 24 and 25, excavated along Transect 17. The elevation profile along the transect is shown in figure 5.29, indicating the positions of the two excavated pits just seaward of the talus slope.

Excavation Unit 24

Unit 24 was situated 114 m inland of the baseline (along the coastal road) and about 10 m from the base of the talus slope. The talus here consists entirely of large subangular boulders, without a colluvial clay component. The ground surface at Unit 24 was sandy loam with a cover of coconut and breadfruit. The stratigraphy of the north face of Unit 24, shown in figure 5.30, follows:

Layer IA: This stratum contains dark brown (10 YR 3/3) sandy loam (A horizon) developed under *Hibiscus tiliaceus*, banana, breadfruit, and other vegetation. The parent material consists wholly of coarse- to medium-grained calcareous sand. The contact with Layer IB is irregular and slightly diffuse.

Layer IB: Light yellowish-brown (10 YR 6/4), coarse- to medium-grained, calcareous sand with a very minor volcanic component makes up this stratum. Also, there is slight humic staining. The contact with Layer IC is gradational.

Layer IC: This white (10 YR 8/2), very coarse- to coarse-grained sand contains lenses of waterworn coral, volcanic gravel, and waterworn branch coral fingers. The sand is dominantly calcareous but with a strong secondary mode of volcanic lithic grains. The contact with Layer ID is fairly sharp and regular.

Layer ID: Coral, gravel, and rubble with waterworn branch coral fragments, in a matrix of coarse-grained sand make up this stratum which appears to represent a single, high-energy depositional event. The contact with Layer IE is sharp and distinct.

Layer IE: The coarse- to medium-grained 'salt-and-pepper' sand of this layer has scattered waterworn coral and volcanic gravel- to cobble-sized clastics.

Layer IF: This stratum contains volcanic, lithic, coarse-grained sand with a slightly dominant calcareous mode. The deposit incorporates large cobbles of waterworn basalt and cobble-sized coral head shingles. It represents a very high-energy beach, with constant input of volcanic source materials to the sediment budget.

The depositional sequence in Unit 24 reveals a gradual transition from a very high-energy, exposed beach directly at the base of the talus slope, then to a lower-energy beach resulting from progradation, and finally to the formation of a stable coastal terrace

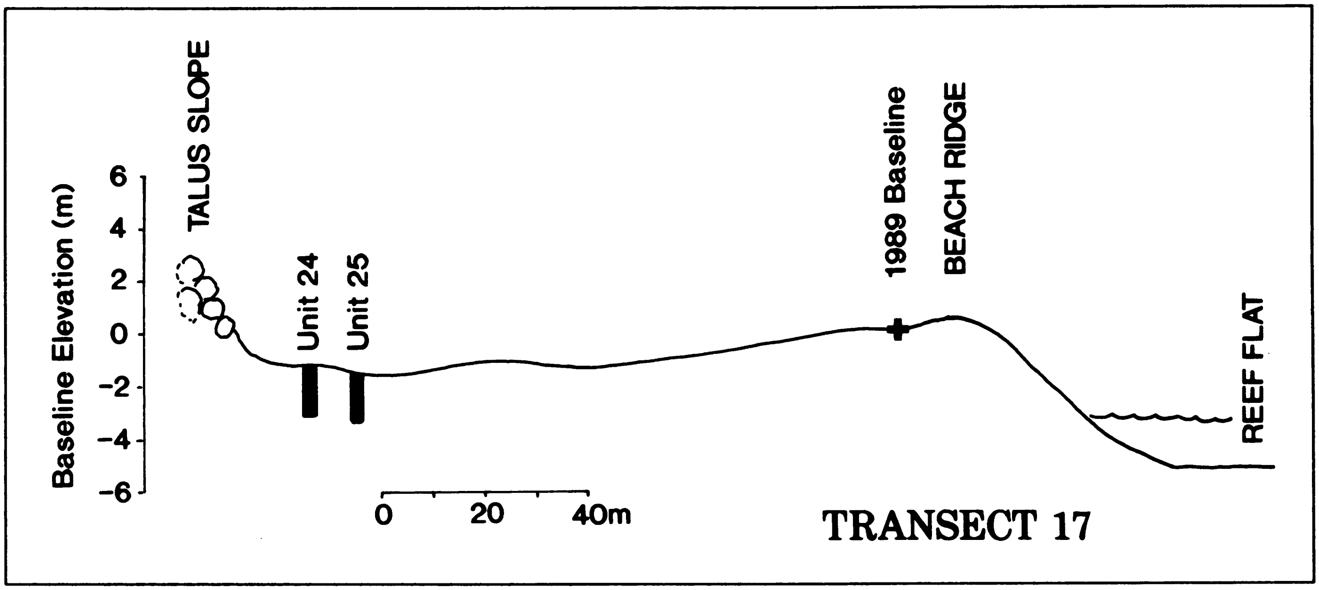


Figure 5.29 Elevation profile along Transect 17, showing the locations of Units 24 and 25 in relation to geomorphic features.

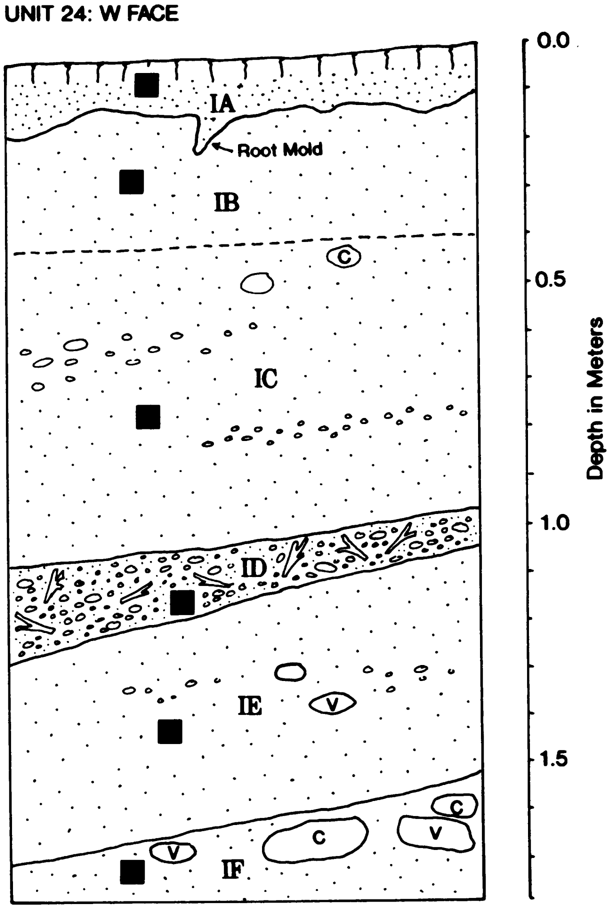


Figure 5.30 Stratigraphic section of the west face of Unit 24. Black squares indicate sediment sampling locations. "C" indicates coral; "V" indicates volcanic.

with soil development under vegetation. Three ceramic body sherds (1 thickware, 2 thinware) were recovered from Layer IB of Unit 24. One of these is particularly unusual in that it is thick, coarse-tempered pottery yet with a very clear red-slipped exterior surface. While thickware is obviously contemporaneous with early thinware assemblages, including those with red slipping, this is the only thickware sherd from the To'aga site with a red slip.

Excavation Unit 25

Unit 25 was positioned 10 m seaward of Unit 24. The stratigraphy of the north face, shown in figure 5.31, is:

Layer IA: The very dark grayish-brown (10 YR 3/2) sandy loam of this stratum has some subangular, fist-sized, volcanic stone inclusions (not fire altered). The contact with Layer IB is gradational over 2-4 cm.

Layer IB: The black (10 YR 2/1) sandy loam of this layer is a very 'greasy' textured cultural deposit of calcareous sand with a heavy carbon and organic material component. Shell midden and fire-altered volcanic stones are present. The contact with Layer IIA is fairly distinct and slightly irregular.

Layer IC: The dark grayish-brown (10 YR 4/2) to very dark grayish-brown (10 YR 3/2) sandy loam of this deposit appears to be identical to Layer IA. It probably represents a fairly long period of coastal

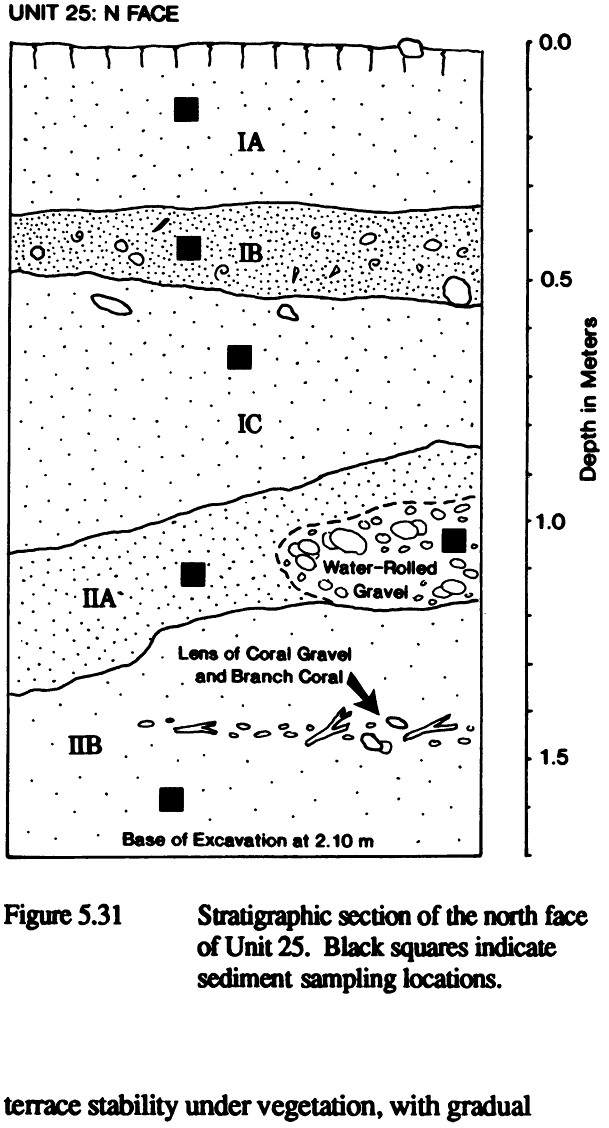


Figure 5.31 Stratigraphic section of the north face of Unit 25. Black squares indicate sediment sampling locations.

terrace stability under vegetation, with gradual accumulation. The contact with Layer IIA is distinct and slightly irregular.

Layer IIA: This layer contains pale brown (10 YR 6/3), coarse-grained sand with a marked 'salt-and-pepper' appearance due to a heavy mixture of volcanic grains. In the northeast corner of the unit there is a facies of sand matrix incorporating water-rolled coral and volcanic gravel/pebbles. The contact with Layer IIB is sharp but slightly irregular.

Layer IIB: The white (10 YR 8/2), coarse-grained, 'salt-and-pepper' sand of this stratum has a lens of water-rolled coral rubble and gravel (incorporating branch coral fingers) at about 145 cm below surface.

The heavy carbon content of Layer IB is suggestive of cookhouse activity. This interpretation is also supported by the presence of fire-alterred volcanic oven stones. No pottery was present in Unit 25.

SUMMARY AND CONCLUSIONS

A detailed discussion of the results of our three seasons of excavations at the To'aga site is best deferred to the concluding chapter of this volume (see Kirch and Hunt, chapter 15). Here we confine ourselves to a brief summary of several key points:

1. *Areal extent of the To'aga site.* One of our primary objectives during the 1989 excavation season was to determine the full horizontal extent of the subsurface cultural deposits at To'aga. Through the use of systematic transect sampling, we have been able to ascertain that buried cultural deposits dating as early as ca. 3000 cal B.P. extend continuously from Transect 3 to Transect 9, a distance of some 700 m. Between Transects 9 and 11 the density of cultural materials declines significantly, but some cultural materials were present in Unit 26 along Transect 11. Transect 17 also yielded a very low density of cultural materials. We were restricted by the local landowners from testing the 600-m gap between Transects 11 and 17 because of the presence of the sacred—and rather feared—Tui Ofu tomb and other surface cultural remains in this area. Based on our transect results, we can now state that subsurface archaeological deposits are present throughout the entire To'aga coastal flat as far as Fa'ala'aga, but that the main pottery-bearing, concentrated midden deposits are restricted to the area between Transects 3 and 9. The buried deposits are concentrated in a narrow band, extending no more than about 30 m seaward from the present base of the talus slope. Shovel tests in various localities in the present beach ridge (on both sides of the road) revealed no archaeological materials. We are also certain that cultural deposits extend inland under the steep talus for an unknown extent. The great thickness of the talus and colluvium, however, prevents testing of these deposits without the aid of heavy machinery which was not available to us. It would probably require the removal of as much as 15 m of massive talus-colluvial overburden to expose some of these buried occupation deposits.

2. *Testing of the morphodynamic model.* The morphodynamic model of coastal terrace formation outlined in chapter 4 has been substantively supported by our stratigraphic and radiometric data from the various transect excavations. In particular, we have been able to confirm that Ofu Island has been

undergoing subsidence at a rate of 1-2 m/kyr during the late Holocene. Rapid progradation and formation of the coastal terrace occurred during the period 1900-1000 cal B.P., largely due to an increase in the marine-biogenic sediment budget. Thus, occupation deposits dating earlier than 2000 cal B.P. are confined to a very narrow, former bench or beach ridge situated at the base of the talus slope.

3. *The Ofu cultural sequence*. The cultural materials recovered from our various transect excavations also provide the basis for outlining a cultural sequence for Ofu Island. This sequence commences at about 3000 cal B.P. with colonization of the island by makers of a ceramic complex including both thin and thickware vessels. While no classic dentate-stamped Lapita pottery has been recovered at To'aga yet, the early ceramic assemblage from AS-13-1 fits well within the Lapitoid ceramic series (see Kirch 1988). Other portable artifacts, such as Type V basalt adzes and shell armbands, are also similar to Early Eastern Lapita assemblages from Tonga and Fiji.

Over the period from 3000-1900 cal B.P., the To'aga site was continuously occupied, and the ceramic assemblages reveal a gradual shift in dominance from thinware to thickware. At around 1900 cal B.P., a rapid progradation of the shoreline commenced, resulting in the construction of the present coastal terrace. Also, the deposition of terrigenous sediments onto the coastal terrace increased, creating a prime zone for horticultural and arboricultural activities. During the past two millennia, the To'aga coastal terrace has been heavily utilized for such subsistence pursuits, although habitations dispersed over the terrace continued to be occupied, evidenced by such features as the *'ili'ili* house mound tested by Unit 13. In chapter 15 we discuss this sequence in greater detail, and compare it with the sequence defined for Western Samoa.

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6

RADIOCARBON CHRONOLOGY OF THE TO'AGA SITE

PATRICK V. KIRCH

THE AGE OF ARCHAEOLOGICAL deposits at To'aga may be roughly estimated by typological comparison of the excavated ceramics and basalt adzes with dated assemblages of similar artifacts from Western Samoa (Green and Davidson 1974), and from elsewhere in Western Polynesia (e.g., Kirch 1988; Poulsen 1987). Such comparisons suggest that prehistoric occupation at To'aga spanned much of the first millennium B.C. and on into the Christian era. Typological cross-dating is always suspect, however, as it depends upon the assumption that stylistically similar artifacts from different islands were used contemporaneously, and thus ignores the possibilities of cultural lag or of independent rates of change. For example, there is no particular reason to assume, *a priori*, that the change from Early Eastern Lapita pottery (characterized by dentate stamped designs) to Late Eastern Lapita should have occurred at the same time throughout the Samoan archipelago. Indeed, the specific aspects of ceramic change may themselves have varied spatially over the Samoan Islands. Likewise, the cessation of ceramic manufacture and use was probably not a contemporaneous event throughout Western Polynesia, as indicated by relatively late dates for pottery from Niuatoputapu (Kirch 1988:139-42). In order to obtain a more precise chronology for the To'aga site, and an independent assessment of the age of the various artifact assemblages sampled from the To'aga deposits, fourteen samples of charcoal and shell were radiocarbon dated. This chapter presents provenience and sample details for each of these dates, and discusses some of the broader implications of the To'aga site chronology for Samoan prehistory.

An initial assessment of the age of pottery-bearing deposits at To'aga was obtained by dating a sample of *Turbo* shell midden obtained from the 1986 reconnaissance test pit adjacent to the landfill dump. This sample (Beta-19742) and another pottery-associated sample from Ta'u Island (Beta-19741) were first reported by Hunt and Kirch (1987). The samples were close in age, with a weighted average of 2605 ± 56.6 B.P., calibrated to 360-50 cal B.C. after correction for marine reservoir effects. Hunt and Kirch noted that these dates from Manu'a were "in close contemporaneity with corrected radiocarbon assays of wood charcoal associated with stylistically and technologically similar ceramic assemblages from 'Upolu Island in Western Samoa" (1987:417). At the conclusion of the 1987 field season, an additional seven samples (six shell, one charcoal) were submitted to Beta Analytic for ^{14}C assay. These dates were reported by Kirch, Hunt, and Tyler (1989), and provided "a stratigraphically consistent chronologic sequence for human occupation of Ofu Island, spanning the period from ca. 3700-3300 B.P. up to the modern era" (1989:10). At the end of the 1989 excavation season, six more samples (two shell, four charcoal) were submitted to Beta Analytic for ^{14}C age assessment. These ^{14}C ages are reported here for the first time, along with their contextual details. The 1989 samples all proved to be internally consistent, both stratigraphically and in comparison with the 1987 ^{14}C series.

In sum, a suite of fourteen radiocarbon dates are now available for the To'aga site, ranging in age from the second millennium B.C. up to the end of the first millennium A.D. All dates are stratigraphically consistent, and in aggregate provide a firm basis for establishing the chronology of human occupation and of geomorphological change at To'aga. Because this series spans virtually the entire "ceramic period" of Samoan prehistory, it is also of considerable significance for the cultural history of the archipelago as a whole.

RADIOCARBON DATING PROCEDURES: CORRECTIONS AND CALIBRATIONS

In selecting samples for radiocarbon dating, emphasis was placed on material which was in firm stratigraphic context (with no apparent disturbance or inversion), and in obvious association with artifacts or features. When possible, charcoal samples were obtained from hearth or oven features, although in four cases finely dispersed charcoal flecks had to be dated in order to ascertain the age of features of particular interest. The charcoal samples consisted of wood charcoal (species not determined) mixed in some cases with carbonized fragments of coconut endocarp (*Cocos nucifera*). With the exception of two shell samples from the stratigraphically oldest beach deposits, the shell selected for ^{14}C dating was culturally-modified midden material about which there was no uncertainty as to cultural associations. All dated shell is of marine origin, consisting of shallow-water, reef-dwelling gastropods and bivalves. Whenever possible, we selected the species *Turbo setosus* for dating, as a further control on consistency of results. This reef gastropod is one of the dominant components of the shell midden assemblages from the To'aga site (see Nagaoka, chapter 13).

All ^{14}C measurements on samples from To'aga were performed by Beta Analytic, Inc. Shell samples were pretreated by etching away the outer layers with dilute acid, to remove any adhering contaminants. The samples were then attacked with further acid to produce carbon dioxide, which was used as the carbon source for dating. The charcoal samples were first picked manually for rootlets, and then given a series of acid, alkali, and acid soakings to remove carbonates and humic acids; they were then rinsed repeatedly to neutrality. One sample (Beta-35600), consisting of very finely dispersed organics (charcoal and other organic material), was picked for rootlets and then dispersed in hot acid to eliminate carbonates. All benzene syntheses and countings proceeded normally (M. Tamers, pers. comms., 21 July 1988; 6, 13 March 1990). Four samples (three of charcoal and the organic sample) had only small quantities of carbon remaining after pretreatment, and thus were accorded extended counting times (four times the normal duration) in order to reduce statistical error as much as practicable. The $^{13}C/^{14}C$ ratios were measured for all samples to establish ^{13}C adjusted, "conventional ^{14}C ages" following the recommendations of Stuiver and Polach (1977). The nonadjusted "Libby ages," conventional ^{13}C adjusted ages, and $\partial^{13}C$ values for all samples are presented below.

Calibration of conventional ^{14}C ages for secular effect, and in the case of marine shell samples for reservoir effect as well, were made following the recent work of Stuiver, Pearson, and Braziunas (1986) for shell samples, and of Stuiver and Becker (1986) for the terrestrial charcoal and organic samples. All calibrations and probability estimates were obtained with the use of the CALIB microcomputer program (Rev. 2.0) developed by Stuiver and Reimer (1986).

As discussed by Kirch and Hunt (1988b:23), the dating of marine shell samples from southwestern Pacific archaeological sites has posed some problems of calibration due to the "reservoir effect" of older carbon present in the world's oceans. Archaeologists have recognized that marine shell samples frequently give ages somewhat older than those of charcoal from identical archaeological contexts, and several attempts have been made to develop correction factors for Pacific island shell dates (Gillespie and Polach 1979; Gillespie and Swadling 1979; Jansen 1984; Athens 1986; Kirch 1989:139). These attempts suggested that southwest Pacific samples of shell from shallow reef environments ranged from about 400-550 years older than the actual age. Recently, Stuiver, Pearson, and Braziunas (1986) produced a first, approximate, global model of these reservoir effects for both an "upper mixed layer" of the ocean (relevant to the To'aga samples) and for the deep ocean. Their model takes into account time-dependent changes in ^{14}C activity, and allows for local geographic variations in reservoir effect (e.g., the effect of upwelling from the deep ocean along continental shelves). The local geographic variations are accounted for by a Δ-R correction factor. Ideally, such a Δ-R factor should be independently determined for Samoa by ^{14}C assay of modern, pre-bomb marine shell. As yet, however, this has not been possible. We therefore have used as a Δ-R correction factor a weighted average of empirically determined Δ-R values from several mid-Pacific islands, specifically Eniwetok, Hawaii, and Tahiti and Mo'orea in the Society group (Stuiver, Pearson, and Braziunas 1986, table 1). This pooled Δ-R value of 100 ± 24 represents a reasonable working value for tropical, central Pacific island samples of shallow-water marine organisms. We have also used this Δ-R value of 100 ± 24 in calibrating radiocarbon dates from a wide range of Lapita sites (Kirch and Hunt 1988a, b). It is significant that following calibration of the marine shell samples according to the above procedure, these are entirely consistent with the calibrated charcoal dates. This is shown for example by samples Beta-35603 and -35604, both from the same excavation level of Unit 28 in Transect 9, which overlap at one standard deviation. (That the charcoal sample appears to be slightly older may reflect the use of wood from a tree that had been growing for a century or more prior to cutting and burning.)

THE RADIOCARBON CORPUS FROM TO'AGA

The fourteen ^{14}C age determinations from To'aga are listed below, by laboratory number, with all relevant information on provenience, associations, sample details, and calibrations. The uncorrected "Libby age" is given first, followed by the $\partial^{13}C$ corrected "conventional ^{14}C age" in boldface type, along with the $\partial^{13}C$ value in parts per thousand. Calibrations for each date are given at one standard deviation; values within parentheses indicate intercepts on the calibration curve.

Beta-19742. 1890 ± 50 B.P.; **2350 ± 50 B.P.**; $\partial^{13}C = +2.9\ ^{o}/oo$.

Marine shell (*Turbo setosus*) from the initial test pit excavation adjacent to the Ofu landfill dump (Layer D, Level 10). The *Turbo* shell consisted of midden refuse in an organically-enriched midden deposit, with calcareous sand matrix. The sample was directly associated with small quantities of thick, coarse-tempered pottery. Cal 28 B.C. (A.D. 45) A.D. 108 at 1 σ; cal B.P. 1977 (1905) 1842 at 1 σ.

Beta-25033. 2190 ± 80 B.P.; **2640 ± 80 B.P.**; $\partial^{13}C = +2.3\ ^{o}/oo$.

Marine shell (*Turbo setosus*, 71 g) from 1987 main excavation trench, Unit 6, Layer IIA-1. The sample consisted of culturally deposited shell midden in direct association with an earth oven feature, and with small quantities of Polynesian Plainware ceramics. Cal B.C. 362 (244) 145 at 1 σ; cal B.P. 2311 (2193) 2094 at 1 σ.

Beta-25034. 2120 ± 80 B.P.; **2570 ± 80 B.P.**; $\partial^{13}C = +2.5\ ^{o}/oo$.

Marine shell (*Turbo setosus*, 70 g) from 1987 main excavation trench, Unit 6, Layer IIB. The sample consisted of culturally-deposited shell midden from the principal occupation deposit in Layer II, in association with Polynesian Plainware ceramics and with *Turbo*-shell fishhooks. Cal B.C. 295 (161) 58 at 1 σ; cal B.P. 2244 (2110) 2007 at 1 σ.

Beta-25035. 3370 ± 70 B.P.; **3820 ± 70 B.P.**; $\partial^{13}C = +2.4\ ^{o}/oo$.

Marine shell (2 specimens: *Asaphis violascens* and *Lunella cincerea*, total weight 48 g) from 1987 main excavation trench, Unit 6, Layer V, 314 cm below surface. Both specimens retained their surface coloration and were not water-rolled, thus indicating deposition in Layer V soon after death. These shells consist of naturally deposited marine shell (rather than cultural food refuse) in a calcareous beach deposit also containing isolated thin-fine ware ceramic sherds. Cal B.C. 1765 (1682) 1600 at 1 σ; cal B.P. 3714 (3631) 3549 at 1 σ.

Beta-25673. 3170 ± 80 B.P.; **3620 ± 80 B.P.**; $\partial^{13}C$ = + 2.2 ^{o}/oo.

Marine shell (*Phalium* sp., 45 g) from 1987 main excavation trench, Unit 1, Layer V, 290 cm below surface. The dated specimen was a single whole gastropod, not waterworn and retaining original surface coloration, thus indicating rapid deposition in the Layer V beach deposit soon after death. Layer V contained isolated thin, fine-tempered ceramic sherds. Cal B.C. 1526 (1441) 1377 at 1 σ; cal B.P. 3475 (3390) 3326 at 1 σ.

Beta-26463. 1460 ± 50 B.P.; **1910 ± 50 B.P.**; $\partial^{13}C$ = + 2.5 ^{o}/oo.

Marine shell (*Turbo setosus*, 72 g) from Unit 3 of the 1987 excavation transect; in Layer II, 40-70 cm below surface. The dated specimen was a single large *Turbo* shell, with the apertural margin displaying chipping due to cultural removal of the operculum (presumably to extract the edible soft parts). The specimen was stratigraphically situated at the basal contact of the cultural, aceramic midden deposit and the underlying sterile calcareous beach sand. The specimen's context thus indicates a time period after the commencement of rapid progradation of the To'aga coastal terrace. Cal A.D. 561 (620) 663 at 1 σ; cal B.P. 1389 (1330) 1287 at 1 σ.

Beta-26464. 2660 ± 140 B.P.; **2620 ± 140 B.P.**; $\partial^{13}C$ = - 27.8 ^{o}/oo.

Charcoal flecks from 1987 excavation Unit 10, Layer IIB, at 70-80 cm below surface. The charcoal was in association with Polynesian Plainware in the Layer IIB occupation deposit. The field sample weighed ca. 1 g, yielding 0.2 g of carbon after pretreatment in the laboratory; the sample was accorded extended counting time. Cal B.C. 967 (801) 454 at 1 σ; cal B.P. 2916 (2750) 2403 at 1 σ.

Beta-26465. 1160 ± 70 B.P.; **1600 ± 70 B.P.**; $\partial^{13}C$ = + 2.0 ^{o}/oo.

Marine shell (*Turbo setosus*, 66.4 g) from 1987 excavation Unit 13, Layer III, 35-45 cm below surface. The dated sample consisted of 1 nearly complete shell and 2 small fragmentary shells, all displaying culturally-induced fractures and chipping (possibly from artifact manufacture). The *Turbo* shells were in direct association with an aceramic cultural midden near the base of a pebble-paved house platform, in which Unit 13 was excavated. Cal A.D. 828 (914) 1000 at 1 σ; cal B.P. 1122 (1036) 950 at 1 σ.

Beta-35600. 1200 ± 70 B.P.; **1190 ± 70 B.P.**; $\partial^{13}C$ = - 26.1 ^{o}/oo.

Finely dispersed charcoal and ash ("organics") from Transect 5, Unit 17, 53 cm below surface in the southeast corner of the unit. The field sample weighed 510 g. The charcoal and ash were dispersed in the interstices of a gravel (*'ili'ili*) pavement layer (see chapter 5), presumably a dwelling house floor. Cal A.D. 694 (781, 789, 805, 821, 829, 839, 862) 943 at 1 σ; cal B.P. 1256 (1169, 1161, 1145, 1129, 1121, 1111, 1088) 1007 at 1 σ.

Beta-35601. 2950 ± 110 B.P.; **2900 ± 110 B.P.**; $\partial^{13}C$ = - 27.8 ^{o}/oo.

Charcoal flecks from Transect 5, Unit 28, base of Layer II, 290-300 cm below surface. The field sample weighed 12 g, and produced 0.6 g of carbon after laboratory pretreatment; it was accorded extended counting time. The charcoal was from a non-concentrated midden deposit containing several sherds of a red-slipped, thin, fine-tempered ceramic ware. Cal B.C. 1308 (1188, 1184, 1127, 1126, 1107, 1105, 1083, 1059, 1054) 930 at 1 σ; cal B.P. 3257 (3137, 3133, 3076, 3075, 3056, 3054, 3032, 3008, 3003) 2879 at 1 σ.

Beta-35602. 2660 ± 100 B.P.; **2630 ± 100 B.P.**; $\partial^{13}C$ = - 26.9 ^{o}/oo.

Charcoal in an ash and sediment matrix (470 g) from Transect 9, Unit 23. The charcoal was contained within an earth oven feature cut from the upper part of Layer IIIA into Layer IIIB, which contained predominantly thickware pottery, with a small quantity of thinware. Cal B.C. 896 (803) 663 at 1 σ; cal B.P. 2845 (2752) 2612 at 1 σ.

Beta-35603. 2660 ± 170 B.P.; **2600 ± 170 B.P.**; $\partial^{13}C$ = - 28.4 ^{o}/oo.

Charcoal (70 g) from Transect 9, Unit 23, from the base of Layer IIIB, 190-206 cm below surface. The field sample of 70 g yielded 0.15 g of carbon after laboratory pretreatment, and was accorded extended counting time. The charcoal flecks were collected from a cultural occupation deposit containing thin, fine-tempered pottery, including some rims with notched decoration. This sample was from the same depositional context as shell sample Beta-35604. Cal B.C. 968 (797) 433 at 1 σ; cal B.P. 2917 (2746) 2382 at 1 σ.

Beta-35604. 2330 ± 80 B.P.; **2770 ± 80 B.P.**; $\partial^{13}C$ = + 1.7 ^{o}/oo.

Marine shell (*Tridacna maxima*, 455 g) from Transect 9, Unit 23, Layer IIIB, 198 cm below surface. The dated specimen consisted of a single valve of *T. maxima*, showing no signs of water abrasion or rounding; the shell was presumably collected live for food and deposited directly in the cultural matrix. It was in direct association with ceramics and other portable artifacts, in the same stratigraphic position as charcoal sample Beta-35603. Cal B.C. 495 (385) 340 at 1 σ; cal B.P. 2444 (2334) 2289 at 1 σ.

Beta-35924. 1640 ± 70 B.P.; **2100 ± 70 B.P.**; $\partial^{13}C$ = + 2.7 ^{o}/oo.

Marine shell (*Turbo setosus*, 400 g) from Transect 5, Unit 15, Layer II, 60-70 cm below surface. The dated sample consisted of numerous culturally modified (chipped and broken) pieces of *T. setosus*, representing food refuse and probably also detritus from the manufacture of *Turbo* shell fishhooks. The shell was dispersed in a dark grey, 'greasy' (carbon-rich) deposit with much fire-cracked rock, apparently a cookhouse cultural deposit. The deposit also contained thick, coarse-tempered ceramics. This is the youngest ^{14}C age from To'aga in direct association with pottery. Cal A.D. 319 (410) 473 at 1 σ; cal B.P. 1631 (1540) 1477 at 1 σ.

The To'aga Sequence

The fourteen samples described above provide a stratigraphically consistent series of dates spanning the period from ca. 3700 to 1000 cal B.P. In figure 6.1 these dates are plotted as calibrated age ranges at one standard deviation, in chronological order. The cultural associations of the samples are indicated on the right-hand side of the diagram. The earliest two dates (Beta-25035 and -25673) are from the Layer V beach deposit of the 1987 main trench excavation and are associated with thin, fine-tempered ceramics. Sample Beta-35601, also associated with this early type of pottery, is from an *in situ* cultural deposit. A suite of four dates (Beta-35602, -26464, -35603, and -35604) is associated with assemblages having significant frequencies of thin, fine-tempered pottery, fishhooks, and other artifacts as well as coarse-tempered thickware. Another suite of four dates (Beta-25033, -25034, -19742, and -35924) is in association with predominantly thick, coarse-tempered pottery, of the sort known in Western Samoa as "Polynesian Plainware" (Green 1974). Some thinware, however, continues to be represented in these later deposits.

These ages indicate a time span of ca. 2400-1500 cal B.P. for the phase of dominant use of thick pottery. The final three dates (Beta-26463, -35600, and -26465) are from aceramic cultural contexts, and all are younger than 1500 cal B.P. Although we have no ^{14}C dates from To'aga younger than about 1000 cal B.P., it is likely that the site continued to be occupied at least until European contact, based on historic artifacts and various surface archaeological indications (house mounds, grindstones, *masi* pits, etc.).

DISCUSSION

The radiocarbon sequence from the To'aga site is the largest suite of dates from any single archaeological site in the Samoan archipelago, and provides an important baseline not only for establishing the cultural chronology of the Manu'a Islands, but for comparisons with sequences from Tutuila and Western Samoa. An initial radiocarbon and stratigraphic sequence for the Samoan archipelago was established by Green and Davidson (1974) on the basis of forty-five dates from a number of sites on 'Upolu and from two sites on Savai'i. The University of Utah Samoan Archaeological Program (Jennings and Holmer 1980) obtained another thirty-four ^{14}C dates from their excavations of sites on 'Upolu and

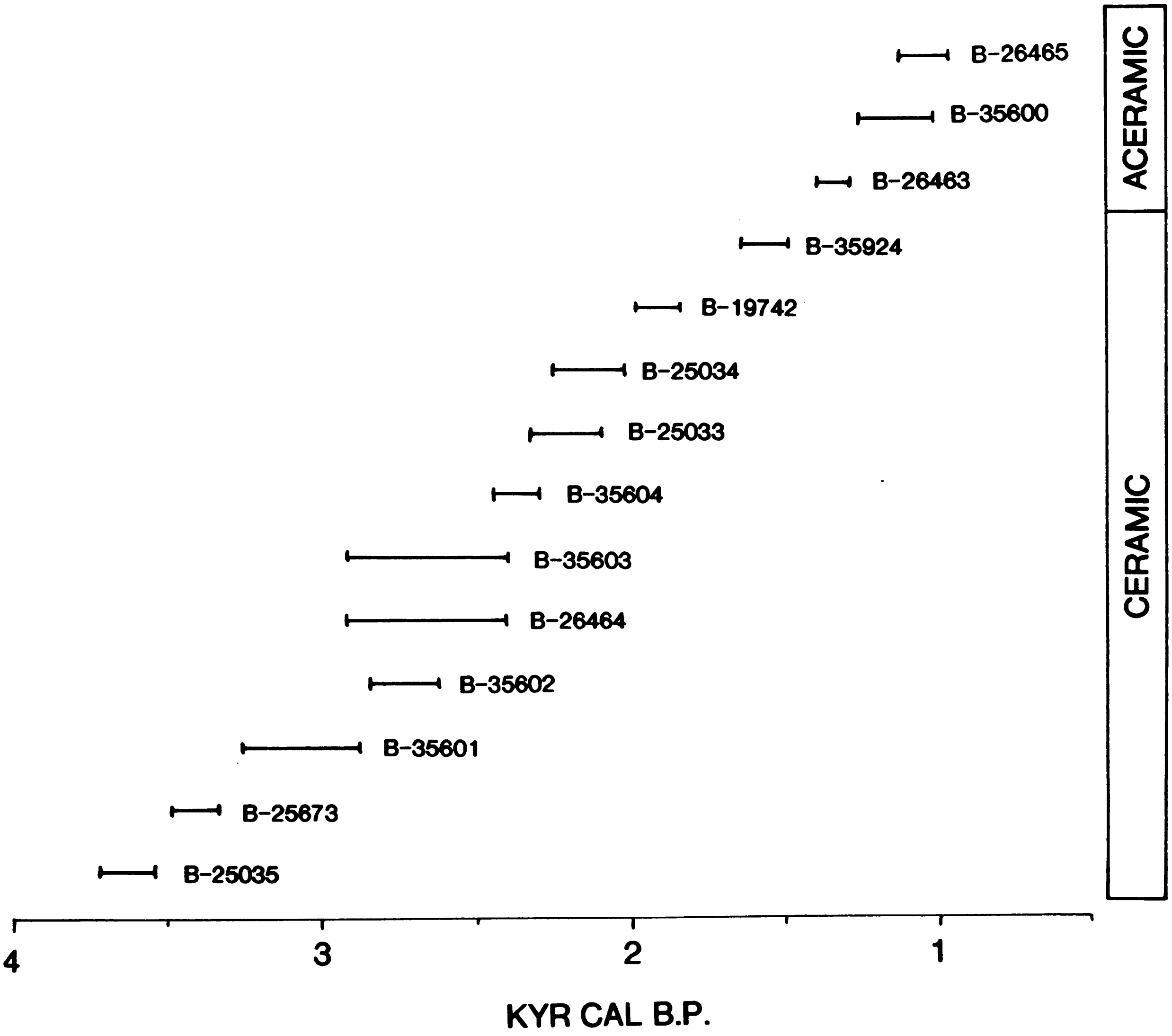

Figure 6.1 Plot of radiocarbon age determinations from the To'aga site (cal B.P. at 1 sigma).

Manono Islet. These seventy-nine dates from Western Samoa provide a firm basis for an 'absolute' chronology.

In American Samoa, the situation is less well developed. Frost (1978) obtained five radiocarbon dates from three sites (AS-21-1, AS-21-2, AS-25-1) excavated by her. One sample, from Tulauta Village (AS-21-1), yielded a very early date of 810 ± 140 B.C. along with a significantly later date of A.D. 1320 ± 70. The other sites all dated to the last thousand years. Best et al. (1989) reported seven radiocarbon dates from the Tataga-matau adz quarry on Tutuila, indicating a sequence of use spanning the past 1000 years. Clark (in press) reviews an additional fifteen radiocarbon dates, largely from Aoa and Leone valleys on Tutuila Island. These include a date of 3389-2749 cal B.P. for initial occupation of the Aoa Valley, as well as very late dates for the use of ceramics. The late dates associated with ceramics have caused Clark (in press) to argue that "pottery was not abandoned uniformly and wholesale throughout the archipelago."

Dating Initial Human Colonization

On archaeological (ceramic) criteria, the oldest known site in the Samoan archipelago is the submerged Early Eastern Lapita occupation at Mulifanu'a, 'Upolu (Green and Davidson 1974; Leach and Green 1989). A sample of marine shell

(NZ-1958) from this site was originally reported as having an age of 2980 ± 80 B.P. (Green and Richards 1975:317). More recently, Leach and Green have indicated that the correct conventional ^{14}C age for this sample should be 3251 ± 155 B.P. (1989:319). They suggest that the "most probable age" for this sample is 3116 cal B.P. (1166 cal B.C.), after taking into account the marine reservoir effect. (Using the 100 ± 24 Δ-R value applied to the To'aga samples, the Mulifanua date would be calibrated to 1280-800 B.C.) This is consistent with other dates on Early Eastern Lapita assemblages from Fiji, Tongatapu, and Niuatoputapu (Kirch 1988, table 48), suggesting initial Lapita colonization of the Fiji-Western Polynesian region by about cal 1200 B.C. (see also Kirch and Hunt 1988a, b).

The earliest two ^{14}C determinations from the To'aga site, from the Layer V beach deposit in the 1987 main trench excavation, range between about 3700-3300 B.P. Although small numbers of thin, fine-ware sherds are present in this beach deposit, we must be cautious in interpreting these dates, because the depositional context is not specifically cultural. As argued in chapter 5, it is likely that the sherds derive from an *in situ* occupation situated on a beach ridge somewhat inland of the Layer V beach, and now buried under several meters of talus and colluvium. That the shell samples used for dating showed no signs of water-rolling or prolonged weathering is noteworthy, indicating that they were deposited in Layer V soon after death. It is conceivable, however, that the sherds became incorporated into the beach deposit somewhat later in time. Although these Layer V dates are not inconsistent with the earliest radiocarbon ages for Lapita colonization in the region, they do fall at the early end.

Sample Beta-35601, from a deep test unit directly against the talus slope, is unquestionably in primary, cultural context and is associated with thin, fine-tempered ware. It dates to 3257-2870 cal B.P. (1308-930 cal B.C.). Thus, we can be certain that Ofu Island, and the To'aga site, were settled by the end of the second millennium B.C. as part of the process of discovery and colonization of the Fiji-Western Polynesian region by Lapita populations (Kirch and Green 1987).

Calibrating the Morphodynamic Model

A second objective of some importance in our work has been to calibrate the sequence of shoreline change and progradation responsible for the creation of the To'aga coastal terrace. Based on the model developed in chapter 4 (Kirch), it was suggested that the coastal terrace would not have begun to prograde significantly until sometime after about 2000 cal B.P., when the Holocene sea-level maximum began to drop to its modern level. This hypothesis is substantially confirmed by the series of ^{14}C dates from To'aga which reveals that the coastal terrace was very narrow and confined to a zone adjacent to the high cliffs until sometime early in the second millennium A.D. Sample Beta-26463, at 1389-1287 cal B.P., comes from a stratigraphic context that post-dates the onset of significant progradation of the coastal terrace.

The Samoan Ceramic Sequence

Finally, the To'aga radiocarbon suite provides a firm chronology for the changes in the ceramic sequence revealed by our excavations and analyses (see chapter 5). Although classic dentate-stamped Early Eastern Lapita pottery was not recovered from To'aga, the red- and orange-slipped thin, fine-tempered ware recovered from the deepest units would appear to be contemporary with the Mulifanu'a Lapita assemblage from 'Upolu. The manufacture and use of thin, fine-tempered ware, some decorated with rim notching, spanned the period from about 2800-2400 cal B.P. This was followed by a phase in which the manufacture and use of thicker, coarse-tempered pottery became dominant between about 2400-1500 cal B.P. The use of pottery appears to have been discontinued entirely by about 1500 cal B.P., thus matching closely the chronology for 'Upolu derived by Green and Davidson (1974). Further details of this ceramic chronology are presented in chapter 9 by Hunt and Erkelens.

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7

A GEOARCHAEOLOGICAL ANALYSIS OF SEDIMENT SAMPLES FROM THE TO'AGA SITE EXCAVATIONS

PATRICK V. KIRCH, ELIZABETH MANNING, AND JASON TYLER

INTRODUCTION

A MAJOR THRUST OF OUR research at the To'aga site has been the investigation of the geomorphological and sedimentary context of the site's extensive buried archaeological deposits. Such an approach is essential both for the understanding of the "formation processes" by which the site was created (Schiffer 1987), and for the broader issues of landscape change in relation to human ecology on the Manu'a Islands. An understanding of the site's geomorphology also relates directly to cultural resource management concerns for, as we shall argue, there are reasons to believe that the To'aga coastal terrace is now in a stage of active coastal erosion. While the deeply buried archaeological deposits at To'aga are not immediately threatened by shoreline regression, they could become endangered should this process intensify, particularly through the effects of global warming and sea-level rise (Geophysics Study Committee 1990).

In chapter 4, a model of the morphodynamics of the To'aga coastal terrace was deduced from the general pattern of Holocene sea-level regimes in the southwestern Pacific, and from certain features of Samoan geological history, especially evidence of tectonic subsidence. The stratigraphic results of our transect excavations, presented in detail in chapter 5, substantially confirmed this model, while the radiometric chronology presented in chapter 6 provided a temporal calibration of the stages of coastal terrace formation. In this chapter, we focus on another line of evidence for testing the morphodynamic model: that of geoarchaeological analysis of sediment samples obtained from the stratigraphic profiles of the various transect excavation units.

Our approach here follows long-established principles of sedimentology (Blatt et al. 1972; Folk 1974; Krumbein and Sloss 1963; Twenhofel 1950; Reineck and Singh 1980) in the context of a geoarchaeological perspective (Stein and Farrand 1985; Shackley 1975). In particular, our aim is to augment our field stratigraphic descriptions and interpretations through laboratory analysis of sediment samples, using a "life history" approach to sediment interpretation. Any sediment, for example a sand layer in one of our transect units, can be understood in terms of four "life history" stages. Each sediment has: (1) a source; (2) a transport history; (3) an environment of deposition; and, (4) post-depositional alterations (Stein 1985:6-7). These stages may be inferred through the application of various analytical techniques including particle-size analysis; grain lithology and mineralogy; point-counting of grain composition; chemical and physical determination of carbonates, organic matter, and pH; colorimetric analysis; and other techniques.

Our geoarchaeological investigation of sediment samples from To'aga was conducted in two phases. In 1987, a series of archaeological and control samples was obtained to check aspects of our stratigraphic interpretation. These samples were analyzed by Tyler at the University of Washington geoarchaeology laboratory, following procedures outlined by Stein (1985). In 1989, a much more extensive set of samples (both archaeological and controls) was obtained from our transect excavations. These 1989 samples were analyzed at the University of California, Berkeley, Archaeological Research Facility by Manning, under the direction of Kirch. The analytical methods applied to the 1989 samples differed slightly from those used in 1987, largely because in the latter case we were able to define more precisely the specific research questions to be addressed by laboratory analysis. For example, in 1989 we recognized that time-consuming pipette determination of the fine-fraction (< 4 phi) was unnecessary to determine the environment of deposition for these predominately coarse-grained, calcareous sediments. Therefore, we concentrated our efforts on mechanical sieving and textural analysis of the pebble- to fine-sand-sized components, with additional determination of grain lithology (basalt versus carbonates) in the -1 to 1 phi (ϕ) size ranges. In other aspects, however, such as pH, organic matter, and carbonate determination, our 1987 and 1989 laboratory techniques were identical. As indicated above, Tyler and Manning were responsible for the laboratory work upon which this chapter is based, while Kirch authored the text and is responsible for the final interpretations and data presentation.

METHODS

Field Sampling

Sediment samples were systematically taken from all units following the completion of excavation, in conjunction with the drawing and description of stratigraphic profiles. In both 1987 and 1989, the exact positions of sampling blocks were recorded on the stratigraphic profiles, and these have been indicated on the various section drawings reproduced in chapter 5. Sample blocks, which usually measured 10 x 15 x 10 cm, were cut into the cleaned section walls with a trowel. Samples were placed directly into heavy plastic bags and sealed for shipment back to the laboratory. As discussed by Stein (1985:7-9, fig. 1), sampling strategies can vary depending upon the questions to be asked in laboratory analysis. Since we were interested primarily in depositional events, our samples were taken from within individual strata, avoiding boundaries or contacts between layers. Where large clastics were present (e.g., > -2 ϕ) which could not be adequately sampled, these were noted in stratigraphic descriptions. Subsampling in the laboratory, for various analytic tests, was carried out with the use of a Jones sample splitter.

A total of 32 sediment samples (including 3 controls) was obtained and analyzed in the 1987 season. Another 70 samples (including 5 controls) were taken and analyzed from the 1989 excavations. Of the 1989 samples, those from Units 15, 19, and 23 were accorded a full analysis, while samples from other units were analyzed only for color, pH, particle size, and lithologic composition.

Controls

Several control samples were obtained in the To'aga area from modern depositional environments, in order to assist in the interpretation of the archaeological sediments. These included samples of active colluvial material from the slope inland of the 1987 excavations, sand from contemporary beach ridges, sand from the beach in front of Transect 7 (fig. 7.1), and a high-energy, sand-and-gravel beach at Fa'ala'aga. Details of these control samples are provided in tables 7.1 and 7.2.

Particle-Size Analysis

A primary aim of laboratory analysis was to interpret the environment of deposition of sediments. This requires a knowledge of the particle-size distribution, since the size ranges and degree of sorting of a sediment reflect the energy levels in that environment. For example, low-energy beaches will be characterized by well-sorted (strongly unimodal) sands in the medium- to very fine-grained size range. Higher energy beaches, on the other hand, display less sorting and a higher frequency of coarse-grained to granule-pebble-sized clastics. Similarly, colluvial sediments deposited by mass wasting can be expected to be very poorly sorted, exhibiting a full size

Figure 7.1 Photomicrograph (10X) of the 1 phi size fraction of a modern control sample of calcareous beach sand from Transect 7.

range from silts and clays up through very large clastics (cobbles to boulders).

Unconsolidated sands generally required no pretreatment prior to particle size analysis. The colluvial samples, however, required pretreatment for the removal of organics, and in some cases, for iron oxides which would otherwise bind individual grains together (Kunze 1965). Organic materials were removed by pretreatment with hydrogen peroxide, H_2O_2 (Jackson 1969). A 1:1 solution of sediment and distilled water was prepared, to which H_2O_2 was gradually added until frothing and foaming subsided. The beaker was then placed in a water bath at 80 °C, with additional H_2O_2 added

Table 7.1
Analytic Data for To'aga Control Sediment Samples (1989)

Sample No.	Location	% Gravel	% Sand	% Silt	Textural Class	pH	1 φ % Calc	1 φ % Basalt
89-131	Fa'ala'aga Beach	2.3	97.7	0	S	9.01	97	3
89-132	Fa'ala'aga Beach	43.0	56.9	<0.1	sG	8.68	90	10
89-133	Fa'ala'aga Beach	97.4	2.5	<0.1	G	8.95	89	11
89-134	T-7, A horizon, beach ridge	1.7	97.0	1.3	S	8.28	100	0
89-135	T-7, beach sand	0.2	99.8	0	S	8.64	100	0

Table 7.2
To'aga Site Sediment Analysis, 1987 Excavations

Sample No.	Description	% Sand	% Silt	% Clay	pH	% O.M.	% $CaCO_3$	Munsell Color Dry	Munsell Color Moist
1	Modern Crest of Beach	100.00	0.00	0.00	8.48	3.13	96.33	10YR 8/2	10YR 7/2
2	"Salt & Pepper" Sand	100.00	0.00	0.00	8.51	2.44	86.95	10YR 8/2	10YR 7/1
3	Modern Colluvium	67.60	21.08	11.32	6.47	10.32	1.60	5YR 2.5/1	5YR 3/2
4	Unit 2, 25cm b.s.	31.73	37.80	30.47	6.74	9.46	3.31	5YR 3/2	5YR 3/2
5	Unit 2, 47cm b.s.	72.48	14.63	12.89	8.17	5.37	76.75	10YR 3/1	10YR 2/2
6	Unit 2, 70cm b.s.	94.78	3.11	2.11	8.42	1.79	97.58	10YR 6/3	10YR 5/3
7	Unit 2, 130cm b.s.	100.00	0.00	0.00	8.56	2.77	96.16	10YR 8/2	10YR 7/3
8	Unit 3, 5cm b.s.	27.86	32.58	39.56	7.63	22.99	5.56	5YR 3/1	5YR 2.5/2
9	Unit 3, 25cm b.s.	74.02	11.61	14.37	8.24	5.29	77.16	10YR 4/1	10YR 3/2
10	Unit 3, 40cm b.s.	94.98	2.93	2.09	8.49	2.54	95.26	7.5YR 4/4	7.5YR 4/4
11	Unit 3, 60cm b.s.	93.92	2.02	4.06	8.33	2.89	95.42	10YR 4/2	10YR 3/2
12	Unit 3, 70cm b.s.	100.00	0.00	0.00	8.54	1.51	98.70	10YR 7/3	10YR 7/3
13	Unit 6, IA	69.11	18.28	12.61	6.82	7.26	2.24	10YR 3/1.5	7.5YR 3/2
14	Unit 6, IB	78.26	13.58	8.18	6.71	3.49	1.61	10YR 3/2	5YR 3/3
15	Unit 9, IC	54.00	16.38	29.61	6.92	7.53	2.05	10YR 2/1	10YR 2/1
16	Unit 5, IIA-1	87.79	8.06	4.15	8.34	2.32	85.99	10YR 5/2	10YR 4/2
17	Unit 6, IIA	97.05	2.90	0.05	8.29	2.72	84.10	10YR 7/2	10YR 6/2
18	Unit 6, IIB	90.87	5.00	4.13	8.27	2.79	79.46	7.5YR 4/2	10YR 3/2
19	Unit 6, IIC	99.34	0.66	0.00	8.50	1.51	71.67	10YR 5/2	10YR 4/2
20	Unit 6, III-1	73.32	20.56	6.12	7.95	4.98	4.21	7.5YR 3.5/2	7.5YR 3/3
21	Unit 6, III-2	74.48	17.38	8.14	8.31	3.59	67.98	7.5YR 4/2	7.5YR 3/4
22	Unit 6, III-3	93.20	4.85	1.95	8.52	2.59	87.65	7.5YR 5/4	7.5YR 4/4
23	Unit 6, IV	100.00	0.00	0.00	8.58	2.60	93.29	10YR 8/2	10YR 6/3
24	Unit 10, IA	61.62	20.89	17.49	7.31	16.85	2.42	5YR 3/2	5YR 2.5/1.5
25	Unit 10, IB	31.76	14.51	53.73	6.95	7.07	2.69	10YR 2/2	5YR 3/2
26	Unit 10, IC	50.02	24.40	25.58	7.40	6.85	2.46	10YR 3/1	5YR 3/2
27	Unit 10, IIA-1	88.40	3.49	8.11	8.16	3.92	66.32	10YR 3/2	10YR 2/2
28	Unit 10, IIA	92.48	5.36	2.16	7.95	2.32	82.94	10YR 7/2	10YR 6/2
29	Unit 10, IIB	93.81	4.19	2.00	8.15	2.23	79.71	10YR 5/2	10YR 4/2
30	Unit 10, IIC	81.20	12.87	5.93	8.12	2.10	73.47	7.5YR 4/2	7.5YR 3/4
31	Unit 10, III	41.59	35.56	22.85	8.02	4.96	42.82	7.5YR 3/2	5YR 3/3
32	Unit 10, IV	94.88	2.95	2.17	8.23	1.93	95.71	10YR 7/3	10YR 6/3

Note: Samples 1, 2, and 3 are modern controls.

until all reaction had ceased. The sample was then cooled, rinsed with distilled water, and centrifuged at 1700 rpm for fifteen minutes. Supernatant liquid was then decanted, and the centrifuging procedure repeated until the solution was clear.

The method for removal of iron oxides was as follows: sediment which had already been pretreated for removal of organics was placed in a 250 ml centrifuge tube to which about 200 ml of citrate buffer solution (sodium citrate dihydrate; sodium bicarbonate $NaHCO_3$; sodium chloride NaCl) was added. Samples were then warmed to 80 °C in a water bath within the fume hood. Four grams of sodium dithionite ($Na_2S_2O_4$) were slowly added while stirring constantly for one minute. Following a fifteen-minute digestion period, 10 ml of saturated sodium chloride (NaCl) was added to flocculate the sample, which was then centrifuged at 1700 rpm for fifteen minutes; the supernatant liquid was decanted and discarded. The procedure was repeated until samples appeared light grey or white in color, indicating the removal of most or all of the free iron oxides.

Pretreated samples were mechanically shaken through a nested set of geological screens of mesh sizes -2 to 4 ϕ (plus pan) for fifteen minutes. Weights of each subsample were determined with a high-precision digital electronic balance. The 1987 samples were further analyzed by the pipette method to determine the particle size distribution of the fine fraction; this was not done for the 1989 samples.

Following mechanical sieving and weighing, the percentages and cumulative percentages of all ϕ classes were calculated, as was the sand:mud ratio (mud is defined as all material > 4 ϕ, i.e., silt plus clay). These statistics permit the textural classification of the sediments according to the system outlined by Folk (1974:27-30, table 1). This system utilizes a triangular diagram with apices of gravel, sand, and mud, reproduced here as figure 7.2. The dominant mode is indicated by a capital letter, supplemented by lower case letters for secondary modes. For example, a sandy gravel is designated sG, while a slightly gravelly muddy sand would be (g)mS.

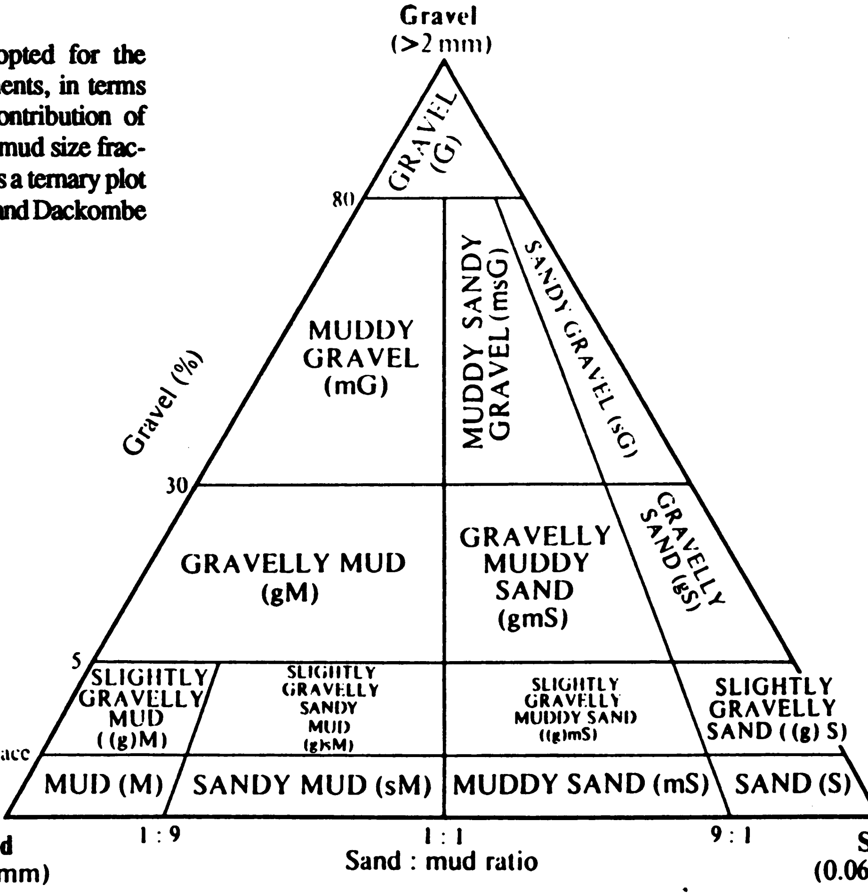

Figure 7.2

Terminology adopted for the To'aga site sediments, in terms of the relative contribution of gravel, sand, and mud size fractions, expressed as a ternary plot (Source: Gardiner and Dackombe 1983:108).

pH

The pH (acidity, neutrality, alkalinity) of samples was determined with a Mettler automatic pH meter. A 20 g sample was prepared in a 1:1 solution with distilled water, and standards set to pH 7 and 10. Three trials were made for each sample, with the reported value being the average of these readings.

The pH values from the To'aga sediments are of interest primarily for the assessment of preservation of organic cultural materials, such as bone and shell faunal remains. pH values for the upper colluvial deposits, or of contemporary A soil horizons with humic materials, tended to range between 6.4-8. Deeper sediments, generally calcareous, had more alkaline pH values ranging from 8 to 9.5. This alkalinity strongly favors the preservation of bone and shell, reflected in the generally excellent condition of the faunal assemblage. In contrast, the relative neutrality of the shallower deposits probably reflects the presence of humic acids. This is evident in the "chalky" nature of shell midden in these upper strata.

Organic Matter and Carbonates

The presence of organic matter and carbonates in samples was determined by the "loss-on-ignition" method (Dean 1974; Stein 1984). This is based on the principle that organic materials will begin to ignite at 200 °C and will burn completely when the temperature reaches 550 °C. Calcium carbonate ($CaCO_3$) evolves to carbon dioxide gas when heated to 800 °C and is eliminated at 850 °C. Thus the loss-on-ignition procedure involves the controlled burning of samples with precision weighing before ignition, after 500 °C, and after 1000 °C burns. All samples were processed in a Thermolyne muffle furnace.

Color

Sediment colors were recorded *in situ* during the description of profiles, using the Munsell Soil Color charts, and have been reported in chapter 5. In addition, the colors of laboratory sediment samples were recorded both dry and moist, also using the Munsell system.

Point-Counting (Lithology and Micro-artifacts)

During the field description of sedimentary units, we observed that the more deeply buried and older strata tended to have sands with a mixed calcareous-volcanic lithology, designated 'salt-and-pepper' sands (fig. 7.3), whereas higher and more recent sands were largely or wholly calcareous. These differences were believed to reflect the process of coastal progradation and terrace formation, which gradually removed sources of volcanic sediment from the To'aga coastal sediment budget. These sources originally would have been volcanic headlands and talus boulders which when exposed to high-energy wave action would generate volcanic-lithic sand grains. In order to quantify more precisely these field observations, we undertook controlled point-counting of samples in the laboratory, following procedures first outlined by Galehouse (1971). The -1, 0, and 1 ϕ size classes were selected for point-counting following mechanical sieving. Subsamples of these ϕ classes were mounted on petrographic glass slides, which could then be examined under a Nikon stereozoom microscope. An average of 100 grains was counted for each sample, with grains being classified as calcareous (consisting of coral sand, foraminifera, marine shell fragments, etc.) or volcanic lithic (basalt or similar materials). These counts were then calculated as percentages.

For Units 15, 19, and 23, we also used the point-counting method to determine the frequencies of the following classes of micro-artifactual or faunal materials: charcoal, marine shell, bone, sea urchin, and terrestrial gastropods. (In order for marine shell to be counted as a micro-artifact constituent, it had to have sharp or fractured edges, as opposed to water-worn or rolled edges, the latter indicating a natural constituent of the sand matrix.) The terrestrial gastropods are of particular interest as they consist primarily of synanthropic species; these are the subject of a separate and detailed analysis in chapter 8.

RESULTS

The 1987 Excavations

Thirty-two sediment samples were obtained from the 1987 excavations (including three control

Figure 7.3 Photomicrograph of a typical "salt-and-pepper" sand with mixed calcareous and volcanic-lithic lithology; from Layer IF of Unit 24 (1 phi size fraction; 10X).

samples). Samples were taken from Units 2 and 3 along the initial transect, from Units 5, 6, and 9 in the main trench, and from Unit 10. Analytical data from all of these samples are reported in table 7.2.

The sedimentary sequence in the main excavation trench is summarized by samples 13-23 listed in table 7.2. The colluvial units (Layers I and III) are similar in their higher frequencies of silt and clay, contrasting markedly with Layers II and IV which are dominated by sand-sized particles. Similar contrasts are expressed in the percent of calcium carbonates in these strata.

The 1989 Transects

Transect 5

Units 15, 16, and 17 were selected for sediment analysis along Transect 5, with a complete set of analyses for Unit 15, and particle-size and lithological analyses only for Units 16 and 17. Complete analytical data for these units are presented in tables 7.3 to 7.5.

The sedimentary sequence in Unit 15 is graphically depicted in figure 7.4, and a more detailed graphic presentation of the grain-size distribution results is provided in figure 7.5. In figure 7.4 several overall trends are apparent. The lower sediments (Layers III to IV) are dominated by sands, with significant gravel components confined to the upper deposits (Layers I and II). This change reflects the shift from a littoral depositional environment to a mass wasting (colluvial) depositional environment. The pH shifts from neutral to somewhat alkaline between Layers IA and IIIA and remains alkaline to the base of the section. Organic matter is greatest in Layers IA and II. The shift from littoral to terrigenous mass wasting depositional environments is also clearly indicated in the percent of $CaCO_3$ and in the lithological composition of basalt and calcareous grains determined by point-counting of the 1 ϕ size

Table 7.3
Analytic Data for Unit 15 Sediment Samples

Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	% O.M.	% $CaCO_3$	1 φ % Calc	1 φ % Basalt	Munsell Color Dry	Munsell Color Moist
89-48	IA	25.7	63.9	10.4	gmS	7.23	5.6	0.9	6	94	5YR 3/3	2.5YR 3/2
89-49	IB	53.4	42.5	4.0	sG	7.55	2.3	1.0	11	89	5YR 4/4	2.5YR 3/4
89-50	II	10.2	81.3	8.4	gS	8.19	11.7	47.2	88	12	2.5YR 2.5/2	10YR 2.5/1
89-51	IIIA	0.3	99.6	0.1	S	8.92	2.3	91.4	94	6	10YR 8/2	10YR 8/2
89-52	IIIA-1	1.8	94.1	4.0	S	8.57	3.3	91.4	96	4	7.5YR 4/2	7.5YR 4/2
89-53	IIIB	1.0	97.3	1.7	S	8.78	2.5	91.4	95	5	7.5YR 6/2	7.5YR 5/2
89-54	IIIC	0.3	99.6	0.1	S	8.94	2.1	84.7	90	10	10YR 8/2	10YR 8/2
89-55	IIID	2.1	97.1	0.8	(g)S	8.80	2.3	89.1	94	6	10YR 7/3	7.5YR 6/2
89-56	IV	3.6	96.3	0.1	(g)S1	9.06	2.6	92.6	97	3	10YR 8/2	10YR 8/3

Table 7.4
Analytic Data for Unit 16 Sediment Samples

Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	1 φ % Calc	1 φ % Basalt	Munsell Color Dry	Munsell Color Moist
89-76	IA	29.7	66.0	4.3	gS	90	10	10YR 2/2	5YR 2.5/2
89-77	IB	25.0	68.9	6.1	gS	95	5	10YR 2/2	10YR 2/2
89-78	IC	6.3	91.4	2.2	(g)S	97	3	10YR 5/3	10YR 3/3
89-79	II	<0.1	99.9	0.01	S	97	3	10YR 8/2	10YR 7/4
89-80	III	25.0	74.5	0.5	gS	98	2	7.5YR 7/4	7.5YR 7/4
89-81	IV	0.3	99.6	0.1	S	98	2	10YR 8/3	10YR 8/3

Table 7.5
Analytic Data for Unit 17 Sediment Samples

Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	1 ϕ % Calc	1 ϕ % Basalt	Munsell Color Dry	Munsell Color Moist
89-66	I	49.1	47.8	3.1	sG	7.84	99	1	7.5YR 3/2	5YR 2.5/2
89-67	II	80.7	17.4	1.8	G	8.42	100	0	7.5YR 5/2	7.5YR 5/2
89-68	IIIA	83.5	14.6	1.9	G	8.51	100	0	10YR 5/3	7.5YR 5/2
89-69	IIIB	83.4	15.1	1.5	G	8.47	99	1	7.5YR 5/2	7.5YR 4/2
89-70	IIIC	63.0	35.4	1.6	sG	8.46	100	0	10YR 5/3	10YR 5/3
89-71	IVA	1.9	95.9	2.1	S	8.48	99	1	7.5YR 5/8	7.5YR 5/6
89-72	IVB	1.4	94.9	3.6	S	8.57	76	24	7.5YR 6/2	7.5YR 5/2
89-73	V	2.3	97.5	0.2	S	8.54	100	0	10YR 8/3	10YR 8/3
89-74	VI	11.5	88.4	0.04	gS	8.90	100	0	7.5YR 8/4	7.5YR 8/4
89-75	VII	0.4	99.5	0.05	S	9.50	93	7	7.5YR 8/2	7.5YR 8/2

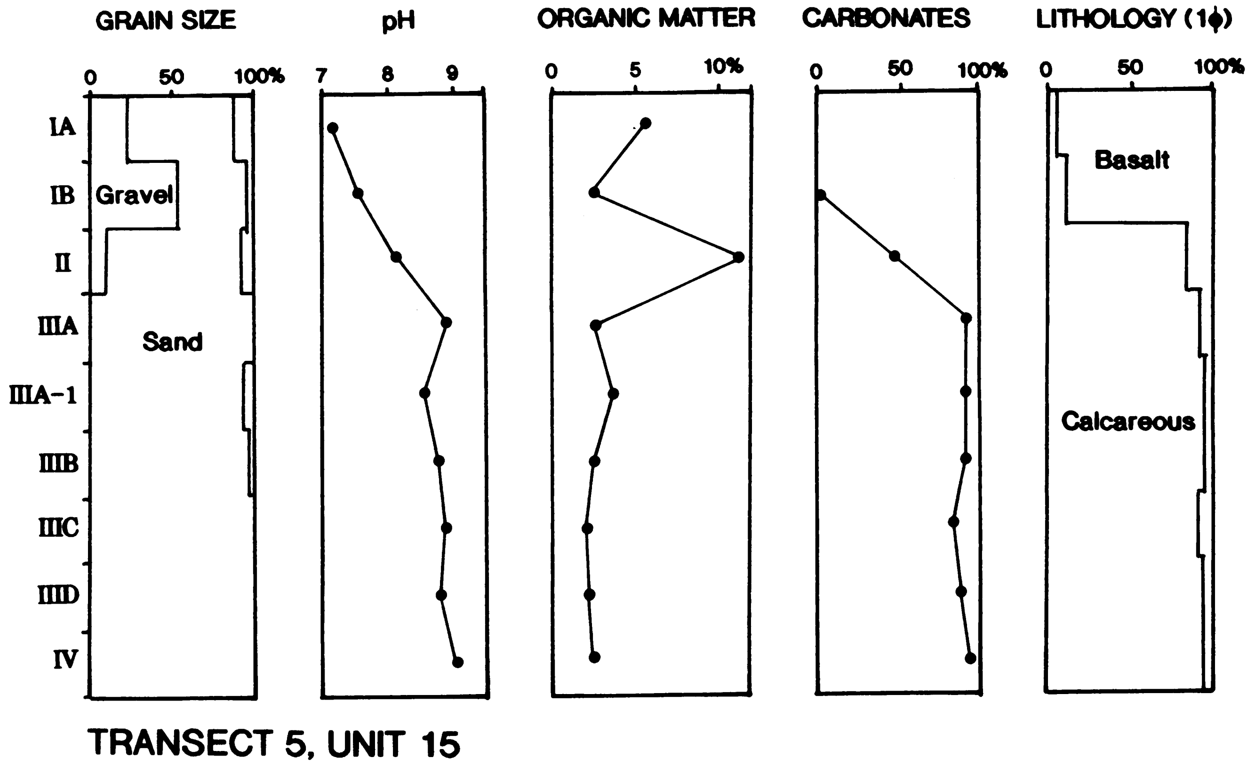

Figure 7.4 Summary diagram of grain size, pH, organic matter, carbonates, and lithology for sediment samples from Unit 15, Transect 5.

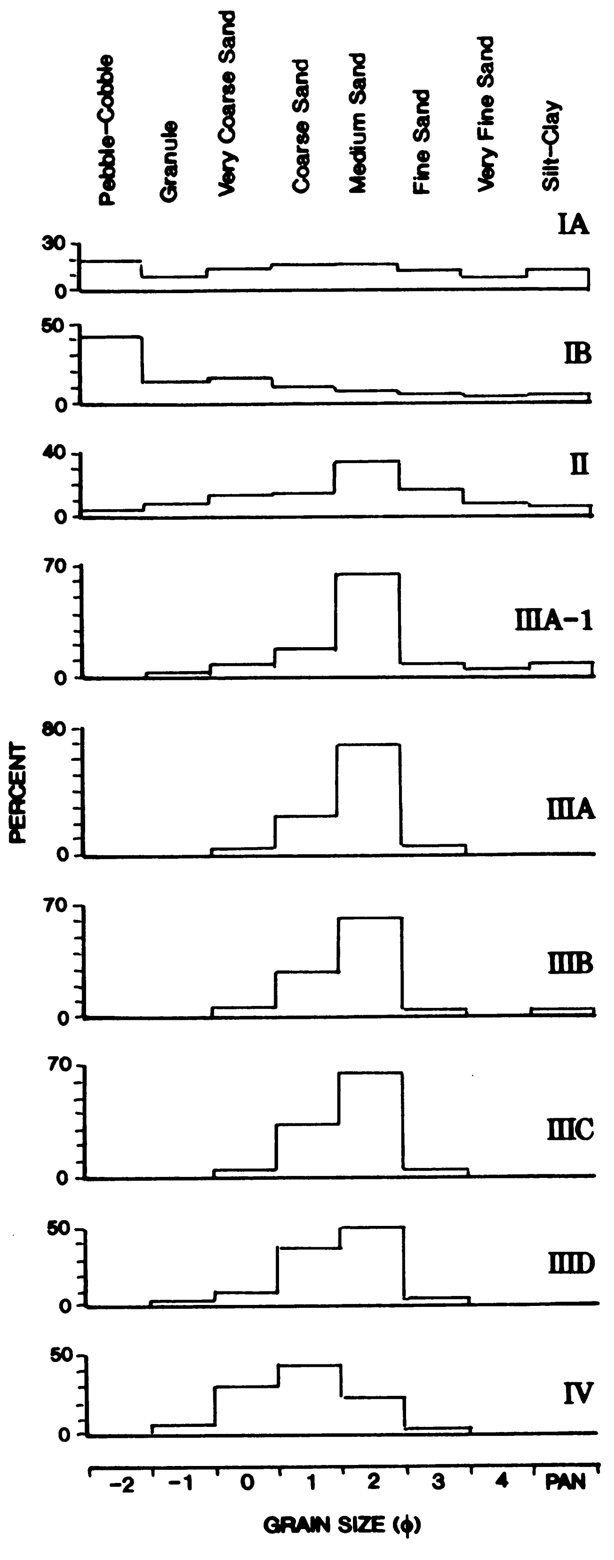

Figure 7.5 Histogram plots of grain size distributions for sediment samples from Unit 15, Transect 5.

class. Photomicrographs of the 0 ϕ size fractions for sediment samples from Unit 15 are shown in figure 7.6; these illustrate the variations in lithology between the various cultural and natural deposits.

The detailed grain-size distributions shown in figure 7.5 likewise document changes in the environment of deposition. The basal sand, Layer IV, consists of rather poorly sorted sands (dominant mode = coarse sand) with a small granule-sized component, suggestive of a relatively high-energy beach environment. In Layers IIID to IIIA-1 there is a steady shift to well sorted sands dominated by particles in the medium sand range (2 ϕ), with granule-sized particles generally lacking. This shift is presumably correlated with the progradation of the active beach seaward of the Unit 15 locus. The Layer II midden deposit displays a very poorly sorted sediment, reflecting the incorporation of cultural materials (including oven stones and other large clastics) into a medium-sized sand matrix. Layers IB and IA are also poorly sorted, with dominant modes in the pebble-to-cobble size ranges (-2 to -1 ϕ). These upper sediments are typical of young colluvium derived from mass wasting of the cliffs and volcanic slopes immediately inland of the site.

In sum, the Unit 15 sedimentary sequence reveals the following geomorphological evolution. The initial environment of deposition (at ca. 3,000 cal B.P., prior to human colonization) was a high-energy beach, indicating an active shoreline very close to Unit 15. The source of sediment was primarily the calcareous reef flat, with the minor addition of volcanic lithic grains derived from exposed headlands and/or talus rockfall exposed to wave action. During the period of human occupation represented by Layers IIID to IIIA-1 (ca. 3000-1600 cal B.P.), the Unit 15 locality shifted to a beach ridge depositional environment, with transport of calcareous sediment primarily by aeolian processes (e.g., saltation of grains inland). Following the Layer II midden occupation on top of a vegetated beach ridge, the Unit 15 locality began to be covered by terrigenous, poorly sorted, volcanic sediments deriving from the steep talus and colluvial slopes inland. The encroachment of these volcanic sediments probably reflects increasing slope instability due to forest clearance and agricultural modifications.

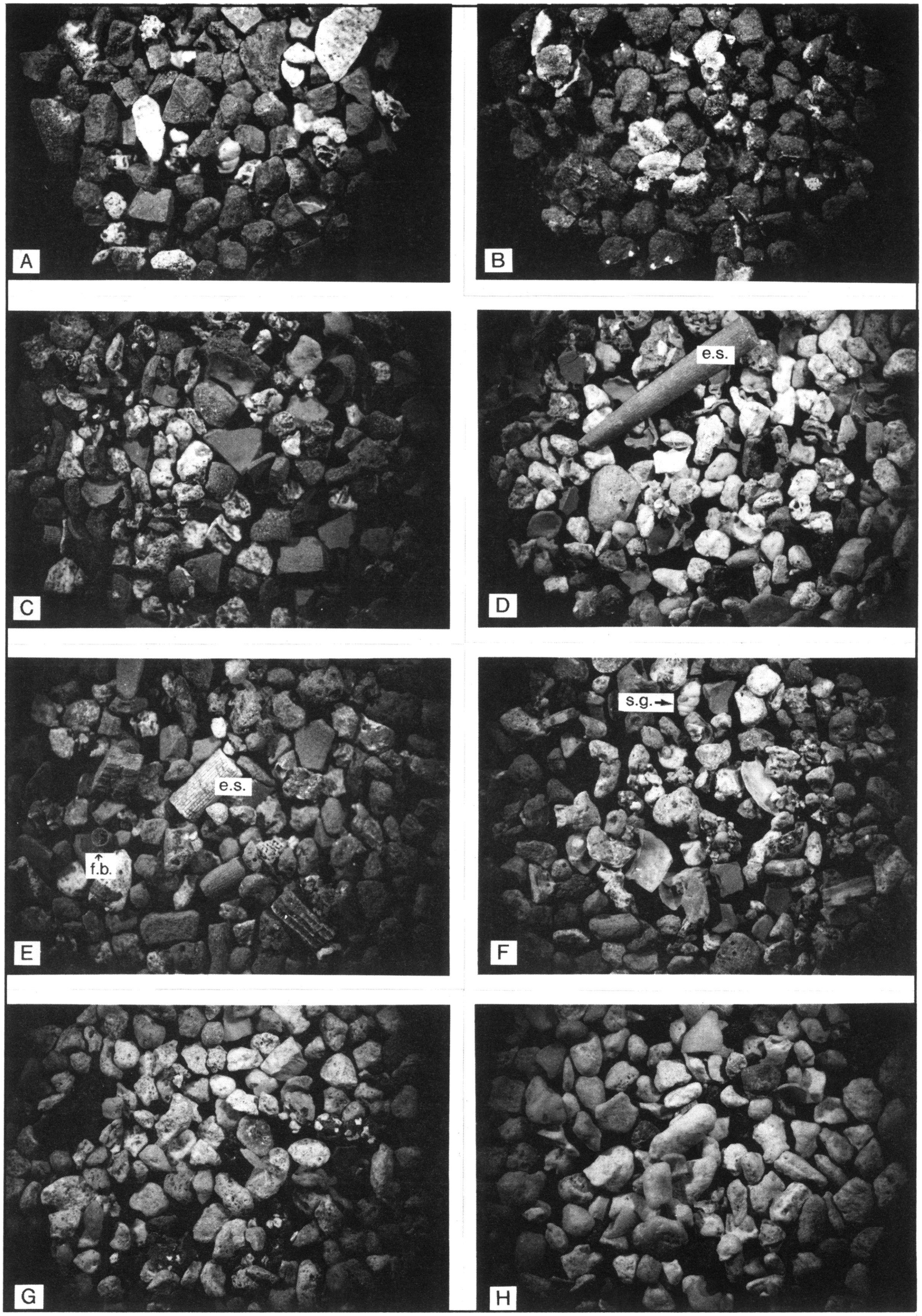

Figure 7.6 Photomicrographs (10X) of the 0 phi size fractions of sediment samples from Unit 15, Transect 5: A, Layer IB; B, Layer II; C, Layer IIIA; D, Layer IIIA-1; E, Layer IIIB; F, Layer IIIB; G, Layer IIID; and H, Layer IV. (e.s. = echinoid spine; f.b. = fishbone; s.g. = synanthropic gastropod).

Transect 7

Sediment analyses were performed on samples from Units 18 and 19 along Transect 7. Tables 7.6 and 7.7 summarize the detailed analytical results.

A graphical summary of the Unit 19 sedimentary sequence is shown in figure 7.7, and the detailed grain-size distributions are depicted in figure 7.8. The overall sequence mirrors that described above for Unit 15, with such features as the shift from neutral to alkaline pH, the rapid decrease in organic matter, and the relative contributions of basalt and carbonate sediment grains. Layers VI to II are all relatively well-sorted sands dominated by a medium-sand (2 ϕ) mode, with the exception of Layer V, in which some larger (-1 and -2 ϕ) clastics represent the incorporation of cultural materials into the sand matrix. The Layer IA colluvium is typically poorly sorted.

Transect 9

Units 21, 22, and 23 were selected for sediment analysis along Transect 9. Tables 7.8 to 7.10 present

Table 7.6
Analytic Data for Unit 18 Sediment Samples

							1 ϕ		Munsell Color	
Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	% Calc	% Basalt	Dry	Moist
89-86	IA	43.8	50.1	6.1	msG	7.42	37	63	5YR 3/3	5YR 3/3
89-87	IB	27.3	64.9	7.8	gmS	8.46	95	5	10YR 3/4	10YR 3/4
89-88	II	1.1	95.6	3.3	(m)S	8.63	99	1	10YR 5/4	5YR 4/6

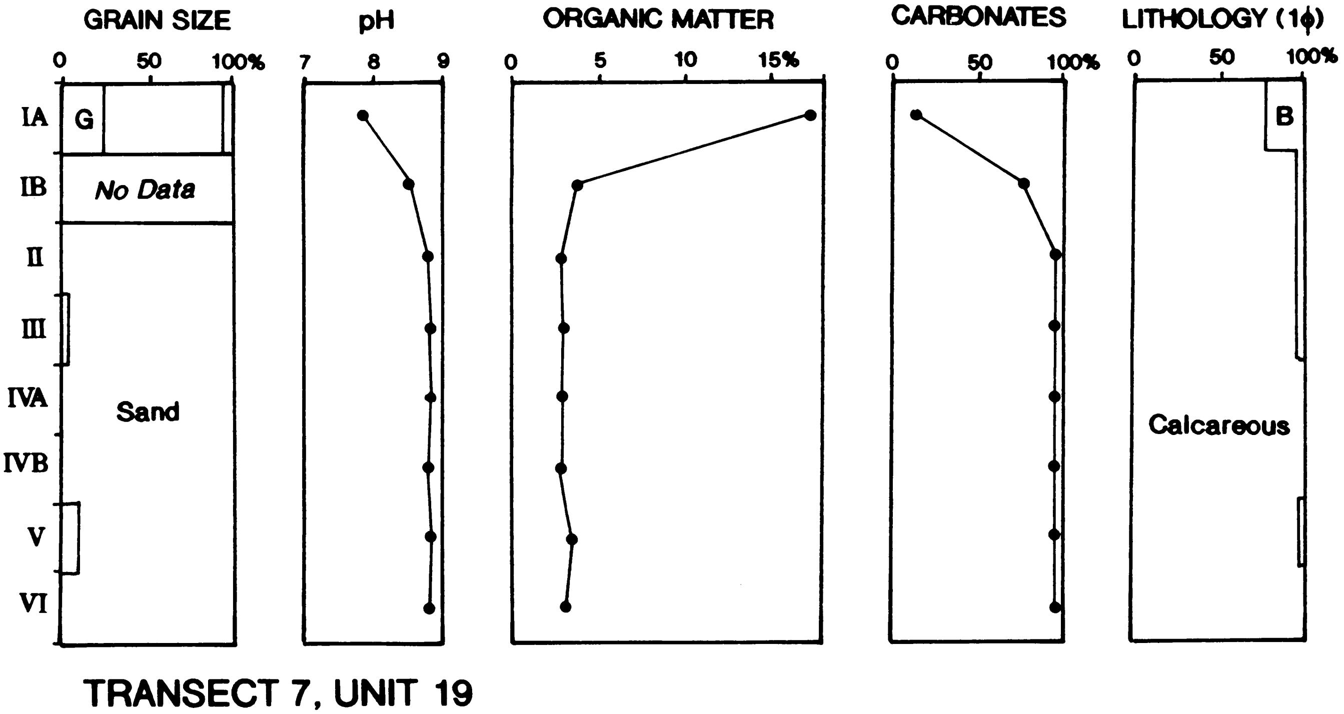

Figure 7.7 Summary diagram of grain size, pH, organic matter, carbonates, and lithology for sediment samples from Unit 19, Transect 7.

Table 7.7
Analytic Data for Unit 19 Sediment Samples

									1 ϕ		Munsell Color	
Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	% O.M.	% $CaCO_3$	% Calc	% Basalt	Dry	Moist
89-89	IA	23.4	71.3	5.3	gS	7.89	17.8	10.9	77	23	2.5YR 3/2	2.5YR 2.5/2
89-90	IB	-	-	-	-	8.55	3.8	75.9	98	2	7.5YR 5/4	5YR 3/3
89-91	II	0.4	99.2	0.4	S	8.83	2.8	94.2	99	1	10YR 8/2	10YR 8/2
89-92	III	1.5	98.1	0.4	S	8.93	2.9	94.1	98	2	10YR 8/2	10YR 7/3
89-93	IVA	0.1	99.7	0.2	S	8.97	2.9	94.4	100	0	10YR 8/2	10YR 8/2
89-94	IVB	0.1	99.7	0.2	S	8.91	2.9	94.2	100	0	10YR 8/2	10YR 8/3
89-95	V	8.1	91.2	0.7	gS	8.85	3.2	93.7	99	1	10YR 5/2	10YR 5/2
89-96	VI	0.4	99.4	0.2	S	8.94	3.0	94.2	100	0	10YR 8/2	10YR 8/2

Table 7.8
Analytic Data for Unit 21 Sediment Samples

							1 ϕ		Munsell Color	
Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	% Calc	% Basalt	Dry	Moist
89-106	IA	22.1	73.5	4.4	gS	8.37	99	1	5YR 3/3	5YR 3/2
89-107	IB	1.9	95.7	2.4	(m)S	8.58	100	0	5YR 3/4	5YR 3/4
89-108	IIA	0.6	99.2	0.1	S	8.87	97	3	5YR 7/4	10YR 7/4
89-109	IIB	19.3	80.2	0.5	gS	8.86	95	5	10YR 5/2	7.5YR 5/2
89-110	IIC	1.2	98.7	0.1	S	8.85	97	3	10YR 3/3	10YR 7/4

the detailed analytical results.

A graphic summary of the Unit 23 depositional sequence is shown in figure 7.9, and the detailed grain-size distributions are illustrated in figure 7.11. Photomicrographs of the 0 ϕ size fraction for sediment samples from Unit 23 are shown in figure 7.10. As seen in figure 7.9, the overall pattern of change is much like that described above for Transects 5 and 7. Of particular note is the presence of basalt grains in the basal sands (Layers IV and IIIC), reflecting the 'salt-and-pepper' lithology observed in the field. The detailed grain-size histograms (figure 7.11) indicate that Layer IV is a coarse-to-medium-grained sand with a 'tail' extending into the larger clastic size ranges, suggestive of a higher-energy beach depositional environment. In Layers IIIB and IIIA, the larger clastics are cultural materials (such as oven stones, marine shells, and large sea urchin spines) which were added to a coarse-to-medium-grained sand matrix. Layer IIA, interpreted in the field as a paleosol horizon, is less well sorted than the underlying sands and begins to incorporate fine-grained terrigenous sediments. The Layers IC to IA colluvial deposits are all very poorly sorted, with increasing quantities of terrigenous (basalt) materials.

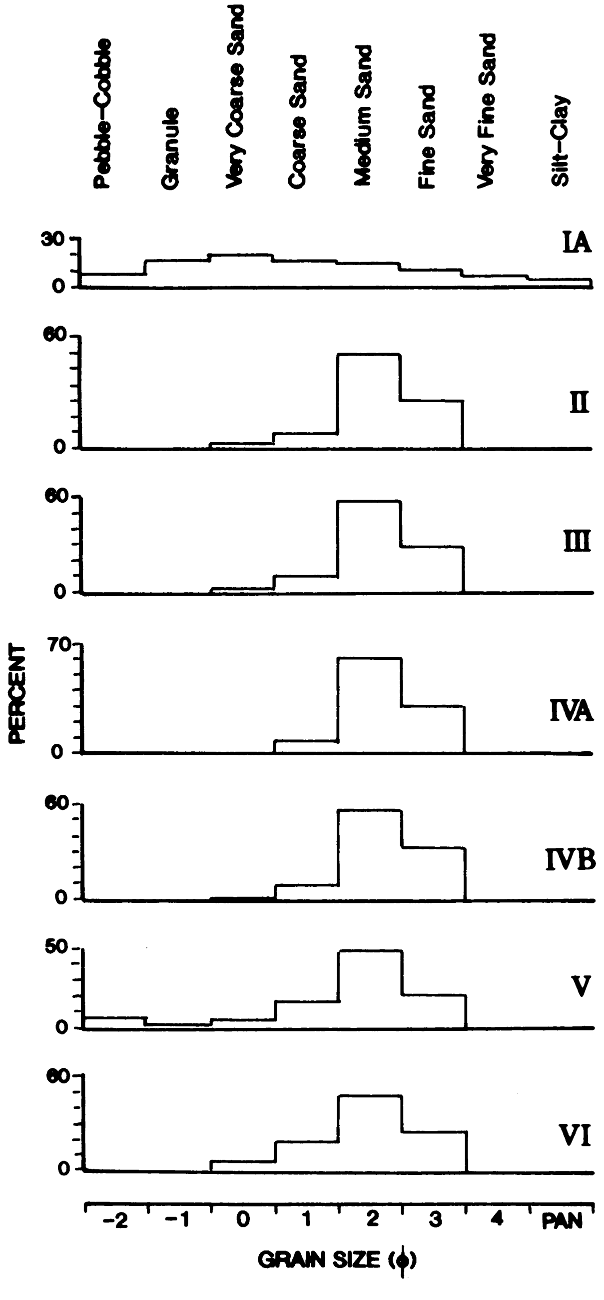

Figure 7.8 Histogram plots of grain size distributions for sediment samples from Unit 19, Transect 7.

Figure 7.12 presents a graphical summary of grain-size distribution and lithology for Units 21, 22, and 23. These results clearly reflect the temporal shift from (1) high-energy beach depositional environments in the basal levels of Units 23 and 21 to (2) beach ridge depositional environments with human occupations, to (3) the encroachment of terrigenous colluvial deposits in the vicinity of Unit 23.

A micro-artifact constituent analysis of sediment samples from Unit 23 is presented in table 7.11, with frequencies for five categories of cultural material indicated by grain size (-1 to 1 ϕ size classes). Charcoal was represented only in the upper colluvial deposit Layer IB, presumably reflecting human-induced burning up-slope, associated with agricultural activities. Other cultural materials, mainly sea urchin and bone, were confined to Layers IIA to IIIB.

Transect 17

Sediment analyses were performed for samples from Units 24 and 25 along Transect 17. Analytical results are summarized in tables 7.12 and 7.13.

In figure 7.13, the results of grain-size distribution and lithology are presented for both Units 24 and 25. A shift from high to lower energy depositional environments is indicated by the grain-size distribution, while a decreasing contribution of volcanic sand grains is reflected in the 1 ϕ lithology.

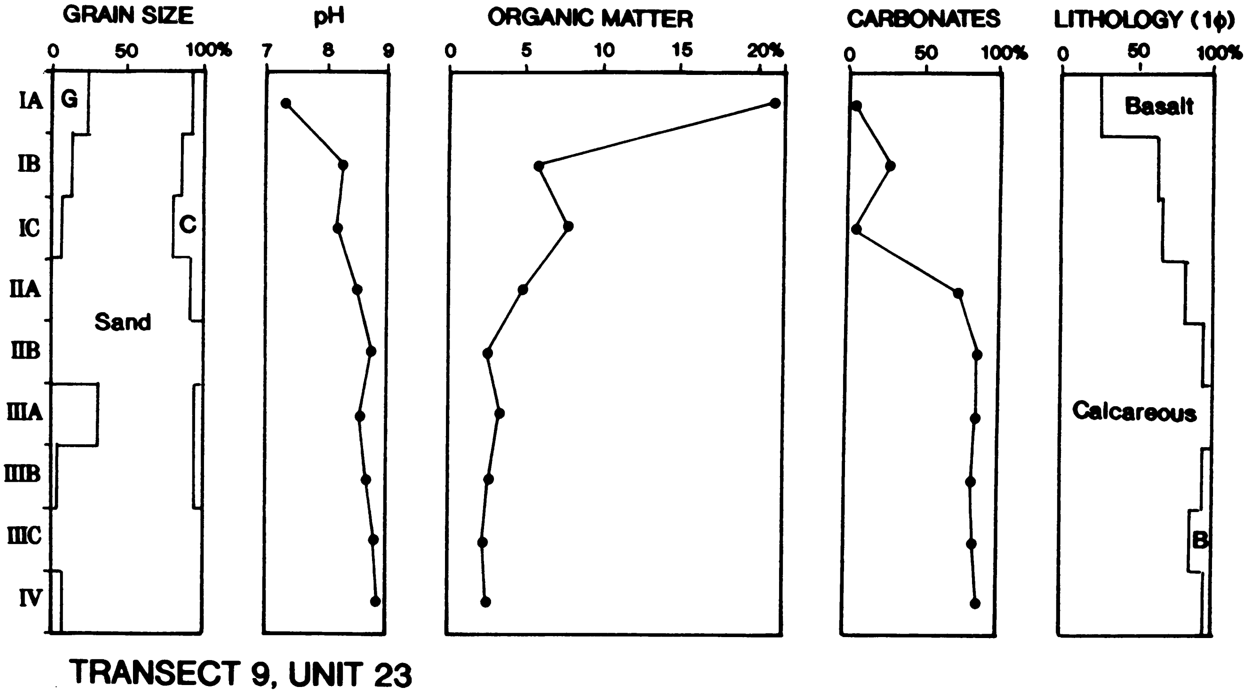

Figure 7.9 Summary diagram of grain size, pH, organic matter, carbonates, and lithology for sediment samples from Unit 23, Transect 9.

Table 7.9
Analytic Data for Unit 22 Sediment Samples

							1 ϕ	
Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	% Calc	% Basalt
89-111	I	15.5	79.8	4.7	gS	8.36	100	0
89-112	II	31.5	67.0	1.5	sG	8.64	100	0
89-113	III	0.1	99.6	0.2	S	8.84	100	0

This indicates the effects of coastal progradation, and the gradual elimination of volcanic boulders and headlands as a source of sand sediment.

The detailed grain-size distribution for Unit 24 clearly reflects the changing depositional environments at Transect 17 (figure 7.14). Layers IF through IC are indicative of very high-energy beaches with substantial components in the granule-pebble-cobble size modes (0 to -2 ϕ). Layer ID, in particular, probably represents a major storm event, possibly associated with a tropical cyclone. Layer IB reflects a rapid shift to a lower energy beach, dominated by coarse-to-medium-grained sands, while the upper Layer IA reflects the development of a stable beach ridge depositional environment. There was no significant encroachment of colluvium over Transect 17.

It is clear that for most of its late Holocene

Table 7.10
Analytic Data for Unit 23 Sediment Analysis

									1 φ		Munsell Color	
Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	% O.M.	% $CaCO_3$	% Calc	% Basalt	Dry	Moist
89-97	IA	23.2	72.8	4.0	gS	7.39	21.3	3.1	29	71	7.5YR 3/2	2.5YR 3/2
89-98	IB	13.7	73.7	12.6	gmS	8.30	5.8	28.4	65	35	5YR 3/4	5YR 3/3
89-99	IC	5.5	76.3	18.1	gmS	8.24	7.9	3.2	67	33	5YR 3/4	5YR 3/3
89-100	IIA	1.0	90.8	8.1	S	8.53	4.8	73.6	83	17	7.5YR 4/2	7.5YR 3/2
89-101	IIB	0.2	98.9	0.8	S	8.77	2.5	89.3	94	6	7.5YR 6/6	7.5YR 6/6
89-102	IIIA	31.4	65.5	2.9	sG	8.67	3.3	83.9	100	0	7.5YR 4/2	7.5YR 3/2
89-103	IIIB	4.6	92.4	2.7	(g)S	8.70	2.8	81.2	94	6	10YR 5/3	10YR 4/3
89-104	IIIC	1.9	97.7	0.4	S	8.85	2.3	84.8	82	18	7.5YR 7/6	7.5YR 6/6
89-105	IV	7.3	92.6	0.1	gS	8.89	2.4	86.7	92	8	10YR 8/3	10YR 8/4

Table 7.11
Microconstituent Analysis of Unit 24 Sediment Samples*

Sample No.	Layer	Charcoal			Marine Shell			Bone			Sea Urchin			Terrestrial Gastropod		
		-1φ	0φ	1φ	-1φ	0φ	1φ	-1φ	0φ	1φ	-1φ	0φ	1φ	-1φ	0φ	1φ
89-97	IA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
89-98	IB	-	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-
89-99	IC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
89-100	IIA	-	-	-	-	-	-	-	-	6.4	-	2.7	-	-	-	2.1
89-101	IIB	-	-	-	-	-	-	-	-	-	-	1.8	1.1	-	-	-
89-102	IIIA	-	-	-	3.2	-	-	-	2.7	-	15.9	16.6	5.8	-	-	-
89-103	IIIB	-	-	-	-	-	-	10.0	-	-	10.0	-	7.2	-	3.2	-
89-104	IIIC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
89-105	IV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Normalized to 200 grains/sample counted.

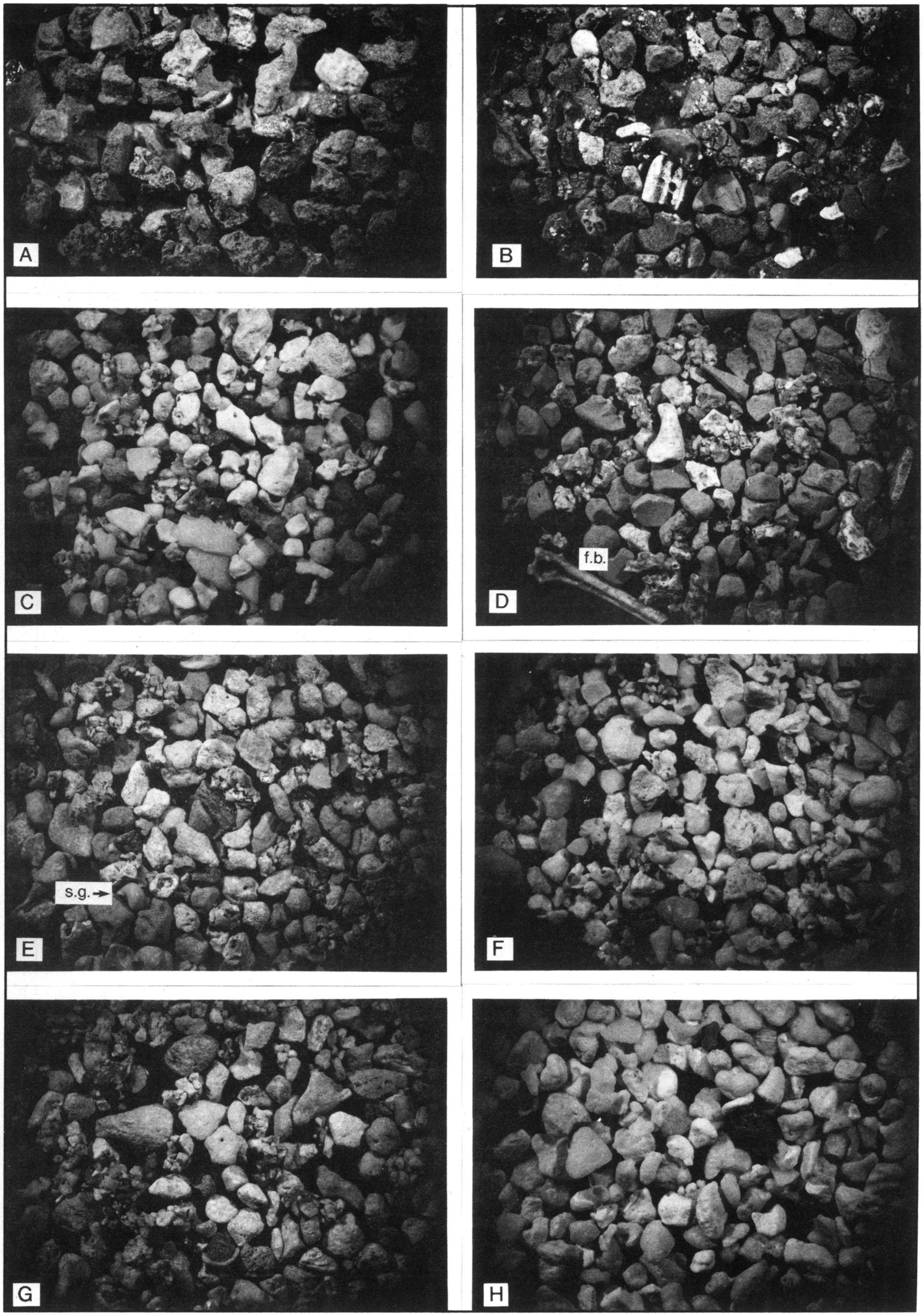

Figure 7.10 Photomicrographs (10X) of the 0 phi size fractions of sediment samples from Unit 23, Transect 9: A, Layer IB; B, Layer IC; C, Layer IIA; D, Layer IIB; E, Layer IIIA; F, Layer IIIB; G, Layer IIIC; and H, Layer IV.

Table 7.12
Analytic Data for Unit 24 Sediment Samples

Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	1 ϕ % Calc.	1 ϕ % Basalt	Munsell Color Dry	Munsell Color Moist
89-125	IA	2.2	95.4	2.4	S	7.96	98	0	10YR 3/2	5YR 2.5/2
89-126	IB	0.8	98.7	0.5	S	8.57	99	1	10YR 7/3	10YR 5/4
89-127	IC	25.6	74.2	0.2	gS	8.68	89	11	10YR 8/3	10YR 7/4
89-128	ID	74.2	25.4	0.4	sG	8.74	99	1	10YR 8/3	7.5YR 8/2
89-129	IE	14.8	84.9	0.3	gS	8.73	71	29	10YR 8/3	10YR 8/3
89-130	IF	12.0	87.8	0.2	gS	8.72	53	47	10YR 4/1	10YR 3/1

Table 7.13
Analytic Data for Unit 25 Sediment Analysis

Sample No.	Layer	% Gravel	% Sand	% Silt	Textural Class	pH	1 ϕ % Calc	1 ϕ % Basalt	Munsell Color Dry	Munsell Color Moist
89-119	IA	6.8	85.4	7.7	gS	8.27	98	2	10YR 4/2	7.5YR 3/2
89-120	IB	8.6	83.2	8.2	gS	8.48	100	0	7.5YR 3/0	5YR 2.5/1
89-121	IC	3.8	91.2	4.9	(g)S	8.50	100	0	7.5YR 5/2	7.5YR 3/2
89-122	IIA	2.2	96.9	0.8	S	8.64	93	7	10YR 7/3	10YR 6/3
89-123	IIA (PF)	47.0	52.7	0.2	sG	8.72	90	10	10YR 8/3	10YR 7/3
89-124	IIB	3.5	96.2	0.2	(g)S	8.80	94	6	10YR 8/3	10YR 8/3

history, Transect 17 has been an area of high-energy beach deposition, which correlates with the lack of significant cultural deposits. The stable coastal terrace probably did not extend into this Fa'ala'aga area until the last 1-1.5 kyr B.P.

SUMMARY AND CONCLUSIONS

The results of detailed sediment analyses from the To'aga excavations provide a set of independent data with which to test the morphodynamic model of coastal change developed in chapter 4. These results are highly consistent between transects and confirm that there has been a significant shift in source, mode, and environment of deposition at To'aga which correlates with shoreline progradation and formation of the coastal terrace. Prior to, and at the time of initial human colonization of Ofu, the shoreline along the southern part of the island was much closer to the volcanic cliffs, in the vicinity of the present surficial contact between the talus slope and coastal terrace. These basal deposits are consistently reflective of high-energy beaches, and the admixture of basalt with calcareous grains indicates that volcanic headlands along with the coral reef provided sources of sediment. A shift to low-energy beach ridge depositional environments by 1900 cal B.P. reflects coastal progradation, as predicted by our morphodynamic model. Subsequently, increased deposition of young, poorly sorted, terrigenous colluvial sediments onto the calcareous coastal terrace suggests increased human disturbance (burning and agricultural activity) on the interior volcanic slopes after about 1900 cal B.P. Further implications of these results are explored in greater detail in chapter 15.

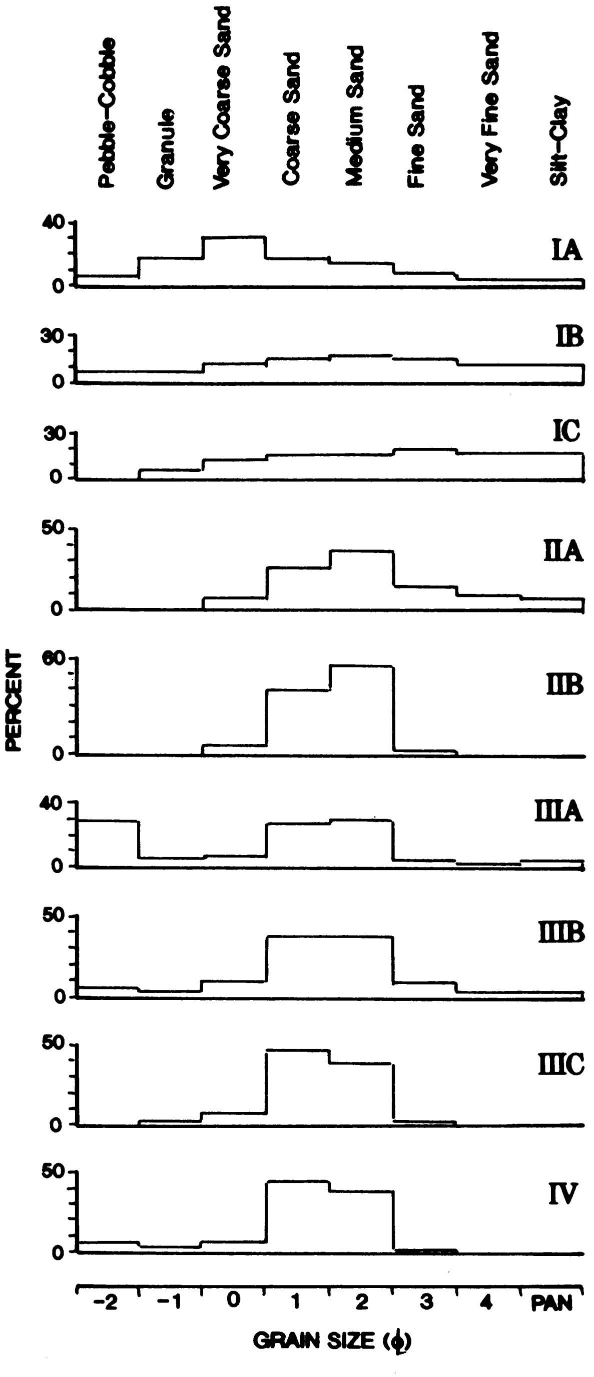

Figure 7.11 Histogram plots of grain size distributions for sediment samples from Unit 23, Transect 19.

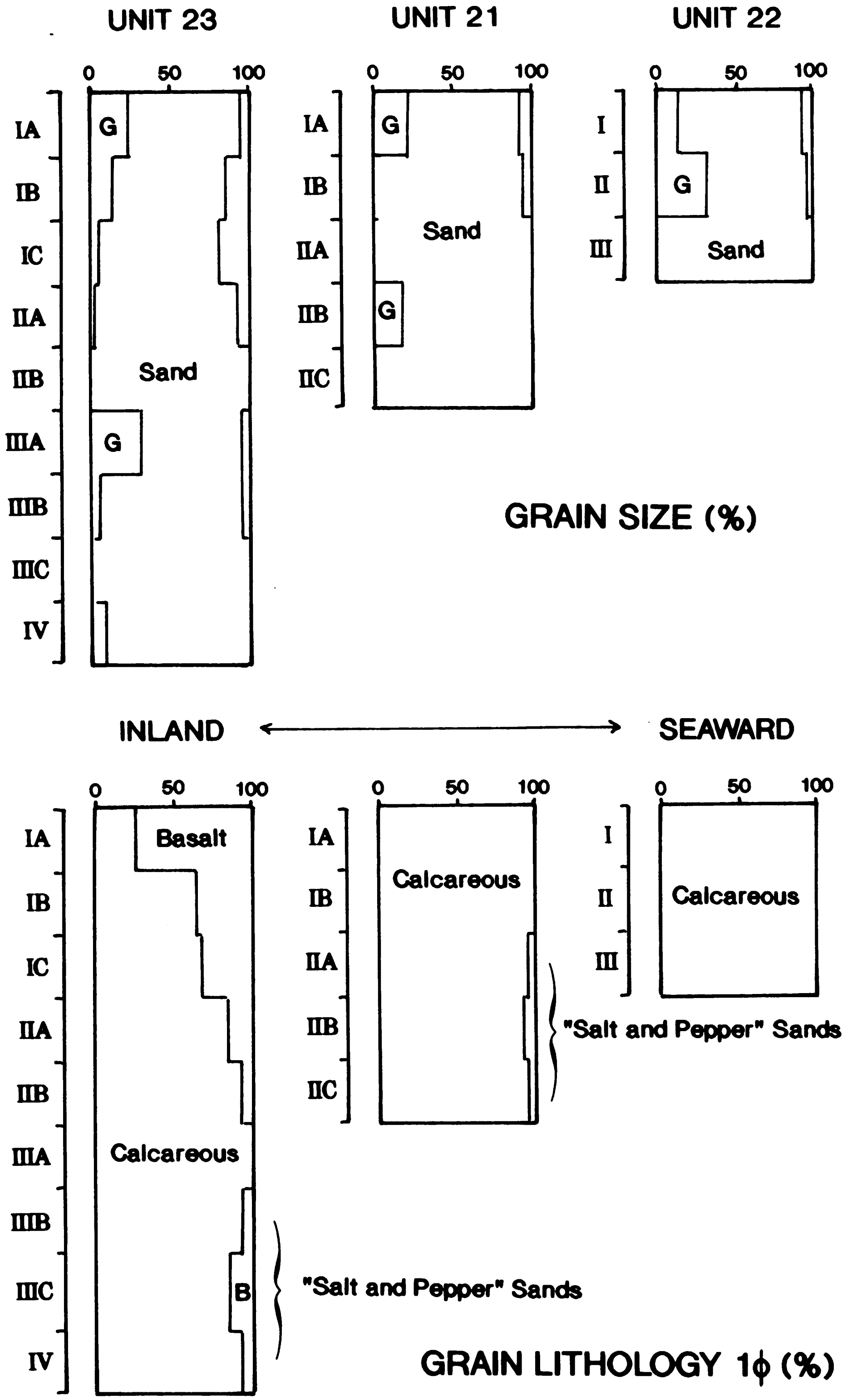

Figure 7.12 Summary diagrams of grain size and lithology for Units 21, 22, and 23, Transect 9.

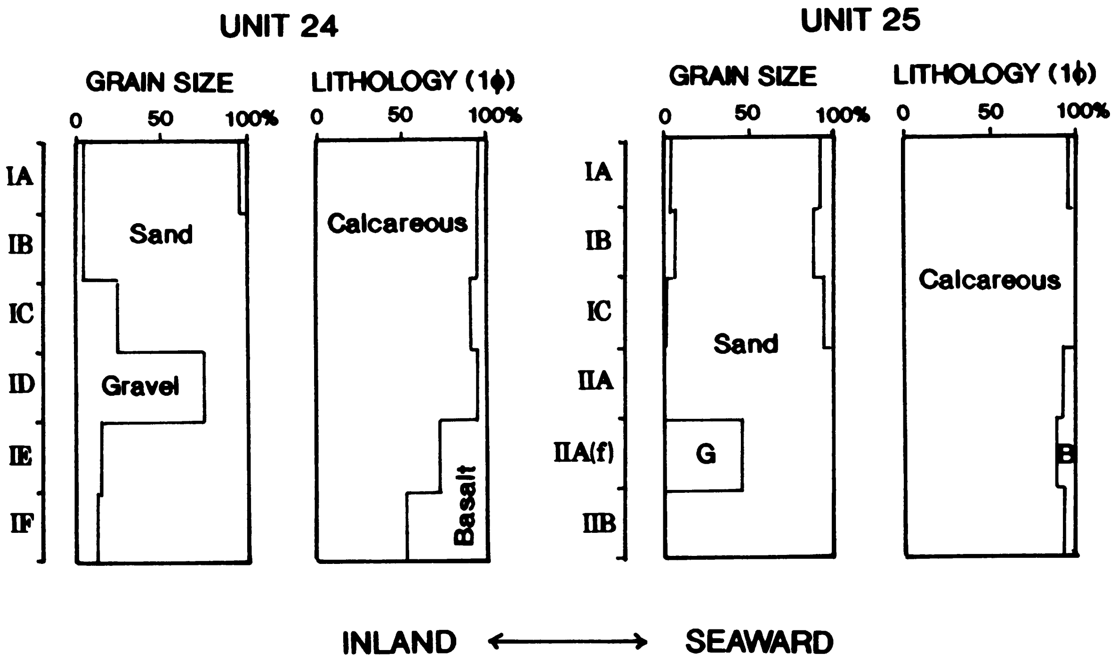

Figure 7.13 Summary diagrams of grain size and lithology for Units 24 and 25, Transect 17.

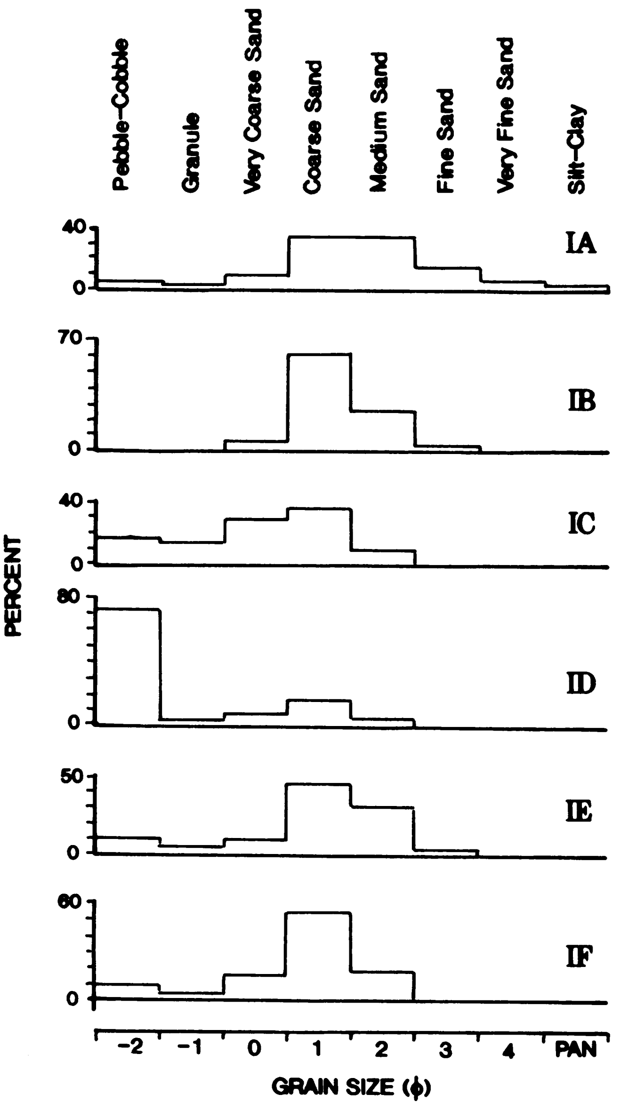

Figure 7.14 Histogram plots of grain size distributions for sediment samples from Unit 24, Transect 17.

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8

NON-MARINE MOLLUSCS FROM THE TO'AGA SITE SEDIMENTS AND THEIR IMPLICATIONS FOR ENVIRONMENTAL CHANGE

PATRICK V. KIRCH

INTRODUCTION

NON-MARINE MOLLUSCS, or "land snails," can occur in high frequencies at archaeological sites where depositional environments are favorable to their preservation (e.g., calcareous sands such as at the To'aga site). In general, these snails are diminutive (often in the 1-3 mm size range), and their presence in archaeological deposits results from natural rather than cultural deposition. Since land snails are highly sensitive to microenvironmental conditions such as vegetation cover, changing frequencies of snail shells in stratified archaeological deposits can provide a proxy measure of environmental change. Snail analysis for the purposes of environmental reconstruction has been carried out in English and European archaeology for many years (Evans 1972), but has been relatively neglected in the Pacific. Beginning in the 1970s, Kirch and Christensen began to apply snail analysis in Oceanic archaeology with fruitful results (Kirch 1975, 1989; Christensen and Kirch 1981, 1986; Christensen 1983). These studies have demonstrated that non-marine molluscs in Pacific archaeological sites can provide significant information with regard to (1) local environmental change (especially in vegetation), and (2) the introduction of exotic biota by prehistoric humans. Local environmental changes are demonstrated through changing assemblages of endemic and indigenous snail species which are sensitive to microenvironmental conditions. The introduction of exotic biota, on the other hand, is signalled by the presence of one or more species of *synanthropic* (or anthropophilic) snails that are closely associated with human habitations, gardens, and disturbed environments.

Pacific malacologists recognized some time ago that a number of widely disseminated snail species in the Pacific had almost certainly been dispersed through prehistoric human agency. C. Montague Cooke, who spent a lifetime researching Pacific snail faunas, wrote that "there is no doubt that about a dozen species were carried by Polynesians in their migrations. At least four species were carried by the latter to the Hawaiian Islands. These for the most part are minute species of snails that are always found in situations just above high-water mark and are fairly uniformly distributed wherever Polynesians live" (Cooke 1926:2279). Among these synanthropic snail species are *Gastrocopta pediculus, Lamellidea pusilla, Liardetia samoensis, Assiminea nitida,* and *Lamellaxis gracilis*. Because these widely dispersed species are highly characteristic of atolls, they have sometimes been described as an "atoll fauna" (Reigle 1964; Harry 1966), although they are just as common in lowland, anthropogenic habitats on high islands.

During the 1987 excavations at To'aga, I observed the presence of non-marine mollusc shells in a number of stratigraphic contexts, and therefore undertook systematic sampling of the 1987 main trench and several other test units for snail shells.

This chapter presents the results of analysis of these samples and discusses the implications of our results for paleoenvironmental change and for the introduction of exotic biota at To'aga.

MATERIAL AND METHODS

Sediment samples for non-marine mollusc analysis were obtained from two columns at site AS-13-1, one from the main trench of the 1987 excavation and the other from Unit 3. The main trench column was taken from the cleaned west face of Unit 9, and the nine column samples spanned the stratigraphic sequence from Layer IIC through Layer IIA-1. No land snail shells were observed below Layer IIC or in the acidic colluvial sediments of Layer I. The position of the land snail column in the main trench is depicted on the main stratigraphic section shown in figure 5.5.

For the most part, the methods used in the analysis of non-marine molluscs at To'aga follow those developed and reported by Christensen and Kirch (1986:55-56) for use in Hawaiian archaeological sites. Sediment samples for snail extraction were taken as continuous columns. Prior to sieving, the sediment samples were air-dried, then weighed and measured volumetrically in order to assure quantitative comparability between samples. In the laboratory, the sediment samples were wet-sieved through 4, 2, and 1-mm mesh nested geological screens, and the washed residues air-dried. Snail shells were then extracted by hand-sorting under a 10X binocular microscope. Snail shells were identified by referring to published taxonomic monographs and to reference material in the collections of the Bernice P. Bishop Museum (Honolulu).

In the next section the various species of non-marine molluscs present in the To'aga samples are listed in taxonomic order, with remarks on their distribution and ecology. This is followed by the presentation of quantitative data on snail species frequency from the two stratigraphic columns.

SYSTEMATIC REVIEW

Family Helicinidae

Pleuropoma sp.

A few specimens of *Pleuropoma* are present in the To'aga samples. It has not been possible to identify these to species level.

Family Assimineidae

Assiminea cf. *nitida* (Pease)

The genus *Assiminea* includes a number of estuarine and standline-dwelling species (Abbott 1958). The most abundant land-snail species in the To'aga site sediments is an *Assiminea* (fig. 8.1) which very closely resembles *A. nitida* (Pease). This species is known to be widely distributed from Southeast Asia eastwards into Oceania.

Family Achatinellidae

Lamellidea pusilla (Gould)

Lamellidea pusilla is (fig. 8.1) one of several species in the Achatinellidae that have extensive distributions throughout the inner Pacific. Cooke and Kondo remarked that "there is little doubt that the wide distribution of *L. pusilla* is due to human agency. It was probably transported from island to island during the Polynesian migrations" (1960:188). The species is distributed from the Marianas and Palau groups in the western Pacific and as far eastward as Mangareva (Cooke and Kondo 1960: fig. 81).

Family Pupillidae

Gastrocopta pediculus (Shuttleworth)

This small pupillid (fig. 8.1) is also abundant in the To'aga samples. Pilsbry made the following remarks on the distribution and geographic origin of *Gastrocopta pediculus*:

> Adaptability to life around habitations has, no doubt, led to the vast Polynesian distribution of *G. pediculus*. I infer that it has been carried from island to island, sticking to native impedimenta, cocoanuts, or other food materials, in the thousand years or more of inter-island canoe voyages of the Polynesians. Its original habitat may have been somewhere between the Philippines and New Caledonia (1916-18:140-41).

Generally distributed in coastal environments, *G. pediculus* shows a strong liking for coconut groves, often being found in large numbers "under leaves and sprouting cocoanuts" (Pilsbry 1916-18:148).

Family Succineidae

Succinea sp.

Only a single example of this species was encountered in the To'aga site sediments, in Unit 3, even though living *Succinea* sp. were observed in leaf litter samples in the arboricultural zone.

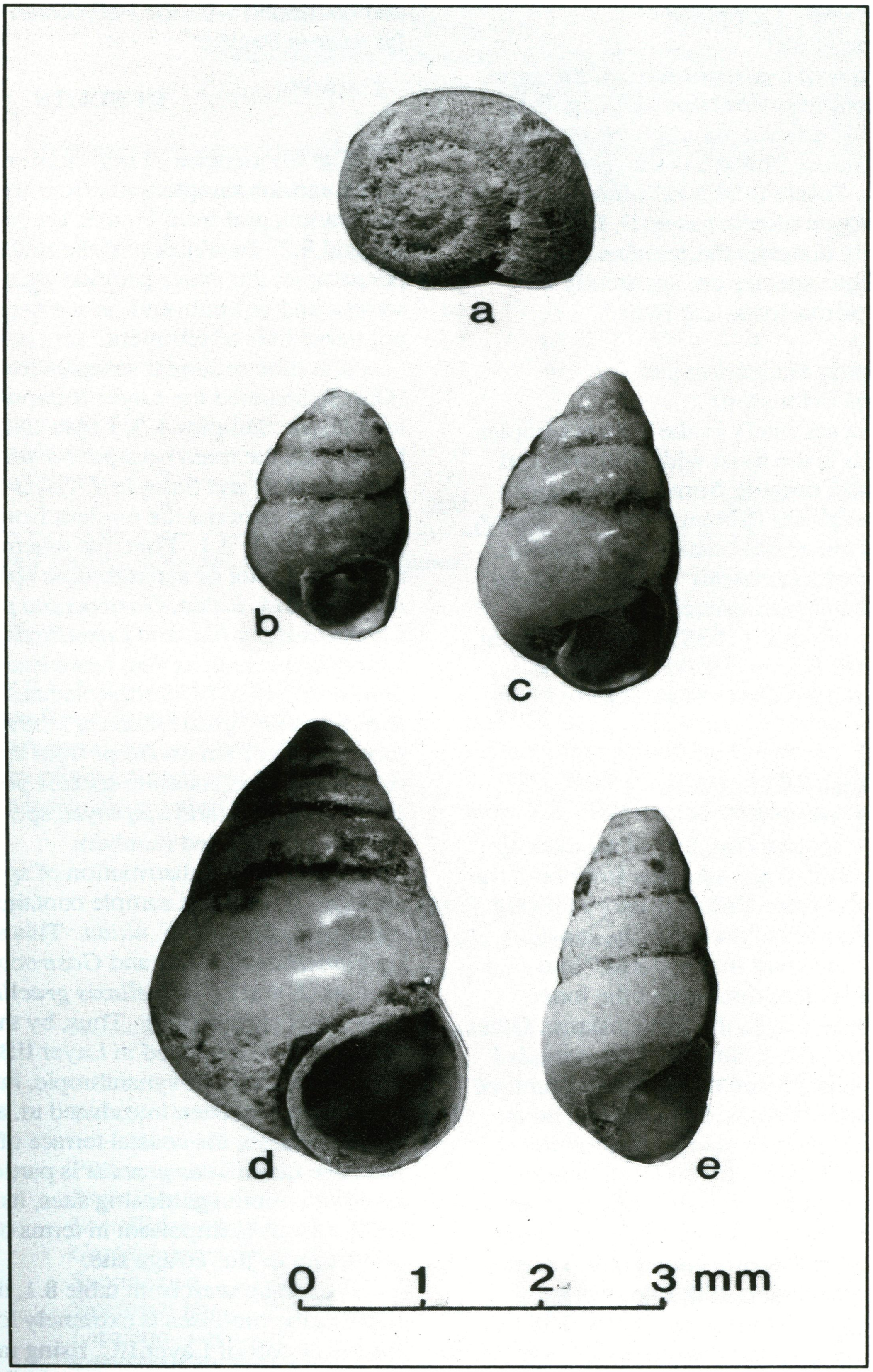

Figure 8.1 Photomicrographs of terrestrial gastropods recovered from the To'aga site sediments: a, *Sinployea* cf. *allecta*; b, *Gastrocopta pediculus*; c, *Lamellidea pusilla*; d, *Assiminea* cf. *nitida*; e, *Lamellaxis gracilis*.

Family Caropidae

Sinployea cf. *allecta* (Cox)

A few specimens of a caropid snail of the genus *Sinployea* are present in several samples (fig. 8.1). This is most likely *S. allecta*, although the closely related species *S. clausa* (Solem) is also present in the Manu'a Group. Solem (1982:127) has described a subspecies, *Sinployea allecta tauensis*, from Ta'u Island which closely matches the remains found at the To'aga site. These species are apparently all lowland dwellers, primarily in leaf litter.

Family Helicarionidae

Liardetia samoensis (Mousson)

This species occurs rarely in the To'aga samples. *Liardetia samoensis* is the most widely distributed member of the genus, ranging from the Bismarcks eastward to the Marquesas (Solem 1959:96). Baker, who monographed the zonitid snails of the Pacific, observed that the genus *Liardetia* "contains species that have been widely disseminated, probably through the agency of man" (1938:12), among them *Liardetia samoensis*. Solem (1959) regards the probable center of distribution of *Liardetia* as Indonesia.

Family Subulinidae

Lamellaxis gracilis (Hutton)

This distinctive species (fig. 8.1) is reasonably well represented in the To'aga samples from both the 1987 main trench and from Unit 3. Pilsbry (1906) remarked that *L. gracilis* is "probably the most widely distributed land snail in the world," and suggested that its dispersal throughout the inner Pacific may have been due to the Polynesians. Other malacologists (Cooke 1934; Solem 1978) regarded its wide distribution as a result of modern commerce. Christensen and Kirch (1981) demonstrated, however, that *Lamellaxis gracilis* was present on the Polynesian outlier of Tikopia by 900 B.C., where Lapita colonists presumably introduced it inadvertently. Subsequently, specimens of *L. gracilis* have been identified from prehistoric contexts in Tonga (Niuatoputapu, in association with Lapita sites, Kirch 1988:233-34), the Marquesas (Rolett 1989, table 5.14), and Hawai'i (Christensen and Kirch 1986:60). The dissemination of this synanthropic species probably began with the Lapita expansion and continued with the Polynesian dispersal into the far eastern Pacific.

RESULTS

The frequencies of non-marine mollusc species in the various sample units from the 1987 main excavation, and from Unit 3, are presented in tables 8.1 and 8.2. In addition to the raw frequency counts per sample, the tables provide information on sample weight and volume, and on the density of snail shells per cubic liter of sediment.

The nine sediment samples from the main trench (Unit 9) spanned the Layer II depositional sequence as follows: Samples 1-3, Layer IIC; Samples 4-6, Layer IIB, the main occupation horizon; Samples 7-8, Layer IIA; and Sample 9, Layer IIA-1. Several significant patterns are evident from the data presented in table 8.1. First, the assemblage is dominated by a suite of synanthropic species, particularly *Assiminea* cf. *nitida*, *Gastrocopta pediculus*, *Lamellidea pusilla*, and *Lamellaxis gracilis*, but with *Liardetia samoensis* also represented. Indeed, the dominance of synanthropic species in these samples is remarkable, greater than any other archaeological example that I am aware of from the Pacific. The two indigenous/endemic species present, *Pleuropoma* sp. and *Sinployea* sp., are represented only in very limited numbers.

The temporal distribution of species is also striking. The oldest sample contains only one species, *Assiminea* cf. *nitida*. This species is joined by *Lamellidea pusilla* and *Gastrocopta pediculus* in Sample 2, and by *Lamellaxis gracilis* and *Liardetia samoensis* in Sample 3. Thus, by the time of occupation represented in Layer IIB, ca. 2500 cal B.P., five species of synanthropic, human-transported land snails had been introduced to, and become established on, the coastal terrace of Ofu Island. Because *Lamellaxis gracilis* is particularly associated with human gardening sites, its appearance by 2500 cal B.P. is important in terms of the economic prehistory of the To'aga site.

As can be seen from table 8.1, the density of non-marine molluscs is extremely low (8 snails/l^3) in the lower part of Layer IIC, rising rapidly to a peak density of 400 snails/l^3 in the middle of Layer IIB, the occupation horizon. Shell density then drops

Table 8.1
Non-marine Molluscs from the 1987 Main Trench, To'aga Site

	Sample No.								
Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Pleuropoma sp.			1	1		1	1	2	
Assiminea sp.	3	5	17	19	51	59	46	47	84
Lamellidea pusilla		4	26	12	10	5	4	1	14
Gastrocopta pediculus		9	26	37	40	17	18	8	19
Sinployea sp.								3	
Liardetia samoensis			1						
Lamellaxis gracilis			5	6	9	8	4	3	11
Total snails counted	3	18	76	75	110	90	73	64	128
Snails/l^3*	8	65	276	269	400	321	203	197	366

* standardized density, adjusted for sample volumes.

somewhat in Layer IIA, but rises again to 366 snails/l^3 in the Layer IIA-1 deposit. This distribution is significant, since it correlates well with the sedimentological history of the column and is precisely the sort of overall density distribution that would be expected with the establishment of human habitations in Layer IIB and of a stable vegetated soil surface represented by Layer IIA-1.

The land snail data for Unit 3 are presented in table 8.2. The overall pattern resembles that in the

Table 8.2
Non-marine Molluscs from Unit 3, To'aga Site

	Sample No.				
Taxon	**2**	**3**	**4**	**5**	**6**
Pleuropoma sp.		1		1	
Assiminea sp.	10	27	44	110	15
Lamellidea pusilla	2	6	3	18	
Gastrocopta pediculus	6	9	7	27	
Succinea sp.				1	
Sinployea sp.		1	2	4	
Liardetia samoensis				1	
Lamellaxis gracilis	3	8	10	13	3
Total snails counted	21	52	66	175	18
Snails/l^3*	71	184	280	735	68 .

* standardized density, adjusted for sample volumes.

main trench, except that the suite of synanthropic snails is already established at the base of the column (Sample 2). The increasing density of land-snail shells and the dominance of synanthropic species suggest the establishment of a stable, anthropogenic vegetation over the To'aga coastal terrace following human occupation of the island.

CONCLUSION

The analysis of non-marine molluscs from the To'aga site provides important corroborative evidence for several interpretations made elsewhere in this volume. That the snail assemblages at To'aga are dominated by a suite of synanthropic species (the so-called "atoll fauna") known to have been widely disseminated by human agency highlights our interpretation of the To'aga coastal terrace as a strongly anthropogenic habitat. The absence of endemic/indigenous species below Layer IIC in the main trench supports our interpretation of the coastal terrace as a narrow, exposed, calcareous depositional environment prior to human colonization. After human settlement and the establishment of crop plants and other introduced vegetation at the beginning of the first millennium B.C., the coastal terrace began to sustain an adventive snail fauna of synanthropic species. The high concentration of these snails in Layer IIA-1 is also consistent with our interpretation of this deposit as a former stable, vegetated A_1 horizon paleosol.

The snail assemblages from To'aga further document of the early spread of synanthropic species into central Polynesia. Such species as *Lamellaxis gracilis*, associated with Polynesian gardening environments, were already known to have been present in Lapita contexts (Christensen and Kirch 1986; Kirch 1988). The presence of this and four other species at To'aga reflects the propensity of early Pacific colonizers to create "transported landscapes."

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9

THE TO'AGA CERAMICS

T. L. HUNT AND C. L. ERKELENS

Ceramics have played a critical role in understanding prehistory in Samoa and West Polynesia. They are usually well preserved, archaeologically visible, and carry a large amount of information on variation in style (temporal and spatial), technology, function, and raw material. While ceramics have proven useful for making culture-historical inferences about Samoa and the region, they also present several interesting problems to be resolved in their own right. First, what is the nature of ceramic variability (temporal and spatial) in Samoa? Second, what kinds of change (stylistic, technological/material, and functional) occurred over the duration of ceramic production in Samoa? And third, why did ceramics disappear in Samoa after an approximate thousand-year sequence of production? In this chapter we describe the ceramic assemblage from the To'aga excavations and begin to address these questions through analyses of ceramic clay composition, technology, function, and style.

THE ASSEMBLAGE

The 1986 excavations on Ofu and neighboring Ta'u produced a total of 147 sherds (32 sherds from To'aga), and were analyzed and reported in Hunt and Kirch (1988:169-71). The 1987 field season added 1464 sherds to the To'aga assemblage. These sherds were described by Kirch et al. (1990:7-8) and are further analyzed here. Excavations in 1989 provided an additional 938 sherds to the previous total. In sum, three seasons of fieldwork at To'aga (AS-13-1) have yielded a total ceramic assemblage of 2434 sherds.

The To'aga ceramic assemblage is significant in several respects. The sherds come from a deep, well-stratified site dated with several radiocarbon determinations (see chapters 5 and 6). The assemblage spans the full duration known for ceramic production in Samoa, and consists of quantities of the pottery distinguished as "thickware" and "thinware" (see Green 1974; Holmer 1980; Clark and Herdrich 1988). Pottery from To'aga, Samoa's easternmost ceramic-bearing site, dates to the first millennium B.C. Finally, the To'aga assemblage is among the largest excavated in Samoa—only the SU-SA-3 (Green 1974) assemblage from 'Upolu is larger—and thus provides an adequate sample to assess several dimensions of variability.

The entire ceramic assemblage has been cataloged, with individual sherds enumerated. In the most general terms, the assemblage can be divided into broad classes of thickware and thinware sherds. This division of wares is based on sherd thickness, temper size, and paste texture. Such distinctions are qualitative (and somewhat impressionistic), however, and do not accurately reflect the range of variability present in the assemblage—hence the need for detailed analysis. Vessel parts include only direct rims (no necks) and body sherds, indicative of a single class of vessel forms comprising open, round-based bowls. While occurring in only minor frequencies, classes of decoration include red-slipped, carved paddle-impressed, incised, and rim sherds with notched, impressed, or crenelated lips. Frequencies of sherds by these broad classes in stratigraphic context are summarized in tables 9.1-2.

Detailed analysis of ceramics is extremely labor intensive. Observations and measurements on individual sherds can require as much as five to ten minutes each. This problem requires selecting a representative sample from the larger assemblage. In the case of To'aga, we chose excavation units with larger samples. Also, pottery was selected from excavation units to span the full temporal sequence represented at To'aga. This strategy enabled us to assess change across the full sequence of pottery manufacture at To'aga.

Sherd samples were drawn from the main areal excavation of 1987 (units 1 and 4-9, see Kirch et al. 1990 and chapter 5) and from units 27 and 28 excavated in 1990. The total sample selected for intensive analysis is 737 sherds.

The main areal excavation of 1987 (units 1 and 4-9) contained a large number of sherds (n=527) within a well-dated, stratified context. The primary ceramic-bearing occupation layers are dated (Beta-25033, 25034) to an averaged corrected range of 306-138 B.C. at one standard deviation (see chapter 6 and Kirch et al. 1990). Units 27 and 28, excavated in 1989, were selected because they provided large samples from early contexts (see chapters 5 and 6).

Based on radiocarbon dates and stratigraphic correlations, the sherds for intensive analysis can be divided into early, middle, and late periods for comparative purposes. The early ceramics, from layer III in units 1, 5-7, 9, and 28, range from approximately 1250-500 B.C. Middle period ceramics, from layer II (B and C) in units 1, 4-7, 9, 27, and 28, range from about 500 B.C. to the beginning of the Christian era. The late period sample, from layer II (A) in units 4-9 and 27, dates from the time of Christ and may span the first 200-300 years A.D. These are not "ceramic periods" or "phases," but simply represent a three-part division devised to analyze change in the sample.

The protocol for intensive analysis was designed to assess variability in raw materials, technology, style, and function. In addition to recording provenience (by unit, stratum, and level) and catalog number for each sherd, the following analytic protocol was used and observations or measurements coded for analysis (using SPSS- PC+; Norusis 1986):

1) Exterior surface treatment:
    0. eroded ("missing data")
    1. plain (untextured)
    2. wiped (striations present)
    3. puddled
    4. slipped
    5. carved paddle impressed
    6. residue obscuring ("missing data")
2) Interior surface treatment:
    (same criteria as above)
3) Orientation of inclusions ("preference") relative to vessel walls:
    1. indeterminate (i.e. no definitive long axis to grains)
    2. random orientation
    3. parallel
    4. perpendicular
4) Interior anvil casts:
    0. indeterminate ("missing data")
    1. present
    2. absent
5) Exterior paddle marks casts:
    0. indeterminate ("missing data")
    1. present
    2. absent
6) Exterior hardness (Mohs scale)
7) Interior hardness (Mohs scale)
8) Exterior surface color (Munsell):
    0. eroded ("missing data")
    1. 7.5R (& value & chroma for all modes)
    2. 5R
    3. 10R
    4. 2.5YR
    5. 5YR
    6. 7.5YR
    7. 10YR
    8. 2.5Y
    9. 5Y
9) Interior surface color (Munsell):
    (recorded same as above)
10) Oxidation/reduction pattern (using pattern template)
11) Organic residue:
    0. absent
    1. interior
    2. exterior
    3. both surfaces
12) Weight of sherd (grams)

13) Mean sherd thickness (mm, 3 measurements/3)
14) Variance in sherd thickness (mm, maximum minus minimum value)
15) Size modality of temper (Wentworth scale using grain size template, sherd viewed under 10X magnification):
    0. cannot determine temper size modality ("missing data")
    1. granule (-1 phi; >2.0 mm)
    2. bimodal granule, very coarse sand
    3. very coarse sand (0 phi; >1.0 mm)
    4. bimodal very coarse, medium sand
    5. medium sand (2 phi; >0.25 mm)
    6. bimodal medium, fine sand
    7. fine sand (3 phi; >0.125 mm)
    8. bimodal fine, very fine sand
    9. very fine sand (4 phi; >0.0625 mm)
16) Rank order of temper by material in hand specimen only (first temper by rank, second, third); materials code:
    0. indeterminate ("missing data")
    1. black trachyte
    2. green olivine
    3. gray basalt
    4. clear translucent crystals (quartz)
    5. calcareous sand
    6. ferrous peds
    7. opaque feldspathic crystals
17) Decoration technique (note: carved paddle-impressed and red slip are included under the dimension of surface treatment):
    0. undecorated (or eroded, "missing data")
    1. tool impressed
    2. incised

Rims Only

18) Rim course (angle to central vertical axis):
    1. direct
    2. inverted
    3. everted
19) Cross-section of lip:
    1. rounded
    2. square
    3. pointed
20) Rim profile (degree of thickening):
    1. none, parallel walls
    2. thinned
    3. thickened, exterior
    4. thickened, interior
21) Mean thickness of rim at lip (mm, 3 measures/3)
22) Variance in thickness of rim at lip (mm, maximum minus minimum value)
23) Estimated orifice diameter (10 cm intervals)

ANALYTIC PROCEDURES

Observation of exterior and interior surfaces allows one to determine the final finishing methods used on vessels prior to firing. Where sherds have an eroded exterior or interior surface, such observations could not be made and were coded as "missing data." Plain surfaces were simply smooth, with no other finishing techniques evident. Wiped surfaces were recognized by fine, parallel striations that were made in the clay prior to firing. Puddled surfaces, sometimes called "self-slipped" (Rye 1981:57), are those formed by wetting the surface, thus bringing the finest clay particles to the surface of the paste. This technique is recognized by textural differences on the sherd surface and in cross-section. Slip, a thin surface coating created from a fluid suspension of clay in water, commonly has a different color than the body (Rye 1981:41). Also, slip differs from the sherd body in texture. Carved, paddle-impressed surface treatment is usually produced with secondary forming using a paddle and anvil. The textured (patterned) paddle leaves a raised design on the vessel surface.

The "preferred" orientation of sand temper inclusions relates to techniques of primary forming (Rye 1981). Slab building and coiling can be detected, in part, by differences in orientation. A definitive long axis for the particles is necessary to observe orientation.

Interior anvil casts and exterior paddle (carved and plain) marks were noted as present/absent. These traits reveal the use of the paddle and anvil technique in secondary forming in the ceramic production sequence.

Hardness was measured on the interior and exterior surfaces of sherds by a scratch test using the Mohs scale. Hardness, measured on this ordinal scale, may relate to ceramic strength, raw materials, firing, and post-depositional diagenesis.

Sherd color was measured on the exterior and interior surfaces using the Munsell Soil Color Chart (1988). Ceramic color, while complex, reflects

Table 9.1
Ceramics from the 1987 Excavation Units

Unit	Layer	Thin n (%)	Thick n (%)	Rims	Red Slip	Other Sherds	Temporal Analytic Period	Total
1	IIB	2 (3)	66 (97)	10			Middle	68
	IIC	0 (0)	0 (0)	1			Middle	1
	III	2 (67)	1 (33)	0			Early	3
4	IIA	0 (0)	7 (100)	0			Late	7
	IIB	4 (44)	5 (56)	0			Middle	9
5	IIA	4 (14)	24 (86)	0			Late	28
	IIB	12 (27)	32 (73)	4			Middle	44
	III	8 (100)	0 (0)	3			Early	8
6	IIA	2 (8)	22 (92)	3			Late	24
	IIB	2 (13)	13 (87)	0			Middle	15
	IIC	17 (74)	6 (26)	0			Middle	23
	III	4 (80)	1 (20)	2			Early	5
7	IIA	1 (13)	7 (87)	1			Late	8
	IIB	5 (71)	2 (29)	0			Middle	7
	IIC	5 (83)	1 (17)	0			Middle	6
	III	4 (80)	1 (20)	1			Early	5
8	IIA	0 (0)	27 (100)	0			Late	27
9	IIA	2 (3)	67 (97)	0			Late	69
	IIB	2 (9)	20 (91)	11		Incised (1)	Middle	22
	III	1 (33)	2 (67)	0			Early	3
10	IIA	1 (25)	3 (75)	0			Late	4
	IIB	1 (50)	0 (0)	0	1		Middle	1
11	IIA	3 (38)	5 (62)	2			Late	8
	IIB	8 (8)	90 (92)	11			Middle	98
	IIC	1 (50)	1 (50)	0			Middle	2
12	III	20 (100)	0	3		Notched rim (1)	Early	20
14	IIA	7 (4)	175 (96)	10			Late	182
	IIB	10 (11)	85 (89)	0			Middle	95
Totals*		128 (15)	663 (85)	(62)				791

* Rims, slipped, and decorated sherds included with thick/thin sherd counts; eroded sherds not included in total.

Table 9.2
Ceramics from the 1989 Excavation Units

Unit	Layer	Thin n (%)	Thick n (%)	Rims	Red Slip	Other Sherds	Temporal Analytic Period	Total
15	II	1 (10)	9 (90)	1			Middle	10
	IIIA	8 (27)	22 (73)	3			Early	30
	IIIB	2 (13)	13 (87)	2			Early	15
	IIID	2 (50)	2 (50)	0	2		Early	4
16	I	0 (0)	9 (100)	0			Late	9
	II	0 (0)	3 (100)	0		Incised (1)	Middle	3
	III	12 (40)	18 (60)	2	1		Early	30
20	IIIA	4 (7)	53 (93)	4			Early	57
	IIIB	12 (9)	120 (91)	10	10	Impressed (6)	Early	132
	IIIC	10 (22)	36 (78)	3			Early	46
21	IIA	1 (25)	3 (75)	0			Middle	4
	IIB	2 (12)	14 (88)	0			Middle	16
23	IIIA	8 (13)	54 (87)	4	2		Early	62
	IIIB	32 (35)	60 (65)	10	1	Decorated (4)	Early	92
	IIIC	17 (28)	44 (72)	3	1		Early	61
24	IB	1 (33)	2 (67)	0	1		Middle	3
27	II	0 (0)	5 (100)	0			Late	5
	IIA	5 (8)	57 (92)	3			Middle	62
	IIIB	3 (30)	7 (70)	1			Early	10
28	IIA	0 (0)	1 (100)	0			Late	1
	IIB	7 (30)	16 (70)	2			Middle	23
	IIC	51 (50)	52 (50)	13	9	Impressed (1)	Middle	103
29	II	0 (0)	12 (100)	0			Middle	12
	IIIA	7 (78)	2 (22)	1			Early	9
30	II	2 (6)	32 (94)	1			Middle	34
	IIIA	11 (28)	28 (72)	6			Early	39
Totals*		198	674	(68)				872

* Rims, slipped, and decorated sherds included within thick/thin sherd counts; eroded sherds not included in total.

variability in raw material, pyrotechnology, and use.

The oxidation/reduction pattern was recorded for sherd cross-sections using an inductively derived pattern template (e.g., Rye 1981:116). These patterns are indicators of the atmosphere and temperature of firing (Rye 1981:115-18).

The presence or absence of organic (carbonaceous) residue was recorded. Residues supply important clues of ceramic function.

Variation in sherd thickness has proven significant in Samoan pottery studies. Sherd thickness is estimated as a mean value from three measurements on different parts of the sherd. This mean value is a more reliable measure of sherd thickness than a single measurement (Barry 1978). Three thickness measures also provide a range expressing the variance in sherd thickness. Variance measures the uniformity or evenness of sherd thickness.

Temper was examined in terms of its rank by raw material as estimated from hand specimens only. Also, the size modality of the sand temper grains was recorded using a template produced with sand samples of varying phi sizes on the Wentworth scale. Sherds were viewed under 10X magnification. Dickinson's study of sand temper petrography offers a much more detailed and reliable (some materials are difficult to determine in hand specimen alone) analysis of a selection of sherds from the To'aga assemblage (see chapter 10).

For sherds with one or more intact surfaces, decoration technique was recorded as tool-impressed, incised, or undecorated (plain). Carved paddle-impressed and red slip, while decorative techniques, are included under the dimension of surface treatment.

Rim sherds were identified in terms of their course relative to the central vertical axis of the pot (e.g., direct, everted). The cross-section of the lip (form) and the profile of the rim, or the degree of thickening, were also classified. Finally, the thickness of each rim was measured, and orifice diameters were estimated.

Of the 737 sherds sampled for intensive analysis, 583 sherds retained both interior and exterior surfaces enabling measurement or observation of the characteristics listed above. The results of intensive macroscopic analysis are summarized and discussed below. These results, together with compositional results (below and chapter 10), provide the basis for reconstructing aspects of ceramic raw material use, production technology, style, and function.

RESULTS OF MACROSCOPIC ANALYSIS

Many of the results used for intensive analysis are summarized in tables 9.3-13. Specific characteristics that relate to material use, forming techniques, pyrotechnology, style, and function are discussed below.

The analysis of sand temper composition and grain size modality (see table 9.4) revealed the following: temper ranges in size from grains measuring approximately 2.5 - 4 mm (i.e., granules

Table 9.3
Frequency of Body and Rim sherds

Sherd	Frequency	Percent	Cum. Percent
Body	683	92.7	92.7
Rim	54	7.3	100.0
Total	737	100.0	

(Valid cases = 737; Missing cases = 0)

Table 9.4
Frequency of Sherds by Temper Size Mode(s)

Temper Size Modes	Frequency	Percent	Cum. Percent
granule	30	4.1	4.1
granule, very coarse	189	25.6	29.7
very coarse	140	19.0	48.7
very coarse, medium	114	15.5	64.2
medium	81	11.0	75.2
medium, fine	91	12.3	87.5
fine	92	12.5	100.0
Total	737	100.0	

(Valid cases = 737; Missing cases = 0)

< -1 phi) in many sherds, to particles visible only under magnification (i.e., fine to very fine sand, > 3 phi). No attempt was made to observe modes of finer (e.g., silt) particles.

Most of the sherds in the sample assemblage (86%) had a mixture of sands and contained more than one temper compositional class. Thicker sherds tended to have coarser temper and thinner sherds tended to have finer temper. Temper size correlates to temper composition ($\chi^2 = 237.21$, df = 9, $p > .0001$) in that well-rounded, calcareous sand grains are smaller than the very coarse (often angular) sand class (0 phi). Grain size and temper composition are also associated with sherd thickness. Calcareous sand temper occurs most often in thinware (73% of this temper occurs in thinware). Yet, thinware cannot be described as predominantly calcareous sand tempered because only 26% of the thinware has a predominance of calcareous sand temper. On the other hand the largest tempers, grains of glassy black trachyte, dull grey basaltic, rounded olivine, pale opaque feldspars, clear crystalline, and red ferrous, rounded grains were represented in the smallest size classes as well.

Color variability was assessed by plotting values in a scatterplot to check for trends or grouping tendencies. Bivariate plots for a three dimensional classification were achieved by plotting Munsell hue against value-chroma (figures 9.1-3; e.g., see Bishop et al. 1988). These plots reveal that color variability in the To'aga ceramics is comparable for all three time periods and for both thick- and thinwares. Sherds range from red (10R) to yellow-red (10YR) and cover an array of value and chroma. The majority of the assemblage is reddish brown or gray in color. Early ceramics include red-slipped sherds (10 R 5/6 and 2.5 YR 5/6) distinctive in coloration from the rest of the assemblage.

Although analysis showed that interior and exterior surface colors have similar distribution, the correlation on individual sherds was poor (Pearson's $r = 0.143$, $p > 0.001$). Oxidation/reduction patterns (table 9.5) play some part in this correlation, since 24% of the sherds have interior surfaces that were not fully oxidized as compared with only 3% for the exterior surfaces. As a result, more sherds have interior surfaces that are darker than their exterior surfaces. Most of the sherds (68%), however, were fully oxidized during firing.

Following analysis, the entire assemblage was inspected to check for further variation in color (or other unrecorded differences in temper, etc.). Five sherds from units 15/29/30 were anomalous in color. These sherds (5 YR 6/6 and 7.5 YR 6/3) are described respectively as reddish yellow and light brown in the Munsell system. The former group of thickware sherds (5 YR 6/6) is similar in color to the predominate color of the sherds from 'Upolu Island designated "Falemoa Tan" by Holmer (1980:114).

Sherd hardness, measured on the Mohs scale,

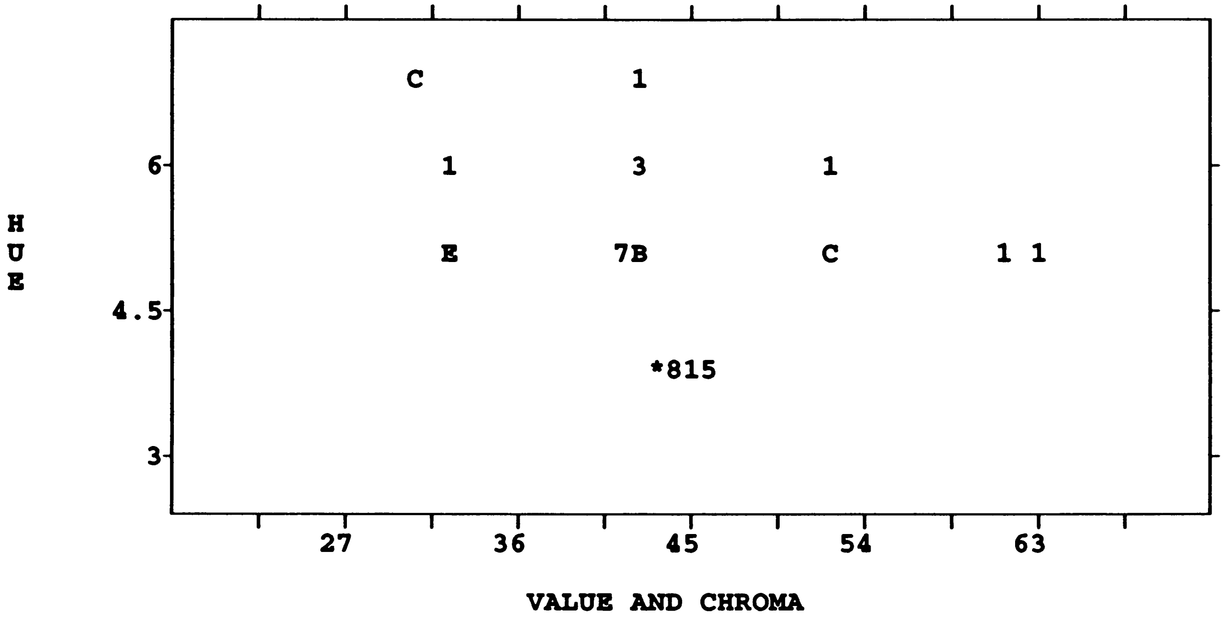

Figure 9.1 Plot of exterior sherd color (hue with value and chroma) for the late period (note to figures 9.1-3: number of cases in each position is shown in sequential order by 1-9; A-; 10-35 cases; and *, more than 36 cases).

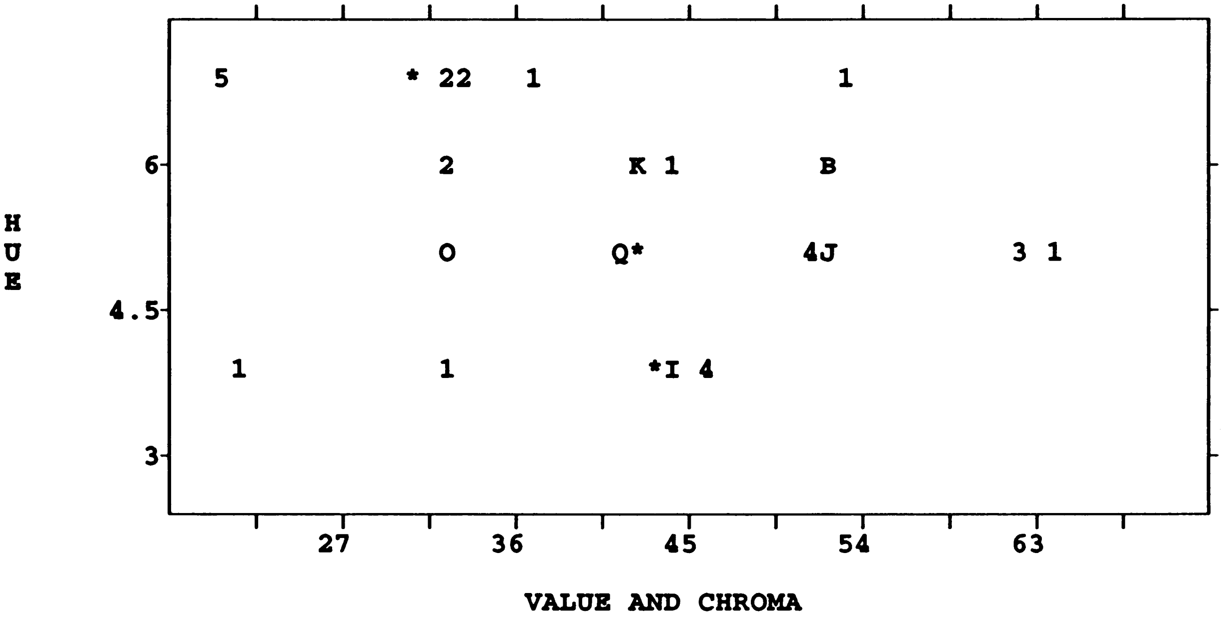

Figure 9.2 Plot of exterior sherd color (hue with value and chroma) for the middle period (see note to fig. 9.1).

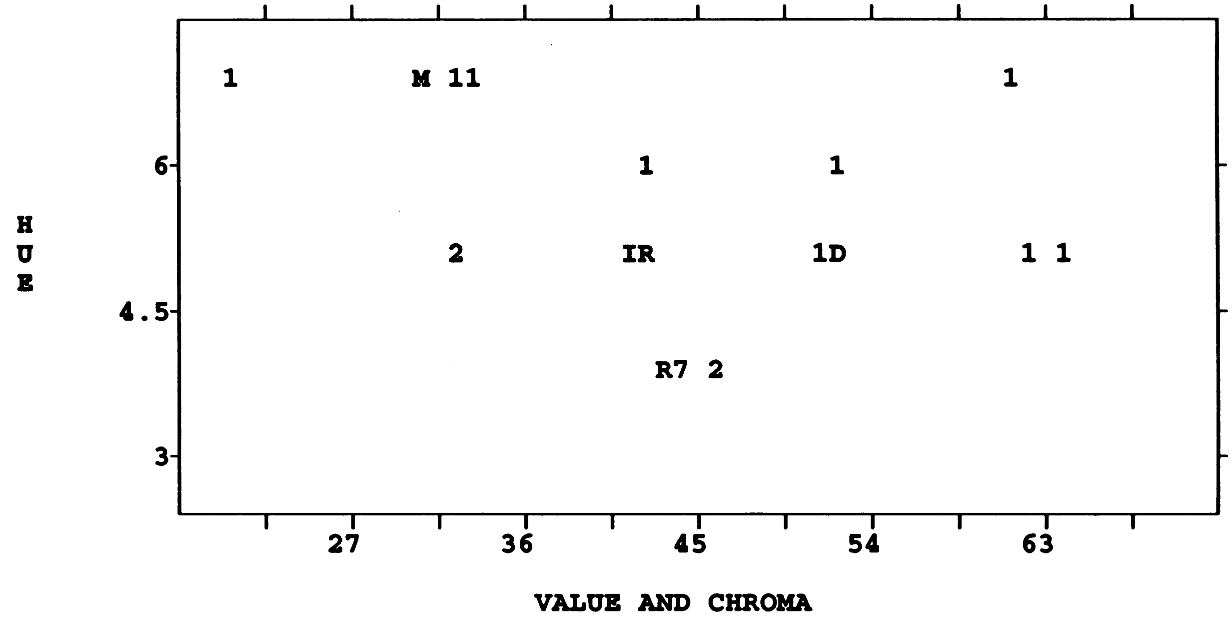

Figure 9.3 Plot of exterior sherd color (hue with value and chroma) for the early period (see note to fig. 9.1).

ranged from 2.0 to 8.0 (tables 9.6-7). This is a remarkable range of hardness, but reflects the difficulty of measuring paste hardness with a scratch test in sherds with abundant temper (which is consistently hard). Ceramic tiles manufactured from colluvial clay samples and fired in an open fire (for approximately fifteen minutes), or in the muffle furnace (500°C for fifteen minutes) were uniformly 3 in hardness. There is a strong correlation ($r = 0.8467, p > .0001$) between the interior and exterior hardness of individual sherds.

The sample analyzed ($n = 737$) had 583 sherds which retained both surfaces (i.e., non-eroded), allowing the measurement of mean thickness for each sherd. Results show that sherds range from 4.20 mm to 16.97 mm in thickness. The total sample mean sherd thickness is 9.42 mm ($\sigma = 2.84$), however the distribution is not normal, but has three modes (figure 9.4). The late portion of the sample ($n = 196$) with 140 measurable sherds, ranges from 5.60 mm to 14.55 mm in thickness. The late sample mean sherd thickness is 10.14 mm ($\sigma = 1.77$) (figure 9.5). The middle period sample ($n = 411$) with 323 measurable sherds, ranges from 4.20 mm to 16.97 mm in mean sherd thickness. The sample mean thickness is 9.97 mm ($\sigma = 3.10$) (figure 9.6). The early ceramics ($n = 130$) had 120 measurable sherds with a mean thickness of 7.09 mm ($\sigma = 1.68$). These sherds range in thickness from 4.30 mm to 14.52 mm in a somewhat normally distributed range of measurements (kurtosis 4.357, skewness 1.783), but skewed toward the thinner sherds (figure 9.7). Differences in sherd thickness are summarized by temporal-analytic periods in table 9.14.

Rims for the entire To'aga assemblage were analyzed and identified to class (see protocol). These forms are illustrated in figure 9.8. One large reconstructed sherd provided a measurable portion of a rim (9% of the estimated total) so that the diameter is reconstructed as 48 cm. About 89% of the rims are oriented 90° to a central vertical axis of the vessel. Other rims have angles approximating 80°. All rim courses are direct, with the majority (80%) having a squared lip cross section. The remaining rims (20%) are rounded in cross section.

The only decorated rims are from early contexts, comprising approximately 7% of the total. The lips of these decorated rims are impressed with narrow tools forming U-shaped notches, repeating parallel lines perpendicular to the rim, or in one case, oblique to the rim. A rim with a crenelated lip was also recovered.

Other decorated sherds are small in number. Only 30 slipped sherds and 11 other decorated

Table 9.5
Frequency of Sherds by "Preferred" Orientation of Inclusions Relative to Vessel Walls

Inclusion Orientation	Frequency	Percent	Cum. Percent
Indeterminate	199	27.0	27.0
Random	458	62.1	89.1
Parallel	80	10.9	100.0
Total	737	100.0	

(Valid cases = 737; Missing cases = 0)

Table 9.6
Frequency of Sherds by Oxidation-Reduction Pattern in Cross-Section

Pattern	Frequency	Percent	Valid Percent	Cum. Percent
Fully oxidized	380	51.6	67.9	67.9
Core oxidized	10	1.4	1.8	69.6
Ext. oxidized	68	9.2	12.1	81.8
Int. surf. reduced	55	7.5	9.8	91.6
Fully reduced	9	1.2	1.6	93.2
Ext. surf. reduced	14	1.9	2.5	95.7
Surfs. reduced	2	.3	.4	96.1
Ext. reduced	7	.9	1.3	97.3
Ext. surf. reduced	15	2.0	2.7	100.0
Int. reduced	177	24.0	Missing	
Total	737	100.0	100.0	

(Valid cases = 560; Missing cases = 177)

Table 9.7
Frequency of Sherds by Exterior Hardness (Mohs Scale)

Exterior Hardness	Frequency	Percent	Valid Percent	Cum. Percent
2	31	4.2	5.0	5.0
3	113	15.3	18.1	23.1
4	109	14.8	17.5	40.6
5	154	20.9	24.7	65.3
6	145	19.7	23.3	88.6
7	53	7.2	8.5	97.1
8	18	2.4	2.9	100.0
Eroded	114	15.5	Missing	
Total	737	100.0	100.0	

(Valid cases = 623; Missing cases = 114)

Table 9.8
Frequency of Sherds by Interior Hardness (Mohs Scale)

Interior Hardness	Frequency	Percent	Valid Percent	Cum. Percent
2	24	3.3	3.8	3.8
3	110	14.9	17.2	21.0
4	122	16.6	19.1	40.1
5	141	19.1	22.1	62.2
6	158	21.4	24.8	87.0
7	52	7.1	8.2	95.1
8	31	4.2	4.8	100.0
Eroded	99	13.4	Missing	
Total	737	100.0	100.0	

(Valid cases = 638; Missing cases = 99)

Table 9.9

Frequency of Sherds by Exterior Surface Treatment

Surface Treatment	Frequency	Percent	Valid Percent	Cum. Percent
Plain	128	17.4	20.4	20.4
Wiped	13	1.8	2.1	22.5
Puddled	481	65.3	76.8	99.4
Slipped	4	.5	.6	100.0
Eroded	111	15.0	Missing	
Total	737	100.0	100.0	

(Valid cases = 626; Missing cases = 111)

Table 9.10

Frequency of Sherds by Interior Surface Treatment

Surface Treatment	Frequency	Percent	Valid Percent	Cum. Percent
Plain	124	16.8	18.9	18.9
Wiped	14	1.9	2.1	21.0
Puddled	508	68.9	77.3	98.3
Slipped	9	1.2	1.4	99.7
Residue	2	0.3	0.3	100.0
Eroded	80	10.9	Missing	
Total	737	100.0	100.0	

(Valid cases = 657; Missing cases = 80)

Table 9.11

Frequency of Sherds by Interior Anvil Casts

Anvil Casts	Frequency	Percent	Valid Percent	Cum. Percent
Absent	85	11.5	22.3	22.3
Present	297	40.3	77.7	100.0
Indeterminate	355	48.2	Missing	
Total	737	100.0	100.0	

(Valid cases = 382; Missing cases = 355)

Table 9.12
Frequency of Sherds by Exterior Paddle Marks

Paddle Marks	Frequency	Percent	Valid Percent	Cum. Percent
Absent	54	7.3	16.1	16.1
Present	282	38.3	83.9	100.0
Indeterminate	401	54.4	Missing	
Total	737	100.0	100.0	

(Valid cases = 336; Missing cases = 401)

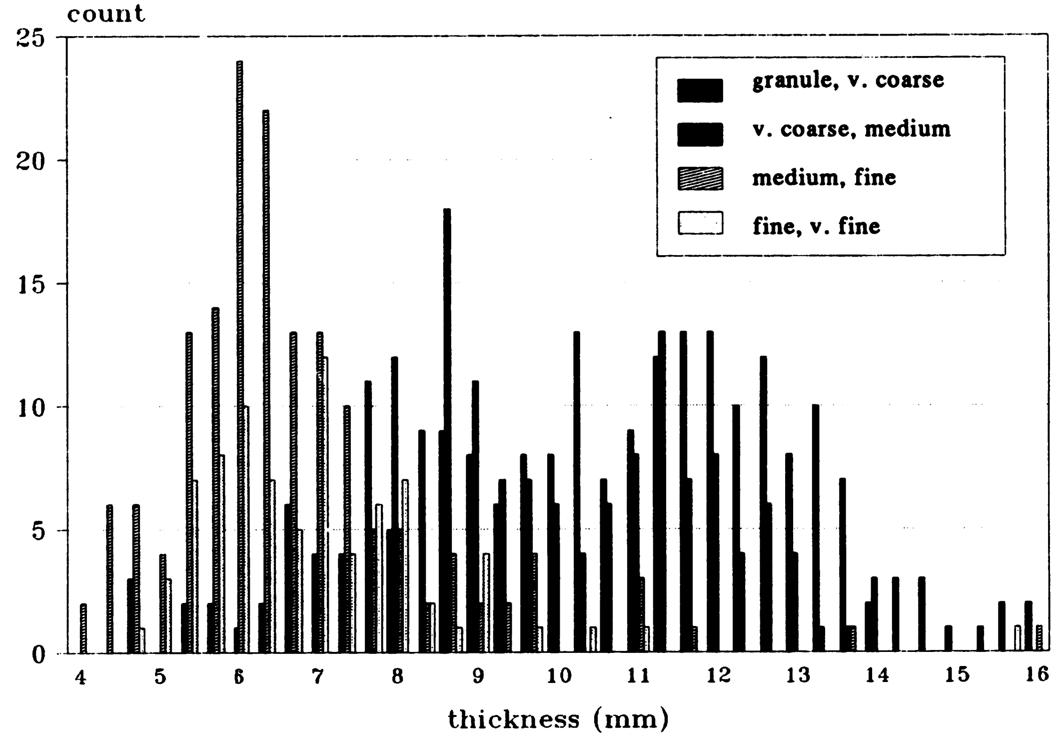

Figure 9.4 Thickness and temper size histogram for the To'aga ceramic assemblage (n = 538). Temper classes are indicated by the variable shading of the histogram bars.

Table 9.13
Frequency of Sherds by Organic Residue

Organic Residue	Frequency	Percent	Valid Percent	Cum. Percent
Absent	725	98.4	98.4	98.4
Interior surface	8	1.1	1.1	99.5
Exterior surface	3	0.4	0.4	99.9
Both surfaces	1	0.1	0.1	100.0
Total	737	100.0	100.0	

(Valid cases = 737; Missing cases = 0)

Table 9.14
Sherd Thickness Statistics by Analytic Time Periods*

Sample	Mode	Median	Mean	sd	Variance	Kurtosis	Skewness	Range	Min.	Max.
All (n=737)	7.40	9.14	9.42	2.84	8.06	-0.833	0.323	12.8	4.2	17.0
Late (n=196)	8.96	10.00	10.14	1.76	3.12	-0.171	0.004	8.9	5.6	14.6
Middle (n=411)	7.40	9.91	9.97	3.10	9.64	-1.090	0.101	12.8	4.2	17.0
Early (n=130)	6.51	6.75	7.09	1.68	2.81	4.357	1.783	10.2	4.3	14.5

* All measurments in millimeters

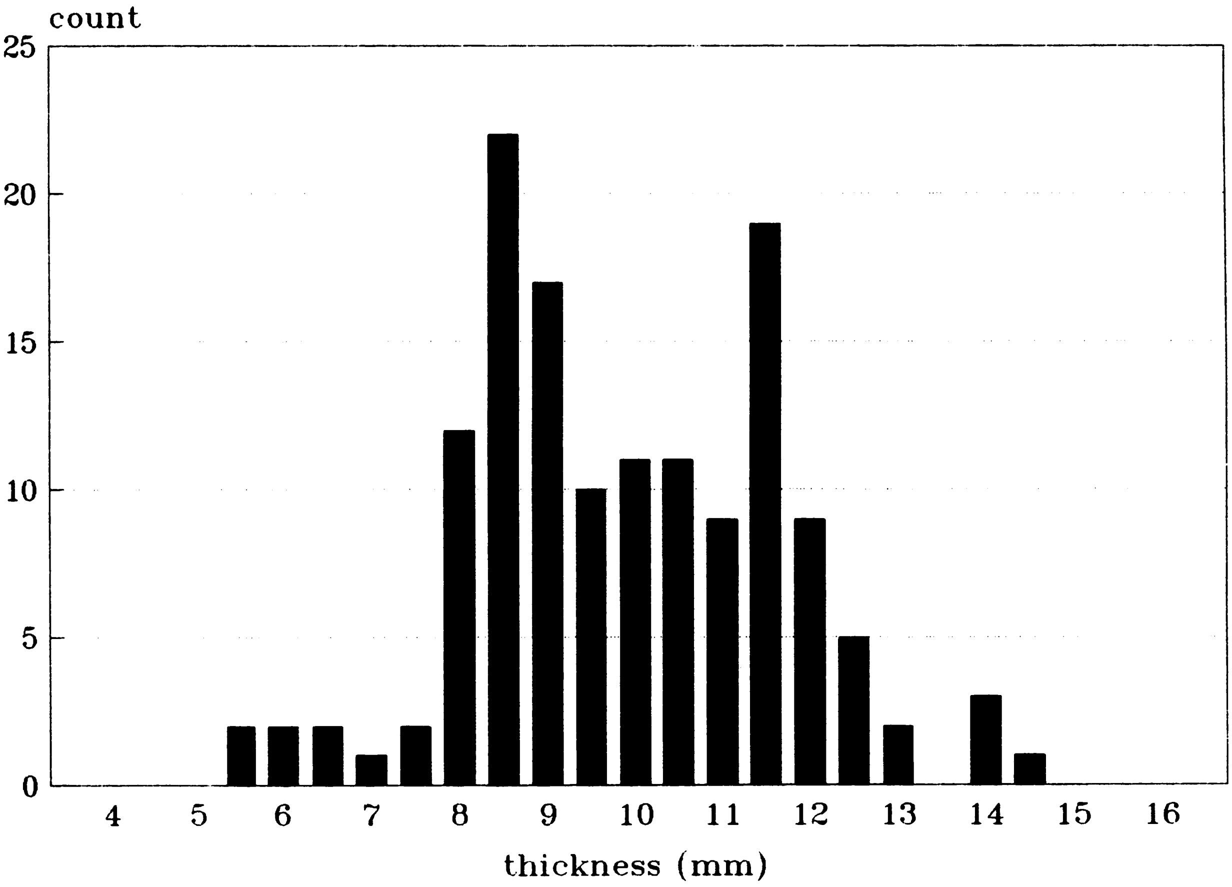

Figure 9.5 Thickness histogram for late period ceramics (n = 196).

sherds were recovered. The color of the slip is red (10 R 5/6 and 2.5 YR 4/6). This slip occurred on both the interior and exterior of the sherds and was found on both rim and body sherds. Three body sherds from the assemblage are decorated. Two sherds have incised lines, although both are small making the overall patterns indistinct. The third is a body sherd with parallel-ribbed, carved paddle impressions on the exterior surface of the vessel. This sherd was from an early context (unit 20, layer IIIB), and compares to other paddle-impressed sherds known from Western Samoa (Green and Davidson 1969:pl. 17).

All sherds recovered during excavations were examined for residue in the field, (i.e., prior to any cleaning). Ten sherds with substantial quantities of carbonized residue were discovered; seven with residue on the interior and exterior, and three on the interior alone. This residue has yet to be identified but is probably the result of cooking starchy foods (see Hill et al. 1985).

CERAMIC COMPOSITIONAL MICROANALYSIS

Analysis of macroscopic ceramic traits supports many research objectives, especially those examined here. Documenting raw material variability requires additional work, especially with respect to temper and clay of the ceramic fabric. The temper component has been analyzed and discussed by Dickinson (chapter 10). Here we present the compositional microanalysis of three clay samples and the clay portion of the ceramics from To'aga. These results allow us to address questions of clay variability (as a part of technology) and the potential for ceramic exchange in Samoa.

A sample of twenty-nine sherds was chosen for their visual differences in thickness, temper, and paste in hand section. Also, this variety of sherds came from excavation contexts that could be inferred to be of different ages (table 9.1). Age differences

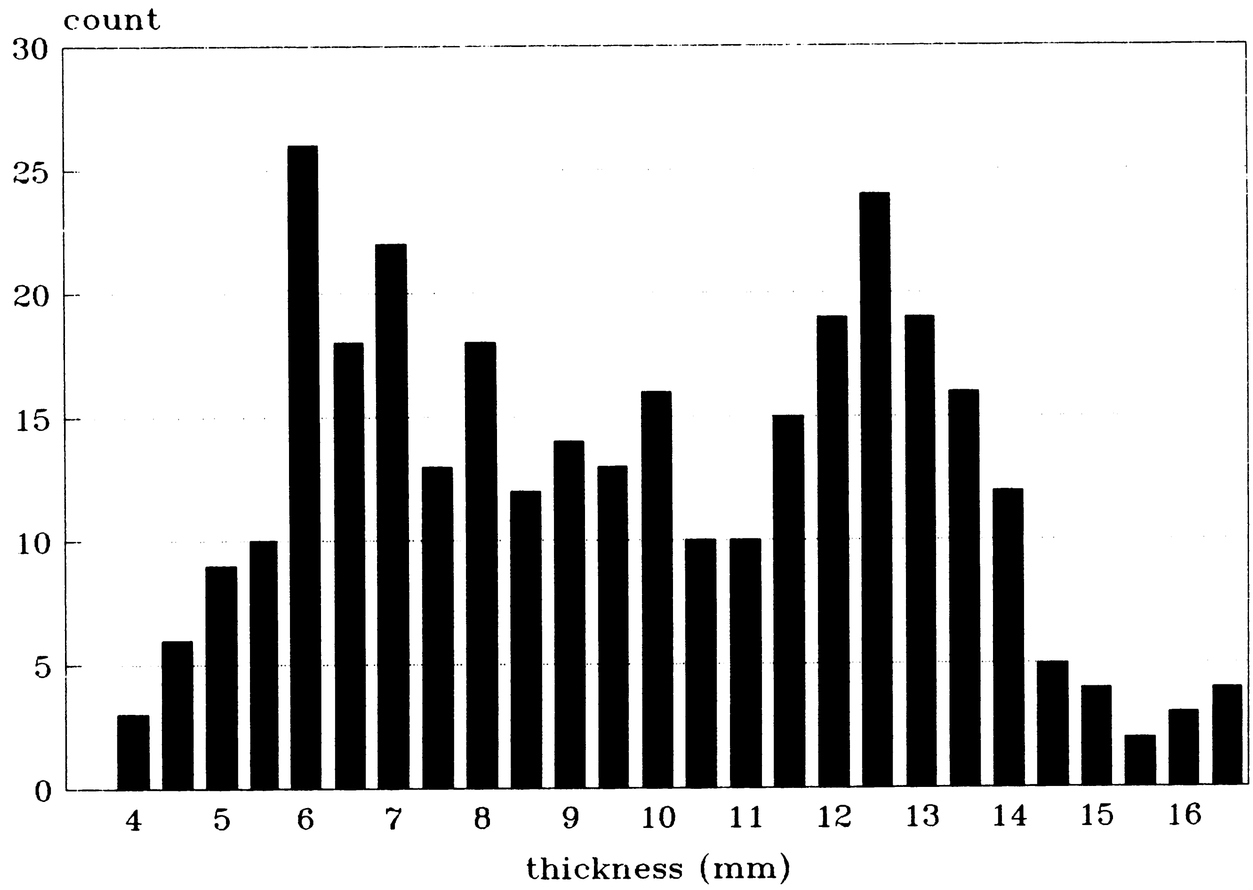

Figure 9.6 Thickness histogram for middle period ceramics (n = 411).

correspond to the analytic divisions made for the larger sample (i.e., early, middle, and late). The sherd samples were also analyzed by Dickinson (chapter 10) for their sand temper petrography. Examination of the To'aga ceramics by both sand temper petrography and elemental analysis takes advantage of the strengths of each approach (Hunt 1988).

In addition to the sherds, three clay samples were collected from colluvium near the base of the cliff at To'aga on transects 1, 5, and 9. These clays were fired in a furnace (at 500°C) for fifteen minutes to produce ceramic tiles resembling sherds. One of these clay samples (from Transect 9) was prepared in the laboratory as a fired ceramic tile (sherd). It was also analyzed by Dickinson (chapter 10) to compare "self-tempered" sherd petrography.

The elemental microanalysis was accomplished using an energy-dispersive spectrometer (EDS) integrated with a scanning electron microscope (SEM). SEM/EDS microanalysis is described in this chapter, and these results are integrated with those from the petrographic analysis. The distinct advantage of the SEM/EDS is in the selectivity afforded by the microscope component of the instrument. Using the SEM in conjunction with an x-ray analyzer, it is possible to characterize the clay matrix alone, or individual inclusions, slips, and residues (e.g., Hunt 1989). Analyses described here were conducted by one of us (TLH) on a JEOL model JSM-840A SEM fitted with a Tracor Northern energy-dispersive x-ray detector housed at the University of Washington.

Selective elemental microanalysis of pottery is possible by the coupling of an x-ray analyzer with the SEM. In the simplest terms, the SEM provides a source of electrons of appropriate energy that impinge on a sample and cause the emission of x-rays. The x-rays emitted have energies and relative abundances that reflect the elemental composition of

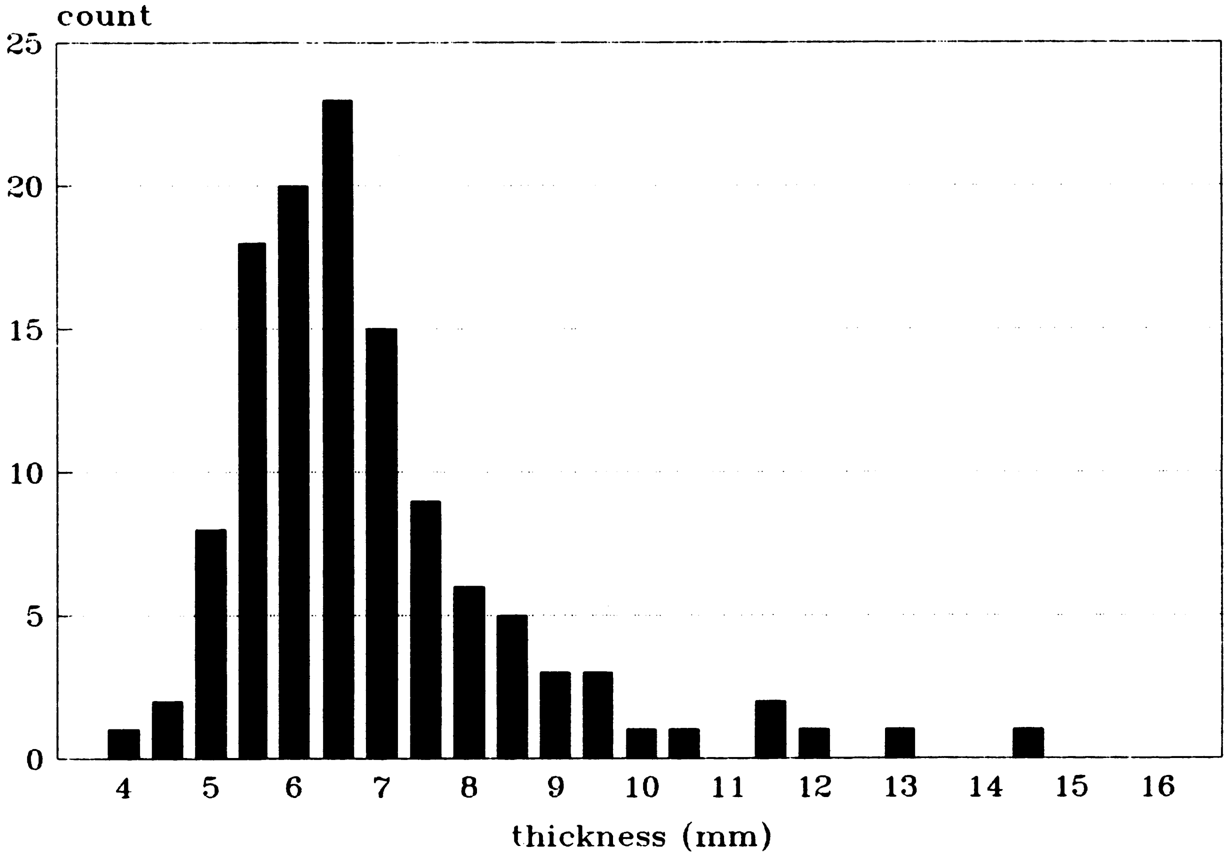

Figure 9.7 Thickness histogram for early period ceramics (n = 130).

the sample. The characteristic x-rays are detected by a lithium-drifted silicon Si(Li) crystal that—together with electronic amplifiers and signal processors—collects and electronically sorts all the energies from the x-rays emitted. Under normal operating conditions, elements with atomic numbers above 10 (Na = 11), and below 100 (Es = 99) are detectable.

The conversion of x-ray emissions into a compositional spectrum (figure 9.9) and potential quantitative data is achieved through a series of electronic components described in some detail by Postek et al. (1980) and Goldstein et al. (1981:222-24). Qualitative and quantitative analysis of the x-ray spectrum for the composition of a particular sample is complex, yet well understood (Goldstein et al. 1981:275-392). As in other recent studies, (e.g., Dunnell and Hunt 1990; Graves et al. 1990; Hunt 1989), quantitative analysis of To'aga ceramic clays used the ZAF correction method (see Goldstein et al. 1981:308). The final values calculated are quantities of elements (by weight and atomic percents) present on the cross-section surface of the sample at the point/area impinged by the electron beam. A goodness of fit between those elements quantified and standard intensities is evaluated by a chi-square test. This test provides an objective criterion to evaluate the goodness of fit for the peak-fitting algorithms used in each particular application (Goldstein et al. 1981:411-12). The analyst can judge the success or failure of x-ray collection for goodness of fit for a particular specimen on statistical criteria for each spectrum and quantitative analysis generated. All these features are available through the Tracor Northern software used.

Minimum elemental detection limits for energy-dispersive microanalysis are below 0.1% under ideal settings, and typically less than 1%, with a relative precision of 1-5% throughout the elemental range detected (Hunt 1989). Rice (1987:375) notes the general concentration range for x-ray analyses as

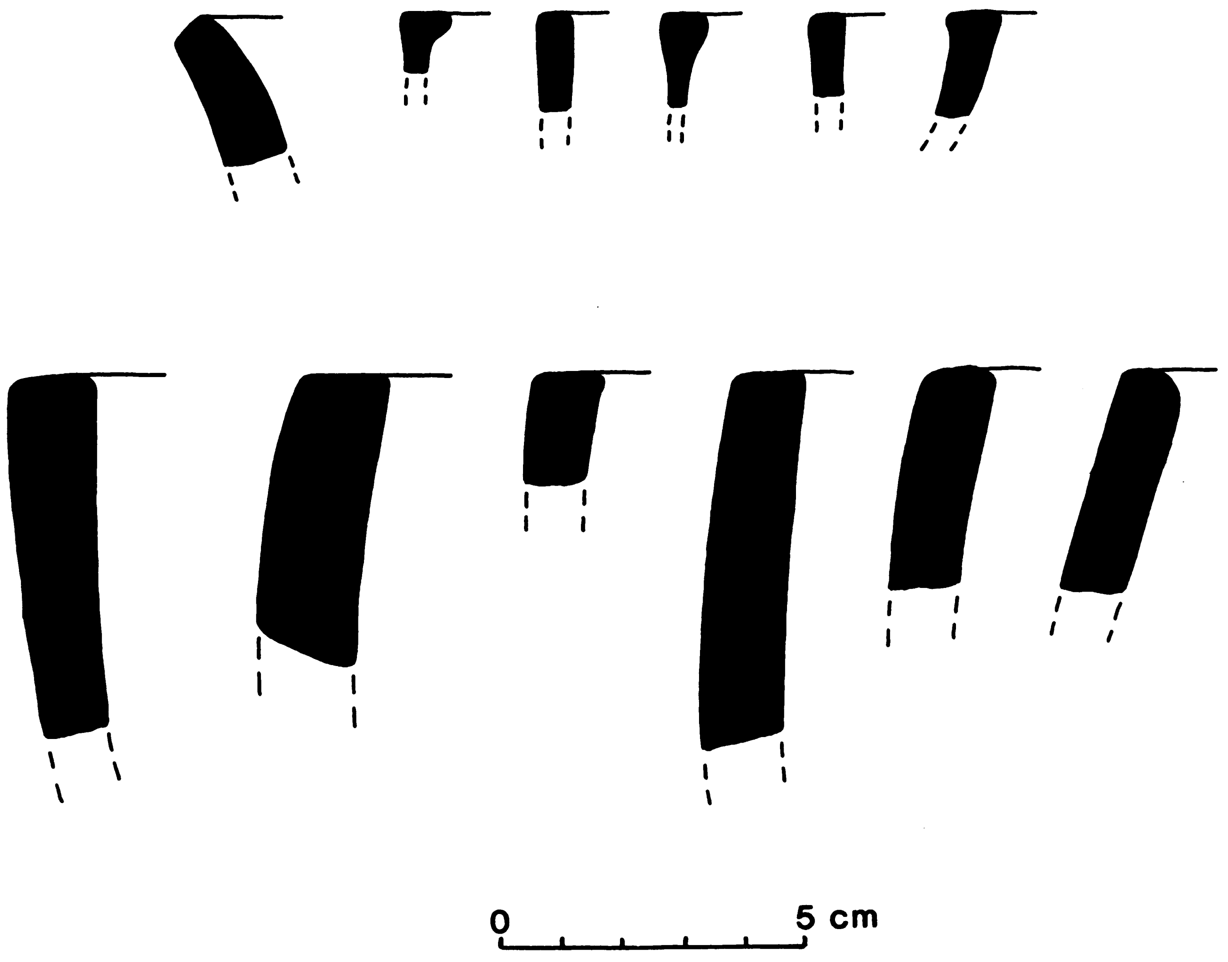

Figure 9.8 Cross sections of selected rim sherds from the To'aga assemblage.

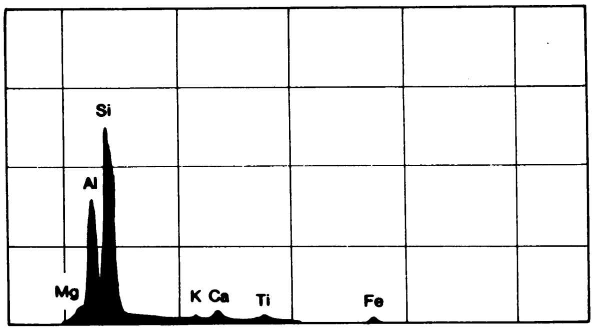

Figure 9.9 Elemental spectrum of clay composition for sherd 22 from To'aga (Univ. of Washington SEM, 27 Dec. 1989, 10KV, 1,2000X).

detection of major, minor, and trace elements (>100 ppm).

Specimens were viewed on the CRT of the SEM while undergoing x-ray analysis. An area that appeared to be only clay was selected at low magnification (30-100X) for analysis. This area was isolated by a step-wise increase in the magnification, allowing careful inspection of the region for inclusions or other anomalies. X-rays were collected from areas that appeared at higher magnification to be clay matrix only. All other specific sample preparation and analytic procedures follow those described in detail by Hunt (1989:155-59).

Twelve major and minor elements, Na, Mg, Al, Si, P, Cl, K, Ca, Ti, Cr, Mn, and Fe, were selected for analysis. These multivariate data for thirty-two specimens (sherds and To'aga clays) form the data matrix used to search for compositional structure in the To'aga ceramics.

Quantitative Analysis of Clay Elemental Data

The goal of analysis of elemental data is organizing or reducing compositional variability into archaeologically meaningful groups (Arnold et al. 1991; Harbottle 1976:42). Ideally, such groups represent discrete clay sources, and thus, the minimum number of production locales represented in the ceramic assemblage. While individual clay sources are not always distinguishable, the method has the potential to sort clays from different regions. Islands offer an especially good setting for sorting ceramic provenance because they vary in age and geologic origin. In addition, clays come from small drainages and do not mix as in continental deposits.

Sorting the clay elemental data matrix into meaningful groups generally requires deductive tests using multivariate statistics (e.g., Bishop and Neff 1989; Davis 1986). Such analyses are usually directed at inferring a probable number of distinguishable clays represented in an assemblage. Distinguishable clays might be used to infer production locales for prehistoric pottery. Some studies are successful at linking prehistoric pottery to specific (known) clay sources, either on quantitative criteria that range from ordinal tests to multivariate ones (e.g., Neff et al. 1988; Topping and MacKenzie 1988). Yet, as Arnold et al. (1991:85) have pointed out, individual clay deposits may not be easily distinguished, and in Oceania an island—or even a group of islands—as a unit of geographic space may form a single "source" in compositional space.

The To'aga compositional data matrix was analyzed for its grouping tendency with two different clustering algorithms: average linkage between groups and Ward's method (Norusis 1986). These algorithms are agglomerative and build groups or clusters from the individual specimens (sherds and clays).

Given the problems of evaluating cluster dendrograms, a rigorous solution is in the use of different algorithms. Then, only those clusters which arise independently in different analyses are considered valid, or accurately descriptive (Alenderfer and Blashfield 1984:65; Dunnell 1983:146; Sokal and Sneath 1963:166). This strategy will work in data sets in which clay groups (i.e., not necessarily individual "sources", see Arnold et al. 1991) are chemically distinctive and can be detected by statistical measures.

Discriminant function analysis was also used to examine compositional structure in the To'aga data. Discriminant function analysis offers a deductive tool for testing structure in a multivariate data set (Bishop and Neff 1989; Davis 1986; Hunt 1989). As Bishop and Neff (1989) imply, ceramic compositional data sets are complexly multivariate and require going beyond an inductive search for structure (see also Harbottle 1976).

Compositional Results

Results of these clustering procedures were plotted as dendrograms (figures 9.10-11). From these dendrograms, comparable clusters of sherds (and clay sample tiles) occurring in both solutions can be deduced. Comparison of the Ward and average linkage between group cluster dendrograms reveals four identical clusters. Table 9.15 provides summary data and results for the sample.

Cluster assignments from the two solutions (1-4, and two cases unassigned) were analyzed and plotted against first and second discriminant functions. The plot (figure 9.12) of discriminant function scores illustrates the distribution of the groups in multidimensional space.

Cluster 4 includes seven sherds of both thick- and thinware as well as the three clay samples collected from To'aga colluvium. This match suggests that local colluvial clay from To'aga was used in some pottery manufacture. The remaining three (1-3) clusters represent clay compositional groups as yet unmatched to samples from Ofu, or elsewhere. These unmatched clays are similar in composition to those of the local colluvial clay sample, and may come from other unknown sources/ source areas on Ofu, elsewhere in Manu'a, or beyond. A determination of local versus exotic provenance for the unmatched sherds would be premature; additional sampling of clays is necessary. Sherds from other islands in Samoa should also be tested for their compositional similarity to those of

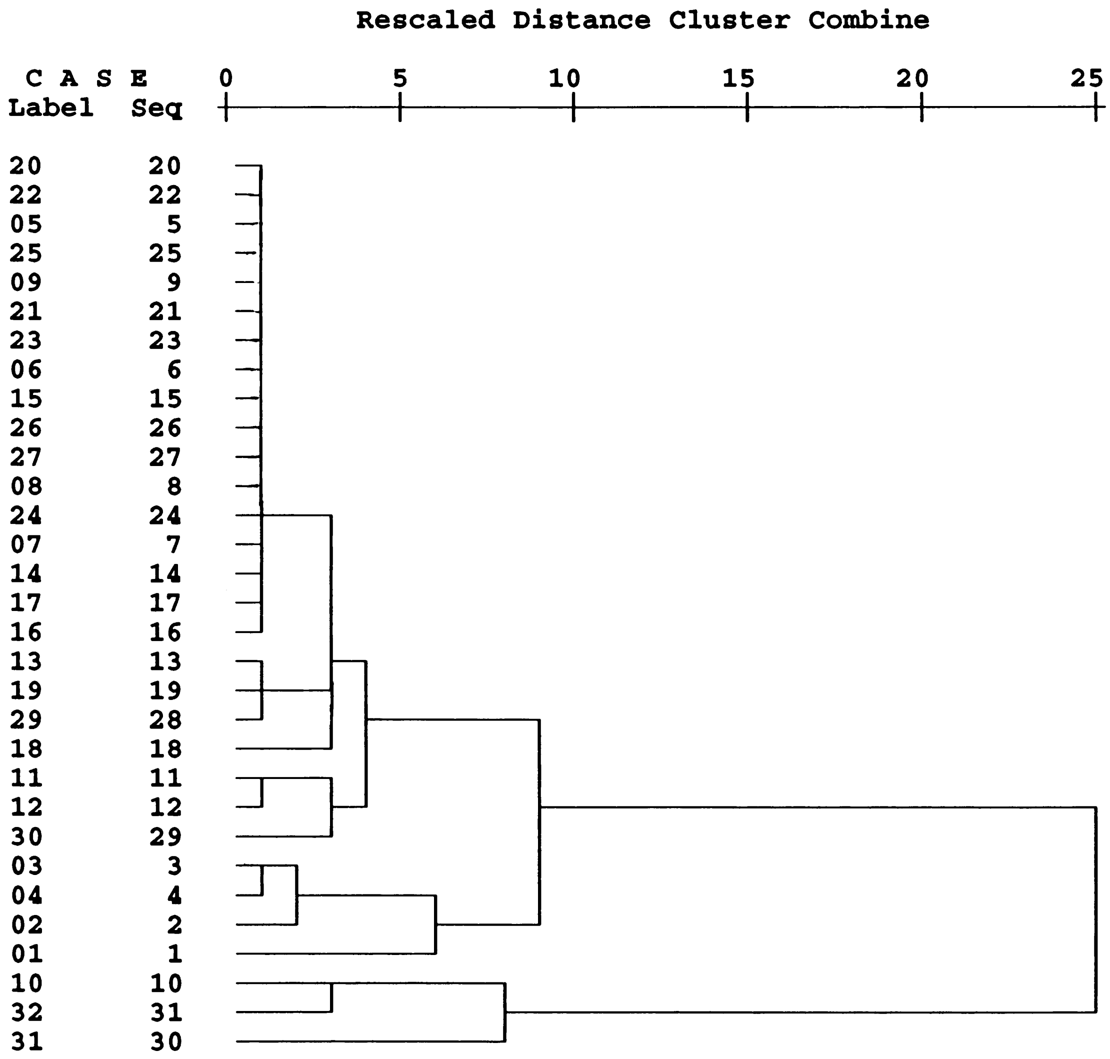

Figure 9.10 Dendrogram of Ofu pottery and clay samples using the Average Linkage (between groups) method.

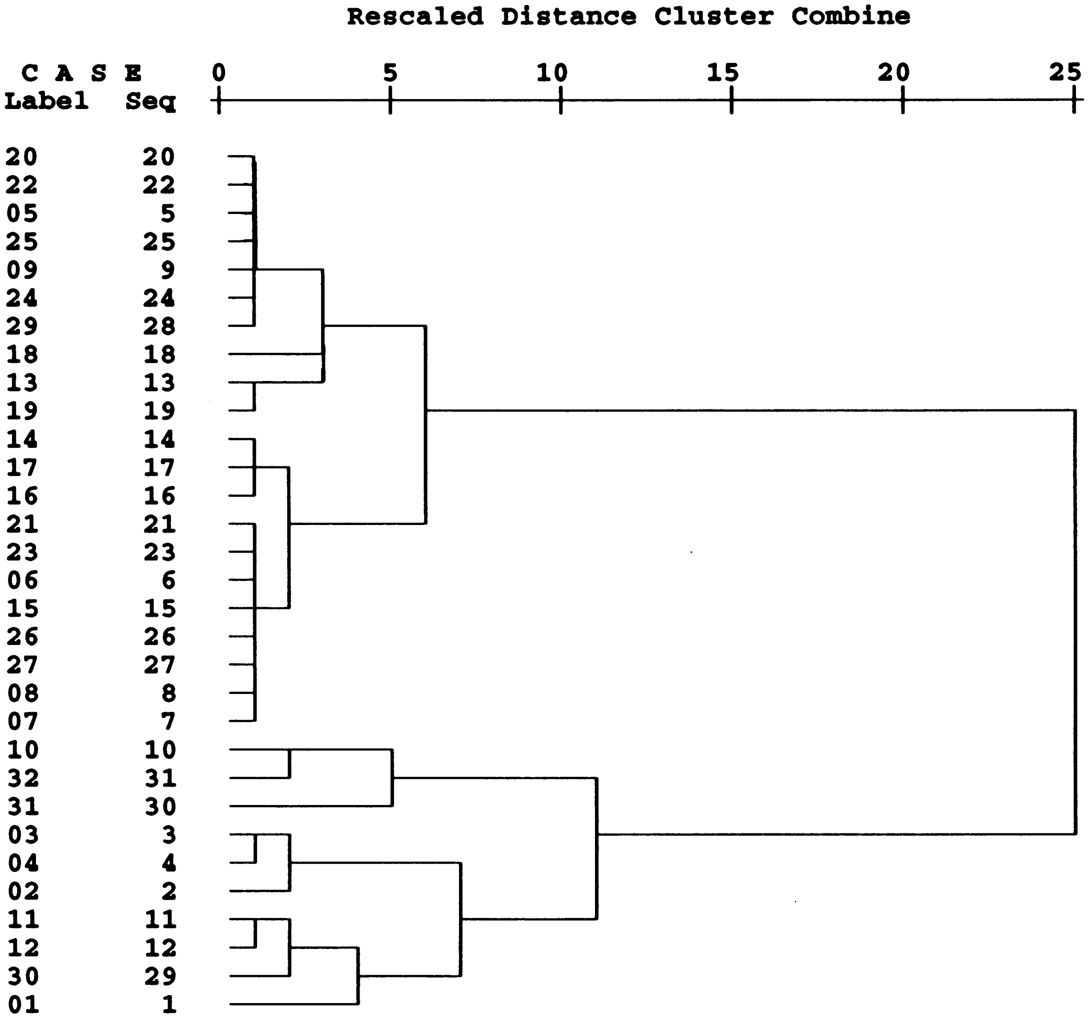

Figure 9.11 Dendrogram of Ofu pottery and clay samples using Ward's method.

the To'aga assemblage.

The association of clay compositional groups with thickware, thinware, red-slipped ware, the paddle-impressed sherd, and the three colluvial clay samples from To'aga (table 9.15) shows that thick- and thinware cannot be separated compositionally. All compositional groups are represented in thick- and thinware. Discriminant function analysis, using ware as the grouping variable, confirmed this observation. Scatterplots revealed little separation along the first and second discriminant functions (figure 9.13). The red-slipped pottery (n = 2) falls into groups 2 and 3, although a larger sample is needed to assess compositional variation in this class. The To'aga colluvial clays (in group 4) match sherds of thickware, thinware, and the carved paddle-impressed sherd.

Comparisons of ware with temper groups (table 9.15) identified by Dickinson (chapter 10) reveal that all four temper groups are represented in thickware. The profuse basaltic temper is found only in thickware, for this sample. Thinware contains sparse basaltic (temper group 2), feldspathic (temper group 3), and mixed (temper group 4) tempers (see chapter 10). The two red-slipped sherds in the sample have sparse basaltic temper. The paddle-impressed sherd and the analyzed "self-tempered" clay sample (from Transect 9 colluvium) have the mixed (temper group 4) temper, including calcareous sand. Calcareous sand in the colluvium suggests saltational transport of grains from the coast over the previously shorter distance to the colluvial deposits where mixing could

Table 9.15
Sherds and Ofu Clays Selected for SEM/EDS Clay Elemental and Sand Temper Petrographic Analyses

Specimen No.	Provenience	Class	Temper Group	Clay Cluster	Period
1	Unit 6 IIa	Thick	1	4	Late
2	Unit 6 IIa	Thick	1	4	Late
3	Unit 6 IIa	Thick	1	4	Late
4	Unit 6 IIa	Thick	1	4	Late
5	Unit 6 IIb	Thick	1	1	Middle
6	Unit 6 IIb	Thick	2	3	Middle
7	Unit 6 IIb	Thick	2	4?	Middle
8	Unit 6 IIb	Thick	4	4	Middle
9	Unit 6 IIb	Thick	3?	1	Middle
10	Unit 6 IIc	Thick	2	4	Early
11	Unit 6 IIc	Thick	4	4	Early
12	Unit 6 IIc	Thick	4	4	Early
13	Unit 20 IIb	Thick	2	2	Middle
14	Unit 20 IIb	Thick	1	2	Middle
15	Unit 20 IIb	Thick	3	3	Middle
16	Unit 20 IIIa	Thin	2	2	Early
17	Unit 20 IIIa	Thick	3	2	Early
18	Unit 20 IIIa	Thick	3	2	Early
19	Unit 20 IIIb	Thin[1]	2	2	Early
20	Unit 20 IIIb	Thin	2	1	Early
21	Unit 20 IIIb	Thin[2]	2	3	Early
22	Unit 20 IIIa	Thick	2	1	Early
23	Unit 20 IIIa	Thick	2	3	Early
24	Unit 20 IIIb	Thin[3]	4	4?	Early
25	Unit 20 IIIb	Thin	4	1	Early
26	Unit 20 IIIc	Thin	4	3	Early
27	Unit 20 IIIc	Thick	2	3	Early
28	Unit 20 IIIc	Thin	2	-	Early
29	Unit 24 II	Thick[4]	2	2	Early?
30	Transect 9	Clay	-	4	-----
31	Transect 5	Clay	4	4	-----
32	Transect 1	Clay	-	4	-----

1 Square rim with an impressed lip
2 Red-slipped
3 Carved paddle-impressed (parallel rib motif)
4 "Thickware" with red-slipped exterior

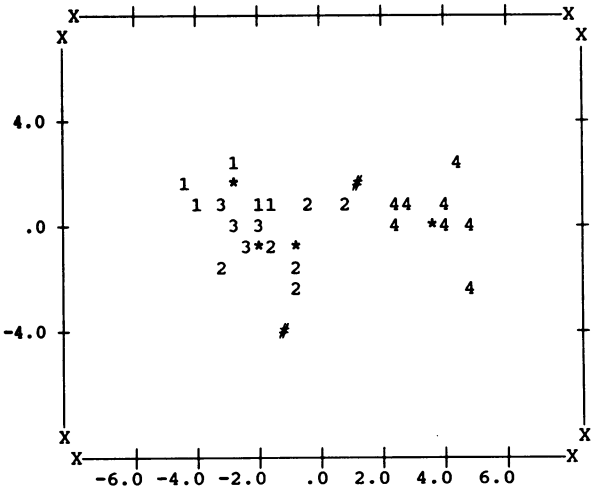

Figure 9.12 First and second discriminant function scores for analysis based on cluster (1-4) as grouping variable; * indicates group center; # indicates unclassified as to cluster.

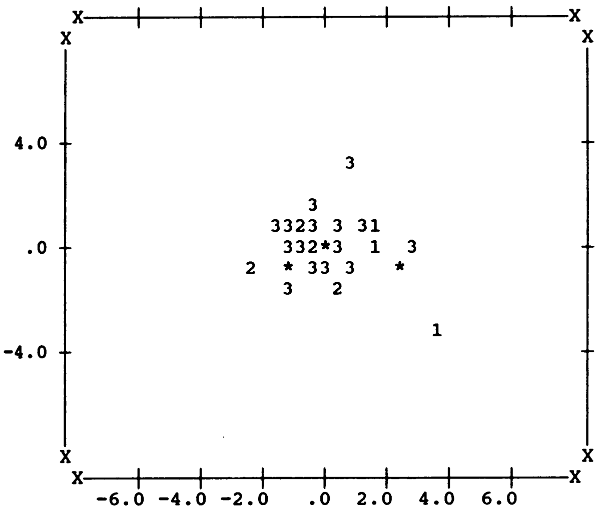

Figure 9.13 First and second discriminant function scores for analysis based on time period (early [1], middle [2], and late [3]) as grouping variable; * indicates group center.

occur naturally. Temper with calcareous sand could also represent purposeful mixing on the part of ancient potters.

The association of clay compositional groups with temper groups (table 9.15) defined by Dickinson reveals some marked correspondence. Profuse basaltic temper (Dickinson's group 1) is associated with cluster 4 (that includes the three "self-tempered" colluvial clays) more than expected by chance alone (expected = 1.7, observed = 4). Furthermore, temper groups 1, 2, and 4 occur with clay compositionally indistinct from the To'aga colluvium samples. All temper groups are associated with clay group 1. It is also noteworthy that the overall association is otherwise somewhat well dispersed. This observation suggests that in many of the specimens, temper and clay composition vary independently.

Compositional groups tabulated by their analytic time periods show a pattern of decline. Compositional variation reflected by temper groups reveals a similar pattern of decline. The early time period (1250-500 B.C.) ceramics fall into all four clay compositional groups, reflecting the greatest variety of clay (source) use. One of the clay sources in use during the early period is the local colluvial clay from To'aga, and it is in both thick- and thinware. The middle period (500 B.C.- A.D. 0) may show a decline to three clay groups, and does not include the colluvial clay from To'aga. The late (A.D. 0-300?) ceramics are only represented by the To'aga colluvial clay in thickware samples. A decline in compositional variability reflects the general simplification and homogenization of the total To'aga assemblage with time. This potential trend, however, could simply result from the smaller samples in the middle and late time periods. Additional samples must be analyzed to test a hypothesis of change in the compositional variability in the To'aga sequence.

CONCLUSIONS

Ceramics provide a critical source of information for building chronologies and inferring cultural relatedness because they vary in style. Recent advances in physico-chemical and archaeological analyses (Rice 1987) open the door to many new questions in ceramic studies. In this study, we focused on ceramics in terms of material composition and provenance, production technology, style, and function. The To'aga ceramic assemblage is particularly valuable for this kind of detailed study. The assemblage is large and comes from a stratified site where a long chronology of pottery production can be delineated. In the discussion that follows, we offer some partial answers to the questions posed at the beginning of this chapter.

Ceramic Provenance and Production Technology

The clay microanalytic and sand temper petrographic results provide a basis for several conclusions and new hypotheses concerning ceramic provenance and production technology. Thickware, thinware, and a carved paddle-impressed sherd from To'aga can be inferred to be of local production, using colluvial "self-tempered" clay source(s) from Leolo Ridge on Ofu. Such clay(s) could be gathered near the base of the cliff at To'aga, immediately adjacent to the prehistoric occupation. Processing of such clay appears to have been minimal. The colluvial source(s) accounts for the greatest amount of pottery in the EDS/petrographic sample.

One class of pottery, the red-slipped (thinware and one thick, red-slipped sherd), does not match the local clays as presently known. The red-slipped pottery in the EDS/petro-graphic sample also contains only sparse basaltic temper (group 2). These distinctions may suggest an exotic provenance for red-slipped ware that arrived on Ofu through inter-island exchange. This hypothesis requires a larger sample to test further.

In sum, the available compositional evidence suggests at least four hypotheses that may be confirmed or falsified with additional research:

1) The decline in compositional groups (both temper and clay groups) merely reflects sample size differences for the time periods (cf. Grayson 1984, 1989; Kintigh 1989). This is, in a sense, the null hypothesis suggesting that with larger samples, the association of time period and clay or temper group will become more even (random in the statistical sense).

2) Local colluvial clay(s) provided a source for most pottery production at To'aga. Such clay(s) underwent little, if any, processing by potters. In most cases the colluvial clays could be described as "self-tempered."

3) Red-slipped pottery does not conform to the clay compositional data known for To'aga (clays and pottery). This ware, and others of similar clay-temper composition may be exotic to Ofu, and represent inter-island exchange.

4) The To'aga ceramic sequence is marked by a decline in the diversity of clays used in production (which in this case is not a product of sample size effects). This decline reflects change in the use or availability of the clay sources. Such a trend might also denote a decline in exchange, including that from other islands (see Hunt 1989; Kirch 1988, 1990).

Reconstruction of production technology is supported by the macroscopic ceramic analysis outlined above. Vessel form (bowls) and the observation of some laminar fracturing in the sherds point to slab-building as the primary forming technique. The analysis of orientation angle was designed to provide evidence for primary forming (table 9.5). However, due to the absence of grains with a definitive long-axis, and perhaps the difficulty of determining "random," "indeterminate," or "preferred orientation," the vestige of possible slab-building is not reflected in attempts to analyze particle orientation.

Secondary forming is indicated by paddle impressions (visible on 17% of the sherds) and anvil marks (present on 23% of the sherds). Two sherds show the unmistakable impression of a finger used for the same purpose.

The majority of the surface treatment is puddling (77%), a finishing technique using water and wiping to bring the finest clay particles to the surface of the paste. Wiping was also evident, occurring commonly on the rim sherds (tables 9.9-10).

Approximately 25% of the sherds in the sample display a pattern of incomplete oxidation adjacent to the interior surface in contrast to 4% with incomplete oxidation at the exterior surface. Only 2% of the sherds show little or no oxidation present. About 67% of the sherds are completely oxidized. Based on this, and other evidence described (hardness and comparison of experimentally fired-clay tiles), we suggest that pottery was fired in open conditions of temperatures reaching approximately 500-600° C. The fact that interior surfaces were darker (less oxidized), suggests that bowls were placed up-side-down for firing. This technique is similar to some documented ethnographically in Melanesia, where pottery is still made in many locations (e.g., Irwin 1985; May and Tuckson 1982).

Explaining the abandonment of pottery production in Samoa remains unresolved. Our To'aga analyses show that diversity of material use may have declined over the period of ceramic production. It could be hypothesized that changes in raw materials, for example the use of "self-tempered" colluvial clays, resulted in a ceramic product of marginal quality. This hypothesis requires additional study (e.g. see Feathers 1990).

Style

The To'aga assemblage is simple in form and carries very little decoration. Vessel parts present (direct rims and body sherds only) indicate that only forms of unrestricted orifice (bowls) were produced. There is no evidence in the To'aga assemblage of globular pots, jars, plates, or other complex vessel forms. Decorative attributes are restricted to impressing and notching on the lip, red-slip, carved paddle impression, and incision. Such a short roster departs dramatically from assemblages of comparable age from Mulifanua, 'Upolu, and from assemblages in Tonga and Fiji.

Style can be defined for analytic purposes in archaeology as traits that are free to vary independent of function (Dunnell 1978). This definition emphasizes style as governed by stochastic processes, and distributional frequencies that behave accordingly. In this perspective, thickness might be treated as a "stylistic" trait. Sherd thickness has received much attention in previous attempts to understand diachronic change in Samoan ceramics (Clark and Herdrich 1988; Green 1974; Hunt and Kirch 1988; Jennings and Holmer 1980; Kirch et al. 1990). The changing (declining) frequencies of thinware, in particular, might be a reflection of homology ("style"), and its independence from functional constraints. The frequency distributions (see tables 9.1-2) of thinware (defined as <7.5 mm) and thickware (>7.5 mm) from To'aga allow the following conclusions:

1) Thickware is present in the earliest deposits, and its abundance over time is relatively stable.
2) Thinware is never dominant in the assemblage but occurs in roughly equal percentages to thickware in the earliest deposits.
3) The presence of thinware declines in real and relative values over time but persists perhaps as long as pottery production itself.
4) Pottery declines in abundance early in the Christian era and then its production disappears entirely.

The evidence from Western Samoa is similar in many, but not all, respects. In spite of early dates for To'aga (i.e., contemporaneous with the Mulifanua Lapita site), no dentate-stamped Lapita pottery is known for this site, or elsewhere in Manu'a. This absence may be paralleled in the cases from Tikopia (Kirch and Yen 1982) and Anuta (Kirch and Rosendahl 1973) where assemblages of pottery date to early times, yet do not share the degree of decoration known elsewhere in the southwestern Pacific. Perhaps this reflects isolation from a larger interisland network that shared ideas of designs, or pots themselves. Manu'a may have simply been far enough away to incur such isolation from other islands of Samoa, Tonga, and Fiji.

Green (1974) proposed a sequence of ceramic change for Samoa. His chronological analysis from 'Upolu was based on a short occupation sequence, with radiocarbon dates ranging from 1840 ± 100 B.P. (GaK-1441) in the lowest cultural layer (V) to 1800 ± 80 B.P. (GaK-1341) in the layer (IV) above (Green 1974:115). These dates overlap at one standard deviation. When calibrated and averaged together, these two dates yield a calibrated age range at one standard deviation of A.D. 117-254 (Stuiver and Reimer 1986). Based on his analysis of over 7400 sherds, Green (1974:130) concluded that, "thin and thick ware sherds occur in association in both layers" and that over time the trend is for thickware to predominate but not totally replace thinware (1974:248). Inspection of Holmer's (1980:116) data, and his comparison to other Western Samoan assemblages, reveals a similar trend for thin- and thickware frequencies.

Function

Vessel function in the To'aga assemblage is suggested by form and the presence of residues. The single vessel form (bowls) might have served functions of storage, cooking, and serving dishes. Carbonaceous residues suggest cooking, at least in a small number of the vessels. Microanalysis for concentrations of phosphorus (P) was performed on three sherds in an experimental effort (Dunnell and Hunt 1990). These and other test case results were varied, and revealed that functional inferences based on P concentrations in pottery are unreliable

(Dunnell and Hunt 1990).

The ceramics from To'aga are among the best studied in the Samoan Islands. Addressing difficult issues beyond questions of chronology and cultural affinities demand detailed studies as we have attempted here. With regard to the questions posed at the start of this chapter, our study contributes to answers that will necessarily come from several studies of comparable detail and scope conducted with assemblages from throughout Samoa and the larger region.

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10

SAND TEMPER IN PREHISTORIC POTSHERDS FROM THE TO'AGA SITE

W. R. DICKINSON

TWENTY-NINE REPRESENTATIVE sherds selected by T. L. Hunt from the collection of artifacts excavated at the To'aga site near the south coast of Ofu Island in the Manu'a Group of American Samoa were examined petrographically in thin section. As there is no current reason to suspect that any of the To'aga ceramic ware was made elsewhere, the purpose of the study was to provide baseline information about Manu'a temper sands. All the sherds examined contain volcanic sand as temper, although this basaltic detritus is mixed with calcareous grains derived from reef sources in some of the sherds. As would be predicted for Manu'a and other parts of Samoa, the volcanic sand is typical of the oceanic basalt tempers common to intra-oceanic Pacific archipelagoes (Dickinson and Shutler 1968, 1971, 1979). Several variants of temper sand are present in different sets of sherds, and available information is inadequate to pinpoint their respective sources. All could probably have been collected on Ofu or nearby Olosega Island, but derivation of some from Ta'u in Manu'a or even elsewhere in Samoa is not precluded by the petrographic data. Their petrologic compatibility with Samoan lavas, however, and their overall resemblance to the spectrum of basaltic tempers studied to date from Samoa, makes importation from outside Samoa quite unlikely. As none of the temper variants are identical to tempers known from Tutuila or 'Upolu, all are regarded provisionally as indigenous To'aga tempers, with the proviso that petrographic evidence alone cannot indicate how far afield ancient potters may have gone in their search for suitable clay and temper within Manu'a.

TO'AGA TEMPER VARIANTS

The following variants of basaltic temper sand are all present in varying numbers of To'aga sherds, and each is described in detail in subsequent passages:

(a) *Profuse Basaltic Temper:* Seven sherds (1-5, 7, 14) contain ferromagnesian basaltic sand so abundant that it forms 50-60 percent of the sherd bodies. The proportions of grain types in six (1-5, 7) of the sherds are statistically indistinguishable, but the seventh (14) contains a related volcanic sand of slightly different composition.

(b) *Sparse Basaltic Temper:* Twelve sherds (6, 10, 13, 16, 19-23, 27-29) contain sparse ferromagnesian basaltic sand of somewhat different composition and texture. The mineral and lithic grains form only 5-15 percent of the sherd bodies, but about a third (25-40 percent) of the temper grains used may have been fragments of broken pottery.

(c) *Feldspathic Basaltic Temper:* Three sherds (15, 17, 18) contain feldspathic basaltic sand, which forms a normal proportion (30-40 percent) of the sherd bodies and is both mineralogically and texturally distinct from the two ferromagnesian variants of To'aga temper. Another sherd (9) contains a similar but sparser temper sand (~15 percent of body) that appears to be a hybrid sand with a significant admixture of detritus from the kinds of bedrock sources that yielded the ferromagnesian basaltic sands.

(d) *Mixed Temper Sand:* Seven sherds (8, 11, 12, 24-26, 30) contain mixed temper sands composed of both basaltic and reef detritus in varying proportions. Ferromagnesian mineral grains and basaltic lithic fragments dominate the volcanic sand components of the mixed tempers, but their proportions are highly variable and plagioclase feldspar grains are also present in some sherds.

TEMPER GRAIN TYPES

The non-calcareous components of all the To'aga temper types are without exception composed of mineral grains and lithic fragments derived entirely from basaltic bedrock sources, either lavas or pyroclastic deposits, together in some cases with fragments of broken pottery. The mineral grains, originally phenocrysts or microphenocrysts in basalt, include clinopyroxene, olivine, opaque iron oxides (magnetite and/or ilmenite), and plagioclase feldspar. The lithic fragments, representing aphanitic groundmass of basaltic lava or tephra, display a spectrum of internal textures reflecting an inherent range of constituent grain sizes. Microphenocrysts in lithic fragments include all the mineral species that were also present in the temper sands as separate mineral grains.

Routine distinction between pyroxene and olivine in thin section was based upon key diagnostic features visible for each grain, and their identifications were checked by observations of optic axial angle and birefringence on suitably oriented grains. Pyroxene grains generally display faint green tints, and many show either cleavage or prismatic shapes. Untinted olivine grains are brighter in plane light, and many are altered along edges and fractures to bright reddish iddingsite. Most basalt lithic fragments have an intergranular internal texture, although the finest grained (here termed "tachylitic") are intersertal with plagioclase microlites set in black basaltic glass (tachylite). The coarsest grained (here termed "slabwork") display blocky to prismatic subhedral pyroxene crystals intergrown with aggregated and multiply twined plagioclase crystals of slablike aspect. Lithic fragments of intermediate grain size (here termed "lathwork") display disoriented mosaics of twinned plagioclase laths with equant and largely anhedral pyroxene grains within their interstices. As all gradations are seemingly present between "slabwork" and "lathwork" and "tachylitic" grains, the distinction made among them is useful in a qualitative sense only. Groundmass iron oxides in lithic fragments range from equant or granular to skeletal or elongate in form without apparent regard to other aspects of internal texture.

PROFUSE BASALTIC TEMPER

The ferromagnesian volcanic sands in sherds with profuse basaltic temper are moderately sorted assemblages of subangular to subrounded grains with a texture suggestive of alluvial origin. Unmistakable rounding of the edges of many grains indicates naturally occurring sand, rather than artificially crushed aggregate, and local ravine streams may have provided the sources of the temper. As would be expected for such a setting, lithic fragments are generally but not uniformly larger than mineral grains. Abundance of subangular silty basalt detritus within the clayey paste in which the temper sand is imbedded suggests that potters collected naturally tempered sandy clay. This circumstance may account for the superabundance of temper sand in proportions higher than typically encountered in Pacific Island sherds. Proportions of grain types in most sherds containing this alluvial temper are quite consistent (table 10.1): half pyroxene, a quarter lithic fragments, a fifth olivine, and a trace of opaque iron oxides. All microphenocrysts in lithic fragments are pyroxene and olivine. As the internal texture of lithic fragments is somewhat variable, being three-quarters "lathwork" in two sherds (1, 7) and two-thirds "slabwork" in four others (2, 5), collecting sites were evidently closely related but not identical. Nevertheless, the average temper composition (table 10.1) for the six sherds in which proportions of grain types are essentially the same is taken here to be the best estimate, petrologically speaking, of proportions of constituents for characteristic To'aga temper.

Table 10.1
Frequency Percentages of Ferromagnesian Mineral Grains[1] and Basaltic Volcanic Lithic Fragments (VRF) in Sherds Containing "Profuse Basaltic Temper"

Sherd	n	Py	Ol	Fe	VRF	Py(Py+Ol)
1	130	51	21	2	26	0.71
2	160	50	23	2	25	0.68
3	210	53	20	1	26	0.73
4	105	51	17	4	28	0.75
5	185	50	24	4	22	0.78
7	260	54	23	1	22	0.71
Ave		52	21	2	25	0.71
14		36	14	3	47	0.72

[1] Py, clinopyroxene; Ol, olivine; Fe, opaque iron oxides

Note: n=number of grains counted in each sherd and average (Ave) composition is calculated for sherds 1-5 plus 7 but not 14.

A seventh sherd (14) contains distinctly more lithic volcanic sand (table 10.1), although its pyroxene/olivine ratio is very close similar to that of the other sherds. Lithic fragments, mostly "lathwork," are also more irregular in shape and some are microvesicular. Curved re-entrants on some lithic fragments and the presence of a few grains of microvesicular brownish basaltic glass suggest a pyroclastic component lacking in the more characteristic six sherds whose tempers were probably derived entirely from bedrock lava sources.

SPARSE BASALTIC TEMPER

The ferromagnesian volcanic sands in sherds with sparse basaltic temper are well sorted aggregates of subrounded grains with a texture suggestive of beach origin. The lack of finer grained grit within the clayey paste suggests that potters added artificial temper to clay bodies. Dark angular blotches within the clayey paste are probably ghosts of broken pottery fragments also added as part of the tempering process. Although recognition of this grog constituent is equivocal in some sherds owing to indistinct outlines of the pottery fragments, its presence may account for the low overall proportion of volcanic sand, which amounts alone to much sparser temper than typically encountered in Pacific Island sherds. Frequency percentages of grain types are highly variable for different sherds (table 10.2), but so few grains are present in each sherd (average of only 20 per sherd in 10 of the sherds) that the statistical significance of individual counts is questionable. Consequently, all grains (250 total) were summed from all sherds counted to yield net frequency percentages, but net and average temper compositions are almost identical (table 10.2). The fact that both measures of bulk composition are similar to values for the single sherd (22) containing the most grains (60) gives confidence that either measure is a valid estimate of the overall temper composition. The sparse basaltic temper, probably beach sand, is less pyroxenic and more lithic than the average composition of the dominant alluvial variant of the profuse basaltic temper, but grain proportions closely resemble those in the more lithic variant of alluvial sand. In general, differences are not great enough to suggest wholly different provenance except for the contrast between stream and beach collecting sites. Proportions of lithic grain types are quite variable from sherd to sherd, but all three types are present in subequal amounts within the suite of twelve sherds as a whole. The net pyroxene/olivine ratio (0.63) is only slightly lower than in the alluvial sands (0.72), and may have been reduced marginally by preferential cleaving of pyroxene grains and winnowing of resulting cleavage fragments during prolonged reworking in a beach environment.

Table 10.2
Frequency Percentages of Ferromagnesian Mineral Grains and Basaltic Volcanic Lithic Fragments (VRF) in Sherds Containing "Sparse Basaltic Temper"

Sherd	n	Py	Ol	Fe	VRF
6	20	5	10	5	80
10	10	40	20	10	20
16	15	47	33	7	13
19	30	33	13	4	50
20	10	30	20	10	40
21	10	40	20	10	30
22	60	42	20	2	36
23	25	32	20	8	40
27	30	40	40	3	17
28	20	25	5	5	55
29	20	25	15	5	55
Net	250[1]	34	20	4	42
Ave		33	20	6	41

[1] Summation of n for 11 sherds listed.

Note: n=number of grains counted in each sherd (note that net and average compositions are essentially the same). Sherd 13 too weatherd to allow accurate count.

FELDSPATHIC BASALTIC TEMPER

The volcanic sand in sherds (15, 17, 18) containing feldspathic basaltic temper essentially lacks ferromagnesian mineral grains (table 10.3), and nearly all microphenocrysts in lithic fragments are plagioclase rather than pyroxene or olivine. One olivine grain is present, however, in one sherd (18), and one olivine microphenocryst is present in another (15). Lithic fragments are consistently larger than separate plagioclase mineral grains, although the two are present in about the same frequency (table 10.3), and the sand overall is only moderately sorted. Most lithic fragments are "tachylitic," many have smoothly curved re-entrants typical of tephra clasts, and some are microvesicular. The textural features of the sand jointly suggest that scoriaceous basaltic ash, possibly reworked locally, was added as artificial temper to the clay body by potters having some selective aim in using such a tempering material. The feldspathic basaltic temper shows no compositional overlap with the ferromagnesian basaltic tempers, but the geographic separation of their respective sources need not have been great. As if to underscore that point, one sherd (9) contains well-sorted and subrounded temper, probably a beach sand, that apparently represents a mixture of feldspathic and ferromagnesian volcanic sands. This anomalous sherd has an apparently sparse temper (~15% of body) but also includes a few fragments of broken pottery as part of its overall temper component.

MIXED TEMPER SAND

The volcanic sands in sherds containing an admixture of reef-derived calcareous grains (15-75 percent) are highly variable in mineralogical composition (table 10.4). Although all are dominantly ferromagnesian volcanic sands, nearly half contain feldspathic components as well. Coupled with the presence of the calcareous grains, the good sorting and rounding of the sands is diagnostic of coastal origin on beaches where mixing of detritus from multiple sources is to be expected. Proportions of temper sand vary from 10-25 percent (8, 11, 12, 24)

Table 10.3
Frequency Percentages of Plagioclase Feldspar (Pl) and Opaque Iron Oxide (Fe) Mineral Grains and Basaltic Volcanic Lithics Fragments (VRF) in Sherds Containing "Feldspathic Basaltic Temper"

Sherd	n	Pl	Fe	VRF	Py	Ol
15	60	43	8	49	-	-
17	35	50	6	44	-	-
18	125	56	4	40	-	-
Ave		50	6	44	-	-
9	60	18	7	59	13	3

Note: n=number of grains counted in each sherd and average (Ave) composition is calculated for sherds 15 plus 17-18 but not 9 (Py and Ol are clinopyroxene and olivine mineral grains in sherd 9).

Table 10.4
Frequency Percentages of Calcareous Grains (calc), Silicate-Oxide Mineral Grains, and Lithic Fragments for Sherds Containing "Mixed Temper Sand"

Sherd	Calc	n	Py	Ol	Fe	Pl	VRF
8	13	65	32	32	3	-	33
11	22	35	14	7	7	-	72
12	20	12	33	17	25	-	25
24	15	30	27	23	-	-	50
25	44	70	21	17	1	1	60
26	18	160	22	18	1	5	54
30	77	60	39	14	2	20	25

Note: n=number of non-calcareous grains counted in each sherd (percentages reported sum to 100 exclusive of calcareous grains)

to 40-60 percent (25, 26, 30), the "tachylitic" variety of lithic fragments form about half the lithic population, and the overall pyroxene/olivine ratio (~0.60) is similar to that in the other sherds thought to contain beach sand temper. Computation of an average or net composition for the sherds containing mixed sand temper would be meaningless, given their inherent compositional variability, but their volcanic sands fit broadly within the spectrum of temper types present in other sherds. Sherds containing only sparse mixed temper sand also contain fragments of broken pottery in uncertain amounts.

DISCUSSION: TEMPER COMPARISONS

Although each of the To'aga temper types has clear distinguishing characteristics, compositional links argue that they form a related temper suite that is presumably indigenous to Manu'a. The two ferromagnesian basaltic tempers have contrasting textures that reflect different sedimentological origins such as stream and beach sands, but the same grain types are present in both in slightly different proportions. The admixture of similar ferromagnesian constituents in one of the sherds containing feldspathic basaltic temper suggests that bedrock sources for the ferromagnesian and feldspathic volcanic sands exist not far apart. This inference is strengthened by the observation that mixed beach sands containing calcareous grains contain a varied spectrum of ferromagnesian and feldspathic constituents.

Prehistoric sherds examined previously from 'Upolu (Dickinson 1969, 1974, 1976) contain generally similar basaltic temper sands composed of the same basic grain types, but none of the 'Upolu tempers is identical in texture or composition to the To'aga tempers. Ferromagnesian basaltic tempers from 'Upolu commonly contain a higher proportion of lithic fragments, typically have a higher ratio of olivine to pyroxene, and generally contain a subordinate proportion of brownish basaltic glass particles not present in To'aga tempers. Moreover, 'Upolu sherds with abundant ferromagnesian tempers contain well-sorted coastal sands texturally unlike the stream sands evident in well tempered To'aga sherds. Feldspathic basaltic tempers from 'Upolu are broadly similar to their To'aga analogs, but internal textures of lithic fragments differ in being coarser grained in the 'Upolu sherds studied to date. Feldspathic trachytic tempers present in all available 'Upolu collections apparently have no counterparts at To'aga.

The generic resemblance of all Samoan temper types examined to date permits the strong inference that the tempers in To'aga sherds are indigenous to Samoa. On balance, there is no reason to suppose on petrographic evidence that any of the To'aga temper types were derived from sites elsewhere in Samoa. The fragments of broken pottery present in about half the To'aga sherds are not common constituents of Pacific Island wares, but do occur in sherds from the Ryukyu Islands, Palau, and the Nan Madol site on Ponape (Dickinson and Shutler 1979; Dickinson et al. 1990). Their presence at To'aga presumably reflects a common paucity of suitable local temper sand, rather than any close cultural relationship between the Caroline Islands region and Samoa.

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11

NON-CERAMIC PORTABLE ARTIFACTS FROM TO'AGA

PATRICK V. KIRCH

ASIDE FROM THE SUBSTANTIAL quantities of pottery described above in chapter 9, the To'aga site excavations yielded a small but typologically diverse assemblage of non-ceramic portable artifacts. Because the site's alkaline, calcareous depositional environment (particularly in the lower levels) favors the preservation of bone, shell, and sea urchin, a variety of artifacts made from these organic materials was recovered, in addition to objects of basalt and coral. This contrasts with most early Samoan archaeological sites, such as Vailele or Sasoa'a on 'Upolu (Green and Davidson 1969, 1974), in which the acidic soils did not preserve a wide range of materials. Prior to our work at To'aga, only the Potusa and Falemoa sites on Manono Islet (Janetski 1980) had yielded a significant array of artifacts of shell, bone, and sea-urchin spine in association with Samoan ceramics. Thus, our knowledge of early Samoan material culture was largely restricted to basalt adzes, non-retouched lithics, and ceramics (Green 1974). This was in contrast to the situation with sites of comparable age in Tonga, where excavations on Tongatapu (Poulsen 1987), Niuatoputapu (Kirch 1988), and Ha'apai (Dye 1987) had produced a diverse array of material culture dating to the Ancestral Polynesian period. Hence, the To'aga artifact assemblage, described in full below, significantly expands our knowledge of the Samoan variants of Ancestral Polynesian material culture in the first millennium B.C.

The non-ceramic artifacts from To'aga are described below according to broad functional classes in general use by Polynesian archaeologists. Comparisons are also made between the To'aga assemblage and other assemblages from Ancestral Polynesian period sites in Samoa and elsewhere in Western Polynesia.

STONE ADZES

Six adzes which were either whole or sufficiently intact to be classified were excavated, primarily from pottery-bearing contexts. These adzes are classified according to the system devised by Green and Davidson (1969) for adzes from Western Samoa. In addition, we recovered five small flakes with ground or polished surfaces, which appear to have been derived from adzes during use or bevel resharpening. Most of these diagnostic specimens were petro-chemically analyzed by M. Weisler in order to determine the range in quarry sources utilized. Weisler used the non-destructive XRF technique and presents the results of his study in chapter 12.

From Layer IIA-1 in Unit 9 we excavated a finely ground and polished, complete adz of Samoan Type V (Green and Davidson 1969:24-26). The adz is of a very fine-grained, light grey basalt or andesite, and most of the original flaking scars have been removed by extensive polishing (fig. 11.1, c).

The bevel is curved, and the poll shows distinct battering, indicating use as a hammer while hafted. The adz is 136.8 mm long, 54 mm wide, and 35.2 mm thick at the midpoint. It weighs 422 g. Type V adzes are commonly associated with plainware ceramics both in Samoa (Green 1974) and in other early Western Polynesian contexts (Kirch 1988:192, 203).

An incomplete section of another Type V adz, consisting of the bevel to the midsection, was found in Layer IIIB of Unit 20 (fig. 11.1, a). The adz is of a light-grey, fine-grained basalt. The bevel is curved and very highly polished, while other parts exhibit remnant flake scars. The plano-convex section is rather high. The incomplete length of the adz is 78.4 mm; the width, 38.2 mm; and the thickness at midsection. 29.1 mm.

Another partial adz of Type V, consisting of the butt to midsection, was found in Layer IIIB of Unit 23 (fig. 11.1, b). Made of greyish basalt, the adz has a low (flattened) plano-convex cross section. In plan view, it also distinctly narrows toward the butt. The front and sides are partially ground and polished, but some flake scars remain. The midsection break displays considerable battering, indicating that the specimen was used as a hammerstone after breaking. The incomplete length is 68.1 mm; its width at the butt, 29.0 mm; the width at midsection, 53.3 mm; and the thickness at midsection, 27.3 mm.

A small adz of fine-grained basalt was recovered from the disturbed landfill site at To'aga during the 1986 reconnaissance. The adz has a sub-triangular cross section, and thus would be classified as Type VI in the Green and Davidson (1969) system. However, it has been well ground on the front, removing the original flaked ridge (and thus rounding off the apex of the triangle). Hence, in some respects, the adz resembles a Type V.

A rather battered remnant section of an adz, possibly of Type V or another type with a subquadrangular section, was excavated from Layer IIIA of Unit 27. This specimen is of dark grey basalt and has polished front and back surfaces. The butt is largely intact, but the artifact has been heavily battered from use as a hammerstone. The thickness is 25.4 mm, and the incomplete length, 75.4 mm.

From Unit 3, in an aceramic depositional context, we recovered the midsection of a partially ground, fine-grained basalt or andesite adz with trapezoidal cross section, probably of Samoan type IV (Green and Davidson 1969:24). The midsection is 24.2 mm thick, with the width ranging from 30.6 to 50.5 mm. Petrochemical analysis by non-destructive XRF, described further in chapter 12, suggests that this adz was manufactured at the large Tatagamatau quarry site on Tutuila Island (Best et al. 1989, 1992; Leach and Witter 1987, 1990). This is noteworthy, since most of the Manu'a adzes assignable to the Tatagamatau quarry were surface finds, also of trapezoidal sectioned types typical of later Samoan prehistory. This adz from Unit 3 is associated with a ^{14}C date of 1389-1287 cal B.P., which indicates that adzes from the Tatagamatau quarry were being distributed as far as the Manu'a Group by at least the mid-first millennium A.D.

In Layer IIIA of Unit 27 we excavated a flaked, tabular piece of dark gray basalt, extensively flaked, but retaining some cortex on one surface. The flake which measures 63.9 by 58.6 mm, and is 16.4 mm thick, may be a large decortication or trimming flake from adz manufacture.

In addition to the large diagnostic specimens described above, we excavated five small flakes, each with one or more ground and polished facets. These are from Units 16, 17, 20, and 22 and all derive from adzes, either from use or resharpening. Four flakes were analyzed by XRF (see Weisler, chapter 12). Two of these can be ascribed to the Tatagamatau quarry site on Tutuila Island.

SHELL ADZ

A small adz of heavy shell, possibly *Cassis* sp., was found in association with plainware pottery at the landfill site during the 1986 reconnaissance. The adz is rectangular in shape with a slightly rounded bevel. Shell adzes are very rare in Samoa and may have been restricted to the earlier ceramic period. Buck (1930:353-54) records only two shell adzes in the Bishop Museum collection from Samoa.

HAMMERSTONES

Two hammerstones, both from Layer IIA-1 of Unit 9 in the main trench, were excavated. One is an ovoid cobble of porphyritic igneous stone (with abundant feldspars). It is 30 mm thick, has a diameter of 93-105 mm, flat sides, and distinct

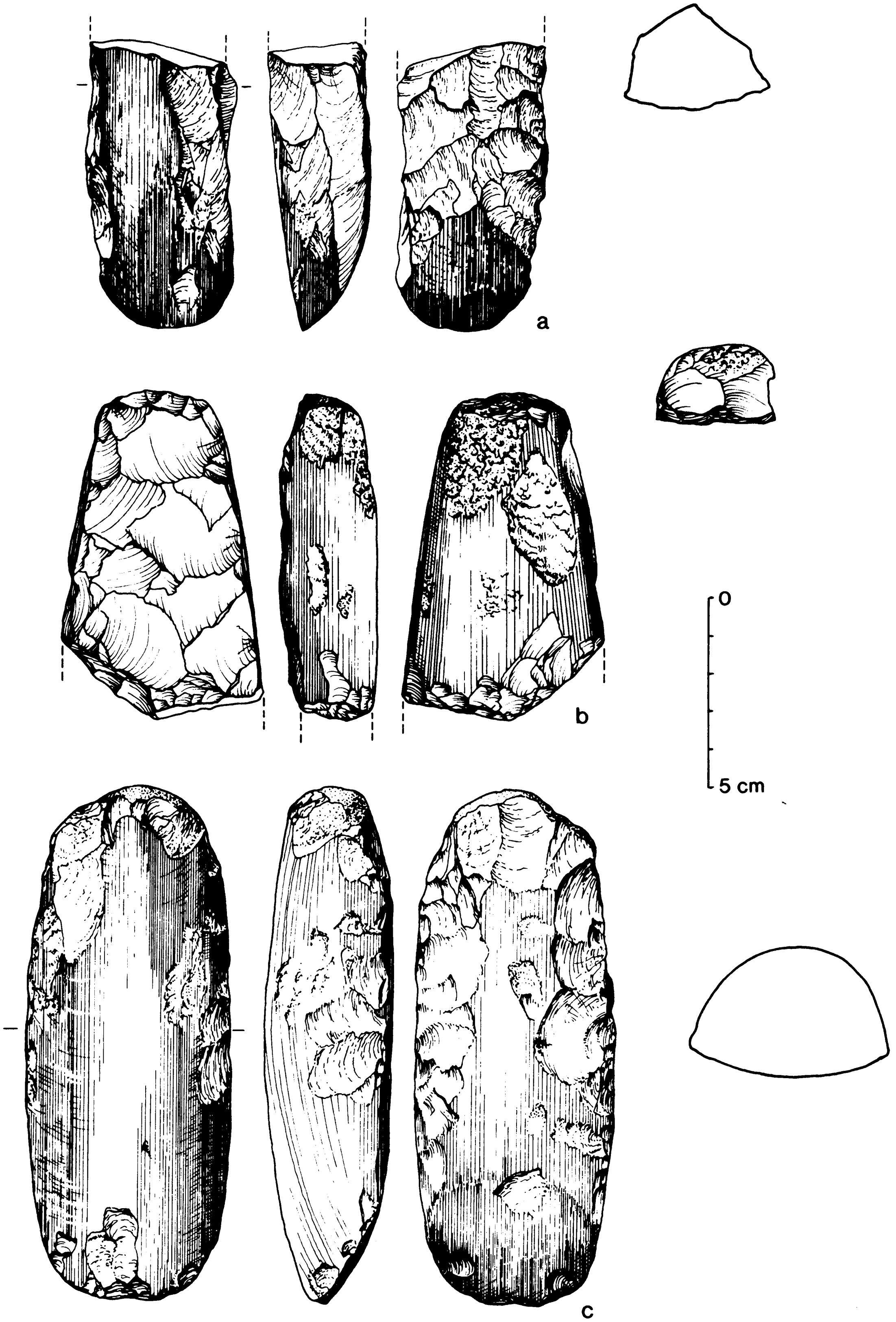

Figure 11.1 Basalt adzes from the To'aga site: a, bevel section from Unit 20, Layer IIIB; b, butt section from Unit 23, Layer IIIB; c, complete Type V adz from Unit 9, Layer IIA-1 (drawings by J. Ogden).

pecking or damage along the margins. One face appears to be ground smooth, perhaps during use as an abrading or polishing stone. The second specimen is an elongate basalt cobble, beach-worn, with pecking damage on the broader end. The cobble measures 147 mm long (max. width 70 mm), and the damaged surface has an area of 17.1 by 26.9 mm.

FISHING GEAR

Turbo-*Shell Fishhooks*

Samoan archaeological sites have been notoriously poor in the preservation of bone or shell artifacts, and only a few specimens of fishing gear have ever been excavated (Green and Davidson 1969, pl. 23; Janetski 1980). The same has been true of other Western Polynesian sites in Tonga and Futuna (Kirch and Dye 1979). In our 1986 test excavation at To'aga, two fragments of small *Turbo*-shell one-piece fishhooks were recovered (Hunt and Kirch 1988:175, fig. 8, b-c). In 1987 the expanded excavations yielded four nearly complete hooks and fourteen hook fragments. In 1989, we recovered an additional eight hooks or hook fragments, and a large number of prepared tabs and unfinished *Turbo* shell fragments. Thus, the total fishhook assemblage from To'aga now stands at twenty-eight whole or incomplete specimens, not including tabs and unfinished fragments. This is by far the largest assemblage of prehistoric fishing gear recovered from Samoa and is a major addition to our knowledge of early Polynesian fishing.

The To'aga fishhook assemblage is remarkably uniform in size and morphology, with only minor variations. The hooks were all manufactured from the body whorls of *Turbo setosus*, a gastropod common on the reef edge of Ofu Island. The various midden deposits contained large quantities of *T. setosus* shell, some of which was probably manufacture debris (see Nagaoka, chapter 13). One worked fragment from Layer IIB of the 1987 trench, probably an unfinished hook tab, was of the larger and less commonly occurring species *Turbo marmoratus*.

Examples of the hooks are illustrated in figures 11.2 and 11.3. They are small, and rather delicate, and were probably used to take smaller reef fish. The complete hooks have shank heights ranging from 13.1 to 30.4 mm. Hook widths range from 10.1 to >20.8 mm. Most hooks appear to have been

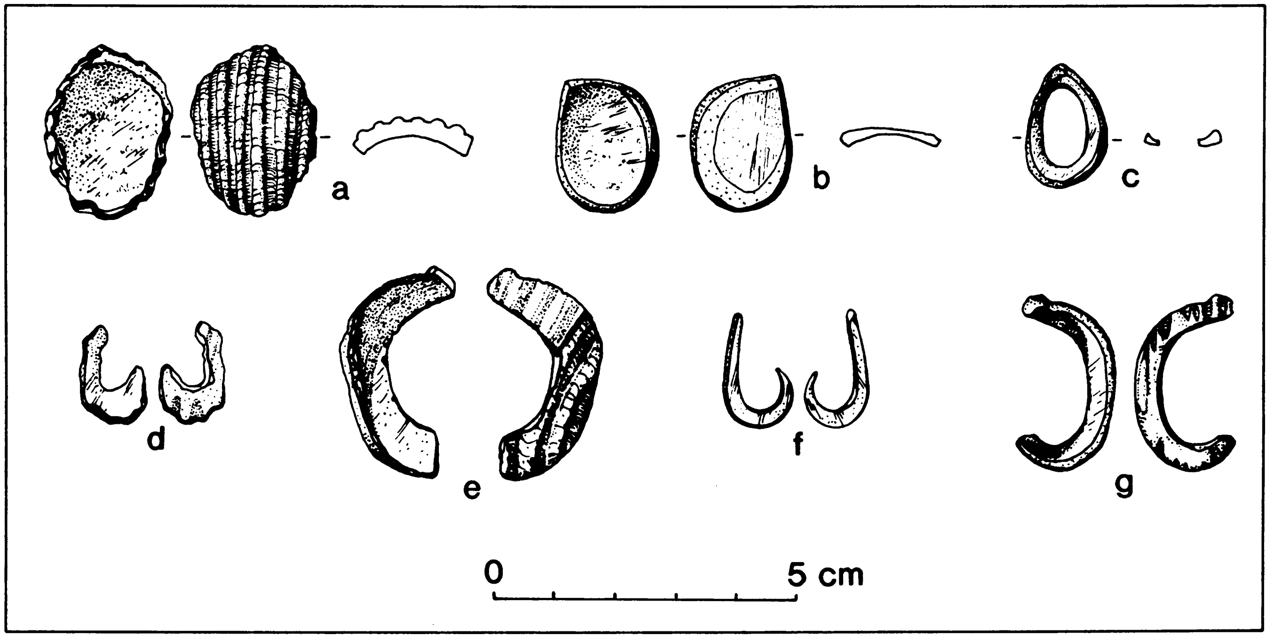

Figure 11.2 *Turbo*-shell fishhooks from the To'aga site: a, roughed-out fishhook tab from Unit 21, Layer IIB; b, well-ground fishhook tab from Unit 23, Layer IIIB; c, ground and perforated tab from Unit 30, Layer II; d, unfinished fishhook from Unit 15, Layer II; e, head and shank from Unit 27, Layer IIIA; f, complete hook from Unit 23, Layer IIIB; and g, hook with sharply inturned shank and head from Unit 20, Layer IIIB (drawings by J. Ogden).

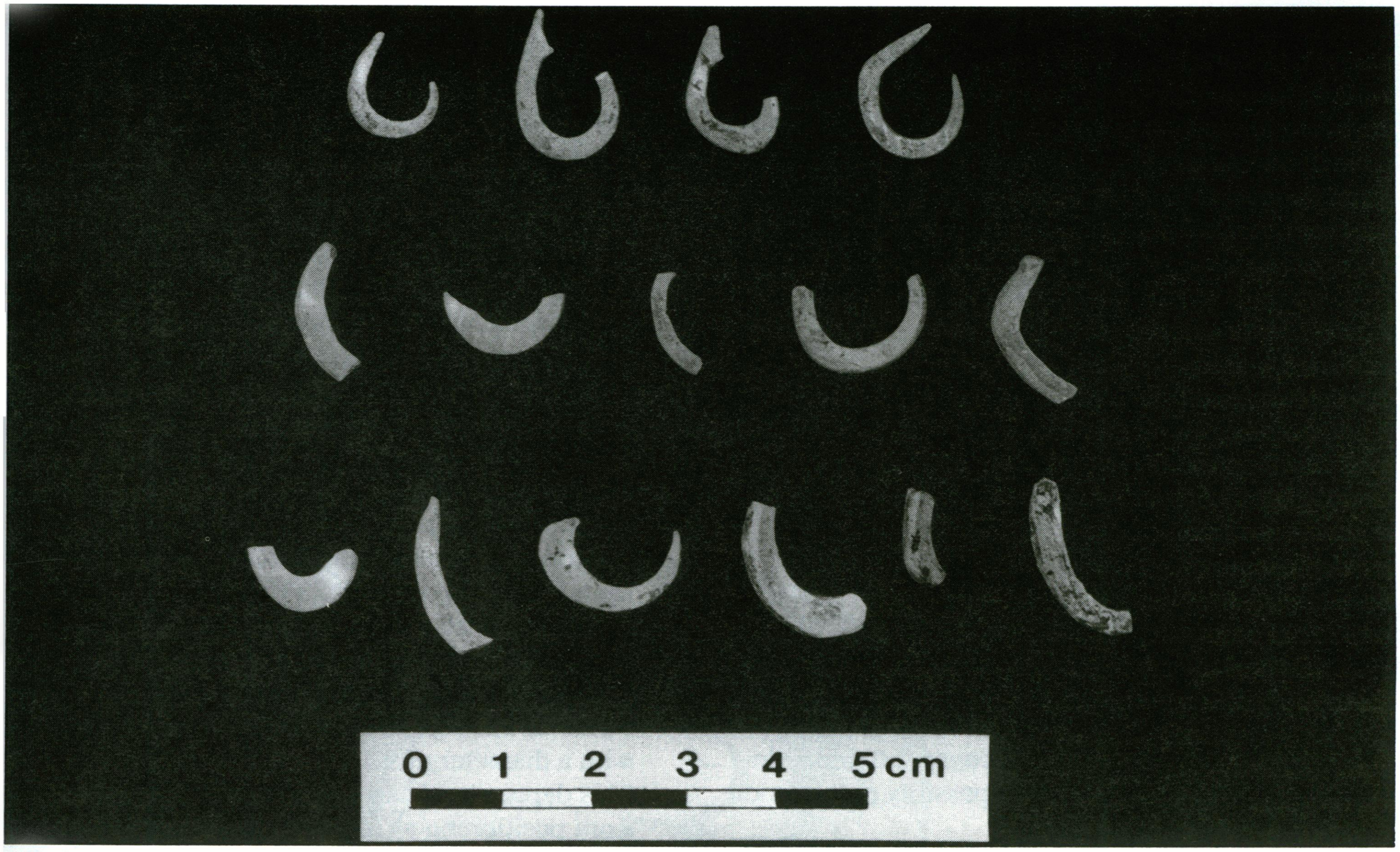

Figure 11.3 *Turbo*-shell fishhooks and fishhook fragments from the 1987 excavation at To'aga.

rotating in form, although one hook is technically of the jabbing variety. The bends have an 'O' or 'U' shape. Three hooks have a distinctive in-curved or "bent" shank, strongly reminiscent of some early Marquesan hooks (Suggs 1961:81, fig. 26). Two specimens have an inner shank knob, presumably to assist in line attachment. Several other shanks have small notches or grooves on the outer shank face, also for line attachment.

Turbo-*Shell Fishhook Tabs*

The manufacture of fishhooks from *Turbo setosus* shell is well attested in the To'aga site by the presence of numerous preforms or tabs roughed out of the body whorls of this gastropod as well as by worked shell fragments and many kinds of abrading tools (see below). Several examples of fishhook tabs are illustrated in figure 11.2. Of particular note is a specimen from Unit 23, Layer IIIB, which has been carefully shaped and fully ground on the exterior surface and around the margins (fig. 11.2, b). This tab measures 21.7 by 16.4 mm. Another specimen (fig. 11.2, c), from Layer II of Unit 30, represents yet a further stage in manufacture, with the entire center of the tab removed by drilling and filing. This specimen measures 19.8 by 13.4 mm. These tabs indicate that the reduction procedure for the manufacture of *Turbo*-shell hooks at To'aga was as follows: (1) a tab was first roughed out of the body whorl of *Turbo*; (2) this roughout was then ground flat on the exterior surface and carefully shaped by grinding around the margins; (3) the interior was then removed by drilling and filing; and (4) the gap between the shank and point was opened last by cutting and filing. Sinoto (1967:353, table 3) remarks that "simple drilling" and "chipping and filing" were the methods used by early Marquesans in hook manufacture. Thus, not only the forms of the To'aga hooks, but the specific manufacture methods, are consistent with the Marquesan hooks for which the To'aga specimens may have been prototypes.

During the 1987 excavations we did not make a special effort to distinguish *Turbo*-shell tabs from *Turbo*-shell midden or worked debris, and no exact counts are therefore available. For the 1989 materials, however, shaped tabs were carefully separated from the shell midden during the laboratory study of faunal materials by L. Nagaoka. The following counts by unit indicate the frequency of such prepared tabs:

Unit 15:	2 tabs
Unit 16:	1 tab
Unit 20:	7 tabs
Unit 21:	11 tabs
Unit 23:	9 tabs
Unit 30:	1 tab

Cypraea-*Shell Caps*

The caps or dorsa of large *Cypraea* shells (especially *C. tigris*) comprised one component of the Samoan octopus lure. Buck (1930:434-38, fig. 257, pl. XLI, B) describes and illustrates this apparatus. Three such dorsa were recovered together in Layer III of Unit 28 and were possibly part of such an octopus lure rig.

ABRADING TOOLS

Coral Abrader

From Layer III of Unit 11 we recovered a tabular shaped abrader of *Porites* sp. coral. The abraded facet has a surface area measuring 50 x 60 mm.

Echinoid-Spine Abraders

The long spines of the slate-pencil sea-urchin (*Heterocentrotus mammillatus*) have a natural abrasiveness and thus were used throughout most of Polynesia to manufacture fishhooks and other objects of shell and bone. Two such abraders were excavated from Layer IIA-1 in the main trench. Both have distally abraded facets at an angle to the longitudinal axis, as do the abraders reported by Janetski (1980, fig. 43, g-i) from the early Falemoa site in Western Samoa. A complete spine which has been slightly faceted at the distal tip was excavated in Layer II of Unit 15. From Layer IIIC in Unit 23 we recovered a sea urchin spine abrader which had been distally abraded to a point (circular section), presumably from use as a drill in the manufacture of *Turbo*-shell fishhooks (fig. 11.4, a). The tip only of a circularly abraded echinoid spine was also found in Layer IIB of Unit 20. A particularly interesting echinoid abrader was found in Layer IIB of Unit 28, and is illustrated in figure 11.4, j. This spine, 73.2 mm long, has been equally reduced on two sides from the distal end to form a thin, saw-like blade. It would appear that this blade edge was purposefully produced in order to cut shell or bone objects. Also from Unit 28 (Layer III) was a small fragment of sea urchin spine which was abraded laterally to form a flat surface. All of these abraders were likely used to manufacture the *Turbo* hooks and other artifacts of shell.

Shell-Bead Abrader

An abrader of *Porites* coral, specifically adapted for grinding small *Conus*-shell beads, was recovered from Layer IIIB of Unit 23 (fig. 11.4, h). The abrader consists of a naturally waterworn coral pebble (68.6 by 46.4 mm and 19 mm thick) which has been flattened on one face by grinding. In the center of this face is a single depression or "cupule" with a diameter of 9.1 mm, about 1-2 mm deep. This depression has a central "nipple" which results from positioning a *Conus*-shell spire in the depression, and then using the abrader to grind the shell against a larger grindstone. Such specialized *Conus*-shell bead abraders had been reported from Vanuatu (Garanger 1972) and from Vanikoro in the Santa Cruz Islands of eastern Melanesia (Kirch 1983:102-104, fig. 16), but were previously unknown from Western Polynesia. Recently, however, Sand (pers. comm.) excavated such an abrader from the Asipani Lapita site on Futuna Island.

ORNAMENTS

Conus-*Shell Beads*

From Layer IIB in the main trench are two delicate beads of *Conus* sp., very well ground, with diameters of 5.6 and 5.9 mm, and thicknesses of 1.9 and 2.1 mm (fig. 11.5). A slightly larger bead or ring of *Conus*, complete and very well ground (fig. 11.4, g), was found in Layer IIIC of Unit 20. This has an external diameter of 15.8 mm and is 2.4 mm thick.

Conus-*Shell Rings*

Layer IIB in the 1987 main trench produced two fragments of larger *Conus* sp. rings, very well ground, with original diameters of about 50 mm (fig.

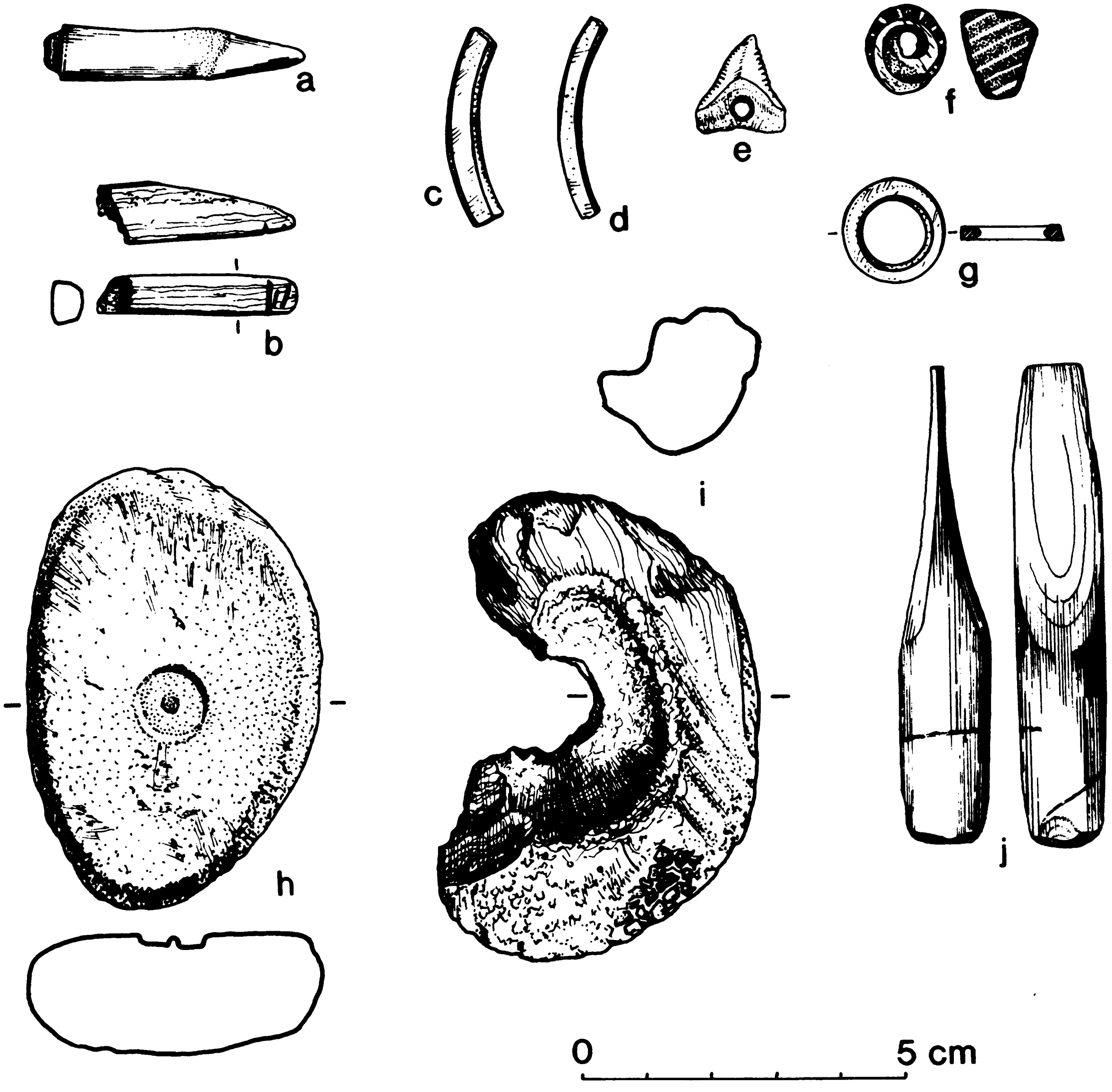

Figure 11.4 Miscellaneous artifacts from the To'aga site: a, echninoid spine abrader from Unit 23, Layer IIIC; b, bone point from Unit 27, Layer IIIB; c, *Conus*-shell ring fragment from Unit 29, Layer IIIB; d, *Conus*-shell ring fragment from Unit 29, layer IIIB; e, drilled shark's tooth from Unit 21, Layer III; f, *Conus*-shell bead from Unit 30, Layer II; g, *Conus*-shell bead from Unit 20, Layer IIIC; h, coral abrading stone for grinding shell beads, from Unit 23, Layer IIIB; i, unfinished*Tridacna*-shell ring from Unit 23, Layer IIIC; and j, echinoid-spine abrader from Unit 28, Layer IIB (drawings by J. Ogden).

11.5). One fragment had been sharpened to a point after breaking. Layer II in Unit 11 produced a fragment of a large shell ring or armband, made either of a large species of *Conus*, or possibly of *Tridacna*. The ring fragment is 7.3 by 11.6 mm in thickness, and has a reconstructed diameter of about 70 mm (fig. 11.5). A similar armband fragment from the Falemoa site is illustrated by Janetski (1980: fig. 45, b). From Layer III of Unit 16 we recovered a fragment of a *Conus*-shell ring with a cross section measuring 3.5 by 4.8 mm, and a reconstructed diameter of about 35 mm. Layer IIIB of Unit 29 produced another *Conus*-shell ring fragment (fig. 11.4, d) with a roughly rectangular cross section (5.3 by 4.8 mm), which would have had an original diameter of about 30 mm. Based on Buck's extensive compilation of Samoan material culture (1930), *Conus*-shell rings were not a part of the Samoan ornamental repertoire in historic times. Indeed, they were probably associated only with the early ceramic period.

Unfinished Tridacna-*Shell Ring*

Approximately one-half of a *Tridacna*-shell ring which broke during the process of manufacture was found in Layer IIIC of Unit 23 (fig. 11.4, i). The *Tridacna* valve incorporates part of the hinge. It was worked by chipping and pecking to create a central perforation. Presumably the artifact broke during this chipping process, prior to the initiation of grinding. The specimen has an outer diameter of 73 mm, and the central perforation is 15 mm in diameter.

Nerita-*Shell Beads*

From Layer IIB in the 1987 main trench were two *Nerita* sp. shells with artificial perforations in the basal whorl, perhaps for stringing as beads. A third specimen was found in Unit 21. Buck (1930:638) mentions the use of sea shells as beads but does not illustrate examples or provide further details.

Gastropod Bead

A small gastropod (species unknown) from Layer II of Unit 30 has had both the spire and basal whorl removed by grinding (fig. 11.4, f), leaving only the midsection of the shell as a bead. It has a diameter of 14.0 mm.

Echinoid-Spine Bead

In Layer IIIC of Unit 20 we found a unique bead made from a section of *Heterocentrotus mammillatus* spine which was double-drilled to form a central perforation. The bead measures 13.5 mm in diameter and is 10.5 mm thick.

MISCELLANEOUS ARTIFACTS

Drilled Shark's Tooth

A small shark's tooth (14.7 mm high) was found in Layer IIB of Unit 21 (fig. 11.4, e). This has been drilled (hole diameter 2.6 mm), presumably in order to lash the tooth to a handle.

Bone Point

From Layer IIIB of Unit 27 was recovered a facet bone "point" of unknown function (fig. 11.4, b). The bone, of either dog or pig, has been carefully faceted to a chisel-like tip, across which were abraded a series of fine grooves.

WORKED SHELL

A large piece of *Tridacna* shell (possibly from *T. gigas*) which has been chipped around the edges to a roughly rectangular shape (measuring 170 by 135 mm) was found in Layer IIIB of Unit 29. This may have been intended as a *Tridacna* adz preform or may have been for the manufacture of some other object, such as a shell ring.

From Layer III of Unit 28 we recovered two matching pieces of worked *Conus* shell. These consist of part of the main body whorl, with a cut and beveled edge near the spire. These are presumably rejected material resulting from the removal of a large *Conus* spire, as a part of the manufacture process for *Conus*-shell rings.

The chipped basal whorl section of a species of *Trochus* or *Textus* shell was found in Unit 21. This may have been intended to be a ring or armband.

Various small pieces of worked shell were recovered throughout the excavations. Most of these are of *Turbo* spp. and relate to fishhook manufacture. In the 1987 excavated material these were not distinguished from the *Turbo*-shell midden. In 1989, however, all worked *Turbo* shell was carefully segregated during faunal analysis by L. Nagaoka, yielding the following frequencies by excavation unit:

Unit 15	2 specimen(s)
Unit 16	5
Unit 17	1
Unit 20	14
Unit 21	3
Unit 22	1
Unit 23	9
Unit 25	2
Unit 26	1
Unit 28	5
Unit 30	1

Five specimens of worked pearl shell (*Pinctada* sp.), were also recovered from Units 11, 22, 23, 29, and 30. A triangular-shaped specimen from Layer

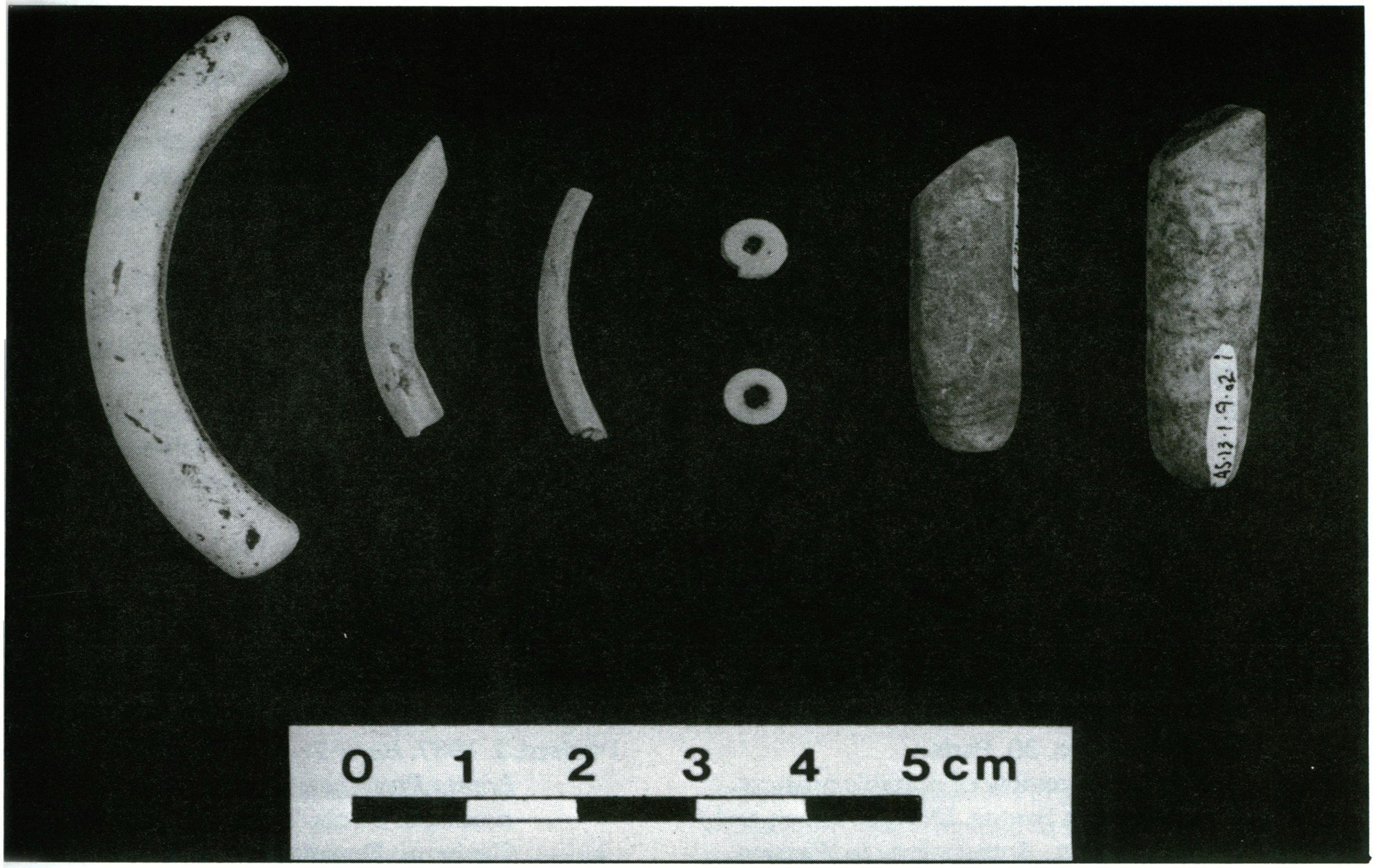

Figure 11.5 Miscellaneous artifacts from the To'aga site: left to right, *Conus*-shell ring fragments, *Conus*-shell beads, and echinoid-spine abraders.

IIIB of Unit 23 is of special interest because it shows distinct filing or cutting marks on all three margins. This piece, measuring 24.9 by 16.9 mm, is probably detritus from the manufacture of some other object, rather than a preform.

UNRETOUCHED LITHICS

Basalt Flakes

Flakes of basalt were surprisingly uncommon in the To'aga excavations. During the 1989 excavations, when particular attention was paid toward the recovery of such lithics during screening, only eighteen flakes were noted. Eleven of these are from Unit 23 [Layer III], suggesting that this may have been a locus of basalt flaking activity. The other flakes are from Unit 28 (three flakes) and Unit 29 (four flakes). Most of these are rather small and could derive from adz use, although they do not show polished surfaces.

Obsidian Flakes

A number of very small flakes of an opaque, black, low-silica volcanic glass or obsidian were found from various excavation contexts. Most of these are less than 5 mm in size. As the dike complex of Leolo Ridge overlooking the To'aga site has many glassy chills along the dike margins (see chapter 2), it is most probable that these "flakes" are natural and simply derive from the talus rockfall above the site.

One small core from Layer IIIC of Unit 23 is completely different, however, from the other obsidian specimens. This is of a reddish-brown color, with black spots and banding. The "core" measures 12.2 by 13.3 mm. Its geological provenance is unknown, but it is very likely an import to Ofu.

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12

CHEMICAL CHARACTERIZATION AND PROVENANCE OF MANU'A ADZ MATERIAL USING A NON-DESTRUCTIVE X-RAY FLUORESCENCE TECHNIQUE

MARSHALL WEISLER

INTRODUCTION

THE COLONIZATION STRATEGIES employed during the settlement of Polynesia and the subsequent diversification of island societies are key issues in Oceanic prehistory. Yet it is only recently that researchers have begun to amass empirical evidence of inter-island communication—throughout island sequences—that undoubtedly influenced the direction and tempo of post-settlement island histories. I refer here to recent finds of Tongan pottery in the Cook Islands (Walter and Dickinson 1989:465), of Samoan adz material in Fiji (Best 1984; Best et al. 1992) and the Cook Islands (Weisler 1993), and of inter-island transport of volcanic glass and fine-grained basalt in Hawaii during late prehistory (Weisler 1990; et al. In prep. [For a review of Polynesian basalt adz provenance studies, see Weisler In press a.]) . Isolation has been invoked as "the most fundamental" mechanism of divergence in Polynesia (Kirch and Green 1987:440), but "how . . . different extremes of isolation have influenced the evolution of human diversity from island to island—and perhaps even on the same island" (Terrell 1986:122-23) remains a problem that must be addressed for each island sequence. Dissimilarities may also originate because of continuing contact (see Terrell 1986:147). Isolation may have contributed to regional variations in portable artifacts, architecture, and language in New Zealand (Prickett 1982), Society Islands (Emory 1933), and Hawaii (Kirch 1985, 1990). In contrast, inter-island communication is inferred by parallel histories in subsistence and technological transformations in the northern and southern Marquesas (Rolett 1990:363) and similar changes in ceramic styles and adz evolution in the Samoa-Tonga-Fiji area at similar times imply continuous inter-island contact (Davidson 1977, 1978, 1979).

Tracking the spread and subsequent communication of prehistoric Polynesian societies has been difficult without the widespread occurrence of pottery and obsidian, artifact classes that have proven especially useful for demonstrating interaction in the southwest Pacific. Without inferring contact from similar styles of fishhooks, adzes, and architecture, Polynesian archaeologists are left with few items to track empirically the intra- and inter-island movement of things. Connecting stylistic nodes, however, may only reflect convergent evolution (Kirch and Green 1987). I may risk being accused of taking a hard-line empiricist view of culture contact and change, but I think it crucial to confront the problem with separating stylistic from functional dimensions (Dunnell 1971:26-30) in relation to documenting the movement of exotic raw materials and finished objects (e.g., pearlshell and industrial stone) between and within island groups. The spatial and temporal dimensions of contact spheres (Irwin 1990:92; Walter 1990; Weisler In press b), can be delimited more accurately using exotic materials than by connecting artifact styles. Consequently, the distribution of exotic materials provides a better framework for evaluating the role of isolation and communication in shaping historical developments of island societies.

This preliminary effort to document inter-island communication during the prehistory of the Manu'a Islands should take into account the region's geography. These islands are situated 100 km east of the most important source of adz material in central Polynesia, the Tatagamatau adz quarry, Tutuila (Leach and Witter 1987, 1990). The distance and often turbulent ocean conditions between Tutuila and the Manu'a Group may have reduced the frequency of contacts (Hunt and Kirch 1988:155).

THE COLLECTIONS

Two questions are addressed by XRF analysis of the Ta'u and Ofu island assemblages and source material: (1) Did any artifacts originate at the Tatagamatau adz quarry complex on Tutuila Island located 100 km to the west?; and (2) What was the geochemical variation of adz material and unmodified basalt flakes from Manu'a sites? Although it seemed unlikely that I would be able to assign a provenance to all artifacts, I could determine if specific geochemical groups were correlated with certain tool classes. Interaction spheres could be delineated by identifying similar rock at different sites and, perhaps, different temporal periods. An additional goal of the XRF analysis was to generate geochemical data for the important Tatagamatau quarry complex on Tutuila and two local To'aga sources that may have been used.

The Archaeological Sample

The archaeological contexts of the Ta'u and Ofu island assemblages are described elsewhere (Hunt and Kirch 1988; Kirch et al. 1990; chapters 5 and 11, this volume) and are not reiterated here. The artifacts selected for compositional analysis consisted of all whole or fragmentary adzes, all flakes exhibiting polished surfaces and assumed to be adz fragments, and a sample of unmodified basalt flakes which represented the macroscopic variability present. Table 12.1 presents characteristics of the analyzed artifacts. Specimens ranged from 1.2 to 421.9 gms and 22.08 to 136.30 mm in length. The thinnest sample was 3.53 mm.

Source Material

During their 1987 field season, Kirch and Hunt collected nine samples of source rock from the Tatagamatau quarry complex on Tutuila (Best et al. 1989; Leach and Witter 1987). On Ofu Island, they collected four samples from dike swarms at Mako Ridge and three samples from Fa'ala'aga. The Tatagamatau quarry complex consists of numerous cut-and-fill terraces, stone-working areas, pits, and possible fortifications along several ridges and scree slopes which together may cover more than 110 acres (Best et al. 1989; Leach and Witter 1987, 1990). The raw material derives from a dike complex at the foot of a waterfall at the head of a small gulch (P. Kirch, personal communication 1990; Leach and Witter 1987:39). Fine-grained dike rock may have been removed from dikes but most likely was prised from the soil and rock scree of slopes and from streambeds. Although I have not visited Tatagamatau, the geological setting appears to be similar to the Waiahole quarry on windward O'ahu (Dye et al. 1985), albeit on a much smaller scale. Two collections of source rock were made by Kirch and Hunt during a visit on July 3, 1989. Eight samples, consisting of large primary or secondary flakes with obvious bulbs of percussion, were collected at three locations along the main spur of the complex which trends NE-SW, and an additional flake was retrieved from Area 3 (figure 12.1). The exterior color of the source rocks varied from dark brown (10YR 3/3), dark gray (10YR 4/1), to dark grayish-brown (2.5Y 4/2) due to weathering and contact with lateritic soil. Fresh saw-cut surfaces are mostly dark bluish-gray (Gley card, 5B 4/1) grading to dark gray (7.5R 4/0 and 2.5Y 4/0). Even prior to geochemical analysis, it was not likely that nine samples would document the total variability of quarry rock from so large a quarry, but this collection did contribute significantly towards developing a strategy for collecting additional material.

Table 12.1
Basalt Artifacts Analyzed by EDXRF

Lab Number	Artifact Number	Weight (g)	Description
89-22*	Fiti'uta 1	24.8	Quadrangular, reworked adz
89-25	11-1-S-4	70.9	Quadrangular adz
89-26*	11-2-S-1	41.4	Quadrangular adz, front section
89-31	11-2-S-2	35.3	Quadrangular adz, butt section
89-30*	11-2-S-3	21.4	Quadrangular adz, front section
89-28	11-2-S-8	33.1	Quadrangular adz, front section
90-30*	11-2-9	60.9	Quadrangular adz, butt section
90-33	11-52-S-9	133.1	Quadrangular adz, front section
89-18	13-S-3	48.4	Quadrangular adz, front section
89-34*	13-S-5	44.7	Quadranglular (?) adz, front (?) section
89-33*	13-S-6	33.8	Quadrangular adz, front section
89-32	13-S-9	44.4	Quadrangular adz
89-19	13-1-S-36	63.9	Plano-convex adz
89-17*	13-2-3-1-1	63.4	Quadrangular adz, midsection
90-22	13-1-9-2-4	421.9	Plano-convex adz
90-23	13-1-13-87	0.7	Adz flake
90-42	13-1-16-1	5.5	Adz fragment
90-46	13-1-16-11	1.5	Unmodified flake
90-45	13-1-16-11-81	127.9	Retouched flake
90-38	13-1-16-12-83	20.5	Retouched flake
90-27*	13-1-20-4-118	3.4	Adz flake
90-37	13-1-20-5-121	1.2	Unmodified flake
90-41	13-1-20-5-122	4.4	Unmodified flake
90-34	13-1-20-5-123	11.3	Unmodified flake
90-48	13-1-20-6-139	11.4	Unmodified flake
90-29	13-1-20-6-140	128.4	Plano-convex adz, front section
90-36	13-1-20-6-141	56.7	Retouched flake
90-40	13-1-20-7-143	3.2	Unmodified flake
90-43	13-1-20-9-147	20.6	Unmodified flake
90-49	13-1-21-7-151	59.3	Used flake
90-44	13-1-22-2-171	3.7	Unmodified flake
90-25	13-1-22-2-173	2.1	Adz flake
90-24*	13-1-22-2-174	0.4	Adz flake
90-26	13-1-23-7-194	211.4	Plano-convex (?) adz
90-31	13-1-27-5-39	89.4	Quadrangular (?) adz
90-39	13-1-27-5-40	128.1	Quadrangular (?) adz, butt (?) section
90-47	13-1-27-5-41	2.1	Unmodified flake
90-35	13-1-27-6-42	9.5	Unmodified flake

* = Probable source is Tatagamatau.

Situated at about 350 m elevation and exposed by a recent road-cut, the Mako Ridge dike swarm on Ofu consists of relatively dense basalt. Weathering has smoothed the normally angular, loose dike rock into sub-rounded cobbles which lie buried within a thick soil matrix. It is doubtful that this material was used for making stone tools, but four samples were collected for chemical analysis. The weathered exterior surface was gray in color (7.5YR 5/0) and fresh breaks, dark gray (2.5Y 4/0).

A large concentration of dikes is found along a steep ridge towards the east end of Ofu. The Fa'ala'aga dike swarm (Stice and McCoy 1968) may have been a more important source of local, medium-grained basalt during prehistory. Angular rock from the eroding dikes form a large scree slope which descends to the To'aga coastal zone where stone is readily available (see Kirch, chapter 2). Three fresh samples were removed from dikes exposed by a modern road-cut (see fig. 12.2) to provide the general chemical composition of the dike swarm although many dozens of dikes may exist each with varying chemical compositions. Surface color of these rock samples is very dark gray (2.5Y 3/0) with fresh breaks being gray (2.5Y 5/0).

METHODS

Because this specific technique of non-destructive, energy-dispersive XRF had not been used previously with adz material from Oceania, each individual source sample was divided and analyzed by two techniques: destructive XRF using pelletized samples and non-destructive XRF using whole specimens. Destructive XRF analyzes a wider range of elements, and results are fully quantitative for most elements and comparable to other data sets now being developed for adz source rock in Polynesia. The non-destructive technique focused on those elements that are more reliably detected with this procedure, and results presented are considered here as semi-quantitative.

Destructive XRF

Source samples from Tatagamatau, Mako Ridge, and Fa'ala'aga were analyzed by Dr. Peter R. Hooper at the Department of Geology, Washington State University, on 16 and 17 October 1989. The equipment and operating procedure are paraphrased from Hooper and Johnson (1987; this manuscript is available from Dr. Hooper or myself). Twenty-seven elements were analyzed on an automatic Rigaku 3370 spectrometer. For the oxides, SiO_2, Al_2O_3, TiO_2, FeO*, MnO, CaO, MgO, K_2O, Na_2O, and P_2O_5, the weight percents are presented. For the other seventeen elements, the weight percent or ppm (parts-per-million) of the element are provided. All elements are analyzed on a single 2:1 lithium tetraborate:rock powder fused disk. Each element analysis is fully corrected for line interference and matrix effects of all other analyzed elements. The results are normalized and printed out with total iron expressed as FeO*.

Whole rock samples were reduced with a tungsten carbide jaw crusher to small chips generally about 1 cm in average size. Chips were hand picked and reduced further in a Tema swingmill shatterbox with tungsten carbide surfaces where they were milled for two minutes. Rock powder weighing 3.5 grams was mixed with pure lithium tetraborate and emptied into a 34.9 mm-internal-diameter, graphite crucible. The samples were fused in a muffle furnace at 1000°C. After grinding, the samples were fused a second time. The lower, flat surfaces of the fused disks were ground on coarse (240) grit and fine (600) grit. Then, they were washed in an ultrasonic cleaner, dried, and loaded into the XRF spectrometer.

The x-ray intensity of each element from unknown samples was measured and compared to values of two beads from each of eight international rock standards (U.S. Geological Survey [U.S.G.S.] standards PCC-1, BCR-1, BIR-1, DNC-1, W-2, AGV-1, GSP-1, and G-2). Standards were run and recalibrated after processing between one and two hundred unknown samples. U.S.G.S. BCRP-84 and GSP-1 were used as internal standards and routinely run after every twenty-eight samples to check instrument performance. Drift between standard calibrations was due almost entirely to iron which produced slightly higher values for other elements presented as oxides, weight %. When thirty analyses of the U.S.G.S. standard BCRP were compared to accepted values, the precision or standard deviation of oxide values to known measures is 0.22% ppm. Values reported for thirteen trace elements in ppm were below 6% ppm at one standard deviation, except barium (16.2%) and vanadium (10.0%). The highest precision was achieved with Rb, Sr, Zr, Y,

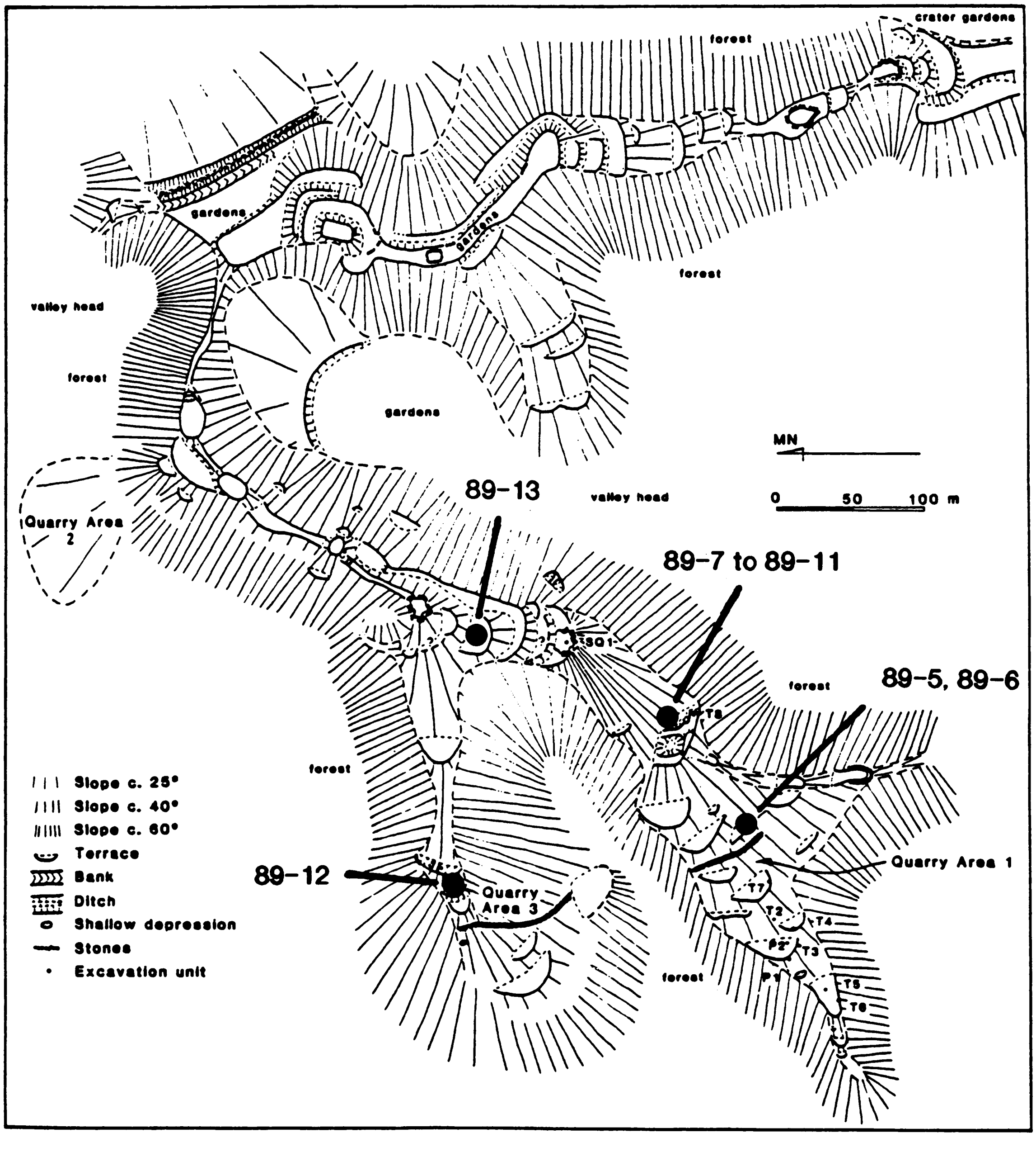

Figure 12.1 Map of Tatagamatau quarry showing locations of source samples (after Best et al. 1989, fig. 21).

Ga, Cu, and Zn. Ni, Cr, Sc, V, and Ba should be regarded as semi-quantitative below the 30 ppm level. Rb, Sr, Zr, Nb, and Y have satisfactory precisions and accuracies down to one to three ppm, while Y and Nb could be measured to 0.1 ppm. Evaluation of accuracy suggested that variation between different samples of standard powder or nonhomogeneity resulting from sample preparation is greater than inaccuracies caused by inadequate matrix and interference correction.

Non-destructive Energy Dispersive XRF

Portions or splits of all source samples from Tatagamatau, Mako Ridge, and Fa'ala'aga were analyzed by Weisler along with thirty-eight artifacts during four runs in late 1989 and early 1990. Sample preparation consisted of submerging specimens

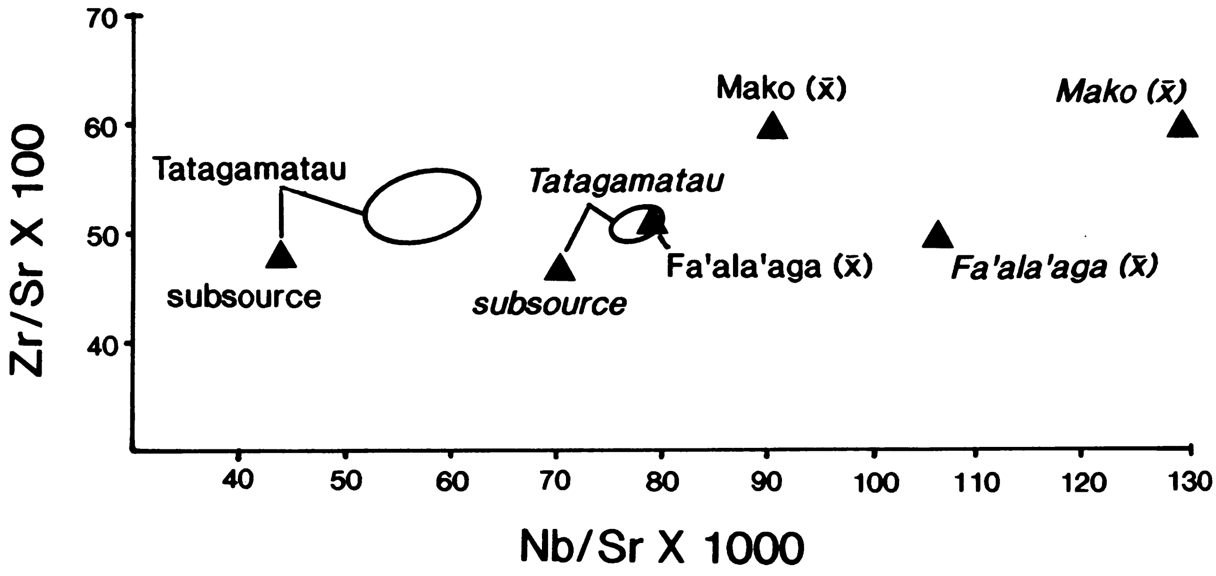

Figure 12.2 A comparison of source rocks analyzed by non-destructive x-ray flourescence using whole specimans and XRF with fused disks (indicated by italic type).

in a sonic bath of distilled water for up to one hour then air drying. Some artifacts, deeply stained with lateritic soil, were scrubbed with brushes as well. Carbonate encrustations on a few artifacts were removed with a 10% solution of HCl and then rinsed in distilled water. The EDXRF instrument is limited to the maximum weight and size of specimen that can be analyzed. Although the opening of the sample holder where the x-ray beam is directed through to the specimen is 32 mm in diameter, careful placement of the artifact or rock in the EDXRF instrument may accommodate samples (as in this analysis) up to 421 gms and 136 mm long. Molding clay can be used to secure specimens on the tray which can hold up to twenty samples. Each artifact was carefully examined to locate the flattest surface for analysis that could be accommodated within the space parameters of the sample chamber (see illustration in Bouey 1991:fig. 5). Source samples were cut to size and only fresh saw-cut surfaces were analyzed.

Laboratory facilities and equipment were provided by the Department of Geology and Geophysics, University of California, Berkeley. The same equipment and nearly identical operating conditions were used as reported by Hughes (1986:esp. 25-30) in his comprehensive study of California and Oregon artifactual and source obsidian. The XRF spectrometer consisted of a Spectrace 440 energy dispersive machine and 572 power supply (50kV, 1mA), 534-1 pulsed tube control, 588 bias/protection module, 514 pulse processor or amplifier, Tracor Northern 1221 100 mHz ADC converter, and a Tracor Northern 2000 computer based analyzer with an LSI-11 microcomputer (Hughes 1986:25). The Si(Li) solid state detector with 144 eV resolution (FWHM) at 5.9 keV in a 30 mm squared area was used for detecting all x-ray intensities. For analysis of trace elements in the mid-z energy range, a rhodium (Rh) x-ray tube was used for primary x-ray excitation at 30.0 keV, .20 mA pulsed, with a .05 mm Rh primary beam filter in an air path at 300 seconds livetime. Analytical lines used for analysis were Ni (Ka), Cu (Ka), Zn (Ka), Ga (Ka), Pb (Lb), Th (La), Rb (Ka), Sr (Ka), Y (Ka), Zr (Ka), and Nb (Ka). For rare earth elements, an Am241 100 mCi radioscope source was used in the 20-60 keV range at 300 seconds livetime (Hughes 1986:26), and analytical values were derived from the Ka lines of Cs, Ba, La, Ce, Pr, Nd, and Sm. The x-ray tube was operated at 15.0 kV, .40 mA pulsed, with an Al primary beam filter in a vacuum path at 200 seconds livetime for Ka lines of Fe, Mn, and Ti.

The elemental data as reported represent one analysis per specimen. While Bouey (1991) has demonstrated some variability with multiple analyses of the same obsidian specimens when values are presented in strictly quantitative (ppm) data, these effects are minimized when presenting data as ratios (see, for example, Jack and Carmichael 1969).

The XRF technique has its greatest accuracy in detecting elements in the mid-z range (e.g., rubidium, strontium, yttrium, zirconium, and niobium) which was confirmed by this study for both destructive and non-destructive sample preparations analyzed on their respective instruments. It is fortunate that these elements are of particular interest to igneous petrologists (Cox et al. 1979:332). For pressed pellets or fused disks these particular mid-z elements have satisfactory precisions and accuracies down to 1 - 3 ppm, while niobium and yttrium could probably be measured to 0.1 ppm (Hooper and Johnson 1987). In basalt, mid-z elements are also present in sufficient concentrations to be easily measured, and detection in whole, unaltered specimens ranges from 10 ppm to 100% with an accuracy of ± 2 - 5% under favorable conditions (Parkes 1986:153). Lighter elements are not only harder to detect and measure by XRF, but they are usually not present in great abundance. Iron, titanium, and magnesium values, reported here, were detected under vacuum. Lead (Pb), although detected during the mid-z analysis, was not used to discriminate sources or characterize artifacts due to its presence in low abundance and its susceptibility to atmospheric contamination (Flanagan 1969:82).

Rock standards have been used in routine XRF analyses for about twenty-five years (Flanagan 1969), and currently at least 272 geostandards are in use worldwide (Govindaraju 1989). Standards are important for calibrating the XRF instrumentation for matrix effect corrections and for monitoring the precision and accuracy during analysis (Germanique and Briand 1985). Using standards thought to be close in composition to the unknowns limits the efficacy of matrix correction programs to a restricted range of elements. Conversely, many different standards provide a greater range of elements and values for calibrating the program and evaluating unknowns. Therefore, more than ten internal standards were used to calibrate the Spectrace 440 machine used in this study. U.S.G.S. standard RGM-1, a rhyolite from Glass Mountain, California, was used to monitor precision and accuracy during analysis and the results are presented in table 12.2. Ppm values reported by Govindaraju (1984, 1989) are preferred "working values" which are the average of at least forty results from more than four techniques of analysis (1989:7). The accuracy and precision values reported for this study in ppm and selected ratios are reasonably close to accepted standard "working values."

Due to its cryptocrystalline texture and homogeneous distribution of elemental abundances, it is not surprising that obsidian has garnered most analytical attention in XRF studies. Large grain sizes can

Table 12.2
Evaluation of Analytical Accuracy and Precision
for U.S.G.S. Standard RGM-1

	Govindaraju 1984	Govindaraju 1989	This study (n=4)	
			Accuracy	Precision
Rb	155	149	159.9	156.3-163
Sr	100	108	107.3	106-108
Zr	200	219	227.2	225.3-229.9
Y	25	25	27.7	25.9-29.2
Nb	9.4	8.9	10.3	9-11.7
Pb	21	24	28.6	27.1-31.1
Th	15	15.1	20.4	18.9-22.1
Zr/Sr	2	2.03	2.12	
Nb/Sr	0.094	0.082	0.096	

Govindaraju (1984, 1989) pressed powder samples; this study, whole specimens analyzed.

distort XRF analysis of whole samples. Pressed pellet samples are prepared by reducing whole rock to a fine powder estimated to be 90% less than 400 mesh (Bice 1980:19) or ca. 40 microns. However, very fine-grained basalt may have more than 130 grains per mm (ca. 160 microns per grain). While this grain-size is early four times larger than pressed pellet samples, it has not been demonstrated that grains of this size adversely effect XRF analysis. This subject should be investigated further. The distribution of elemental abundances within a single basalt specimen may not be as homogeneous as obsidian, but a comparison of the date in table 12.3 is quite instructive. Here, the distribution of selected elements within a quarry (1.8 hectares in size) are indeed quite regular, and perhaps this is more so for individual rocks or artifacts.

Another factor which can affect XRF analysis is an uneven specimen surface. Analyzing adz material has a distinct advantage, however, especially over bifacially flaked obsidian artifacts, because, almost by definition, most adz surfaces are extremely flat and, in many cases, are ground to a near mirror-like finish. Recalling that fused disks are finished by 240 (coarse) and 600 (fine) grit prior to XRF analysis (Hooper and Johnson 1987), I examined under 10-40X magnification source rock from eight west Moloka'i Island basalt quarries whose material exhibited a range of textures and phenocryst sizes and densities. These samples were polished with 600 grit mesh and compared to the adz material in the present study. The prepared specimens had uniform, smooth surfaces and occasional striations formed by disintegrating phenocrysts that had been trapped between the rock and grinding plate. Although the artifacts were not as uniform in contour and had many more striations, portions of the artifacts were as smooth—if not more finely polished—than the prepared specimens. Therefore, careful selection of artifact surfaces for EDXRF analysis may limit the amount of analytical distortion caused by uneven sample surfaces.

To reduce or eliminate the effects of uneven sample surface, many researchers have advocated presenting elemental abundance values as ratios. "In spite of variations in effective sample surface of randomly broken pieces or loosely packed grains, relative intensities may be very precisely determined" (Jack and Carmichael 1969:30; see also Stross et al. 1968:82). Sheets et al. (1990:149-50) concur that errors introduced by sample size and shape are largely cancelled by "the use of abundance ratios of elements having nearly the same energy (e.g., Rb, Sr, and Zr)." These observations were

Table 12.3
Variation of Oxides and Elements from the Mo'omomi Basalt Quarry, Hawaiian Islands

	Mean **n=10**	**Range**
Oxide (weight %)		
SIO2	46.16 ± 0.12	45.96-46.36
AL2O3	15.72 ± 0.04	15.66-15.81
TIO2	4.17 ± 0.01	4.157-4.183
FEO*	14.21 ± 0.20	13.91-14.04
MNO	0.19 ± 0.01	0.178-0.202
CAO	8.53 ± 0.03	8.50-8.58
MGO	6.32 ± 0.08	6.18-6.42
K2O	0.92 ± 0.02	0.90-0.95
NA2O	3.52 ± 0.07	3.40-3.67
P2O5	0.62 ± 0.01	0.613-0.634
Element (ppm)		
Ni	68.30 ± 1.90	64-70
Cr	5.40 ± 1.69	3-8
Sc	18.50 ± 2.58	15-23
V	302.20 ± 7.70	283-310
Ba	215.50 ± 20.69	187-258
Rb	14.40 ± 0.92	12-15
Sr	786.00 ± 6.62	775-798
Zr	272.50 ± 2.91	268-278
Y	37.80 ± 0.98	37-40
Nb	27.09 ± 1.19	25.0-28.9
Ga	23.30 ± 1.79	21-26
Cu	11.80 ± 5.62	4-21
Zn	133.30 ± 1.90	131-137
Pb	4.30 ± 1.35	2-6
La	18.80 ± 9.05	2-31
Ce	62.00 ± 9.89	49-80
Th	0.80 ± 0.98	0-3

*total iron

Analyst: Dr. Peter R. Hooper, Dept. of Geology, Washington State University taken into consideration for the present study.

Ever since the pioneering work of Parks and Tieh (1966), selection of elements for obsidian analysis has been fairly standard. Regarding data reduction, however, two "camps" have emerged somewhat recently. For reasons cited above, elemental abundances are usually presented in semi-quantitative ratio form including ternary diagrams (e.g., Best 1984; Jack and Carmichael 1969; Shackley 1988; Stross et al. 1968) or scatter plots (see fig. 12.3, this study; Jack and Carmichael 1969). Hughes (1986, 1988a, b) suggests that simple bivariate plots of zirconium and rubidium in ppm are sufficient for distinguishing raw material and determining artifact provenance in some regions. However, Bouey (1991) demonstrated that multiple analyses of the same specimens produced "widely divergent determinations in ppm concentrations," while ratio level presentation reduces this error significantly (cf. Jack and Carmichael 1969; Sheets et al. 1990). Hughes (1986) and Walter (1990) have applied statistical clustering programs to define geochemical groups. Multivariate statistics are quite appropriate for some problems, however their use eliminates any consideration of the elemental abundances (either in ppm or at a nominal level) as having any geological value. For example, on west Moloka'i, Hawaiian Islands, relatively high values of Y signal one particular quarry (David Clague, personal communication, 1989) and, simple bivariate plots of silica and total alkalis can be very informative for determining sources and characterizing geochemical groups. Statistical clustering techniques should only be used after the data have been examined for geological information that can inform on the "provenance environment," that is, the geology of the suspected interaction sphere. Conversely, groups created by statistical manipulation are an end in themselves.

RESULTS

The results of the fused disk XRF analysis of sixteen source rocks from Tatagamatau, Mako Ridge, and Fa'ala'aga are presented in tables 12.4-6 and summarized in table 12.7. According to a recent comprehensive and international evaluation of the systematics of igneous rocks (Le Maitre 1989), the Tatagamatau and Mako Ridge rocks are classified chemically as hawaiites and the Fa'ala'aga rock as basalt. Rock names were assigned by plotting silica values between total alkalis. Between sources, marked differences are found with the oxides, Al_2O_3, FeO, CaO, and P_2O_5, and most trace elements. The samples from the Tatagamatau source reveal important intra-source variability between Areas 1 and 3. Oxide values for Al_2O_3, MnO, Na_2O, and P_2O_5 demonstrate marked differences as well as the trace elements Ni, Cr, and Cu. Until additional samples collected from several areas of the 110-acre Tatagamatau quarry complex are analyzed and the geochemical variability of source rock is understood in greater detail, Ni and Cr may well be significant trace elements for demonstrating intra-source variability; that is, at least between Areas 1 and 3.

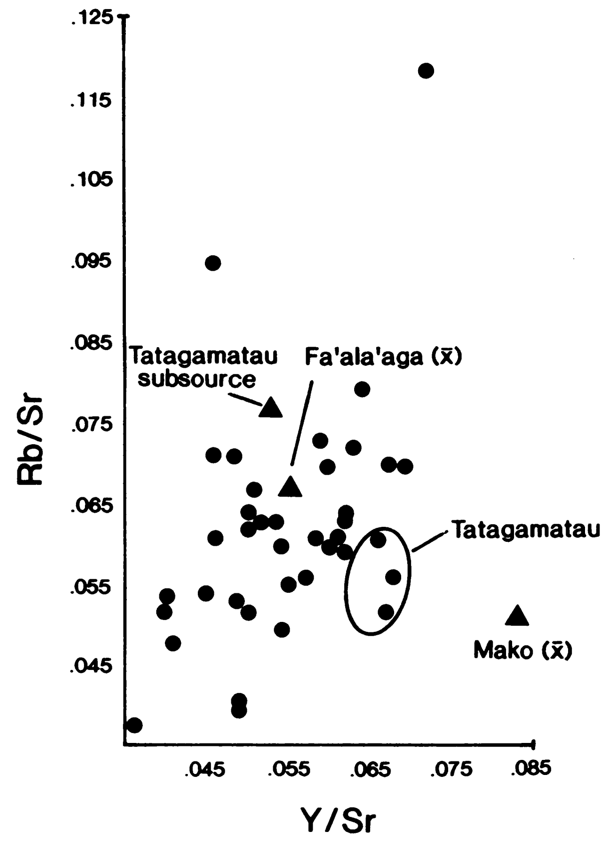

Figure 12.3 A wide dispersion of data points results when ratios of rubidium, strontium, and yttrium are used to assign specimens to possible sources.

Table 12.4
Geochemistry of Tatagamatau Source Rock (Fused Disks)

	Sample No.									Range	Mean
	89-5	89-6	89-7	89-8	89-9	89-10	89-11	89-12	89-13		
Oxide (Weight %)											
SiO2	49.66	49.66	50.26	49.94	50.4	49.56	50.56	49.32	50.11	49.32-50.56	49.94
Al2O3	15.62	15.35	15.43	15.43	15.46	15.4	15.5	13.86	15.4	13.86-15.62	15.27
TiO2	3.429	3.413	3.385	3.412	3.39	3.385	3.42	3.649	3.467	3.385-3.649	3.439
FeO*	12.64	12.9	12.56	12.82	12.63	12.81	12.34	12.4	12.73	12.34-12.90	12.65
MnO	0.178	0.179	0.173	0.176	0.178	0.175	0.179	0.167	0.177	0.167-0.179	0.176
CaO	7.62	7.56	7.7	7.6	7.63	7.58	7.68	7.8	7.69	7.56-7.80	7.65
MgO	4.65	4.67	4.55	4.62	4.77	4.7	4.76	7.06	4.76	4.55-7.06	4.95
K2O	1.54	1.62	1.6	1.57	1.57	1.58	1.59	1.79	1.54	1.54-1.79	1.60
Na2O	4.06	4.02	4.01	3.96	4.01	4.06	4.09	3.45	3.95	3.45-4.09	3.96
P2O5	0.814	0.792	0.802	0.805	0.803	0.796	0.805	0.71	0.783	0.710-0.814	0.790
Total	100.211	100.164	100.47	100.333	100.841	100.046	100.924	100.206	100.607		100.425
Element (PPM)											
Ni	0	0	0	0	0	0	0	173	0	0-173	19.2
Cr	2	0	3	3	0	1	0	181	0	0-181	21.1
Sc	16	17	22	19	16	23	15	27	22	15-27	19.7
V	202	217	200	204	214	207	203	233	215	200-233	210.6
Ba	293	286	302	282	268	292	301	331	300	268-331	295.0
Rb	42	43	45	43	42	43	43	50	42	42-50	43.7
Sr	698	704	707	707	706	708	699	683	694	683-708	700.7
Zr	357	362	354	360	355	357	352	325	348	325-362	352.2
Y	47	48	49	48	47	49	48	37	45	37-49	46.4
Nb	55	56	54.8	55.5	55.2	53.9	52.9	47.9	52.4	47.9-56.0	53.73
Ga	29	30	30	30	27	28	31	26	30	26-30	29.0
Cu	9	0	0	1	0	1	0	31	1	0-31	4.8
Zn	176	168	167	172	165	174	178	153	170	153-178	169.2
Pb	8	5	4	6	8	4	6	5	8	0-8	6.0
La	43	36	34	13	50	29	44	43	33	13-50	36.1
Ce	99	98	88	108	109	102	88	99	110	88-110	100.1
Th	6	6	3	5	7	6	6	2	3	2-7	4.9

* total iron

Analyst: Dr. Peter R. Hooper, Dept. of Geology, Washington State University, 16-17 October 1989.

Table 12.5
Geochemistry of Mako Ridge Source Rock (Fused Disks)

	Sample No.				**Range**	**Mean**
	89-1	**89-2**	**89-3**	**89-4**		
Oxide (Weight %)						
SiO2	46.48	49.84	43.44	48.12	43.44-49.84	46.97
Al2O3	18.22	17.22	19.72	18.33	17.22-19.72	18.35
TiO2	3.552	3.238	3.886	3.473	3.238-3.886	3.537
FeO*	12.10	10.68	13.20	11.48	10.68-13.20	11.87
MnO	0.21	0.193	0.231	0.208	0.193-0.210	0.211
CaO	6.65	8.42	5.50	7.29	5.50-7.29	6.966
MgO	4.44	4.41	4.42	4.24	4.24-4.44	4.38
K2O	1.89	1.79	1.98	1.37	1.37-1.98	1.76
Na2O	3.45	4.18	2.55	3.84	2.55-4.18	3.51
P2O5	0.988	0.897	1.070	0.960	0.897-1.070	0.979
Total	97.980	100.868	95.997	99.311		98.533
Element (PPM)						
Ni	0	0	0	0	0	0
Cr	3	0	8	1	0-8	3
Sc	23	13	19	12	12-23	16.75
V	228	206	246	204	204-246	221
Ba	433	421	471	450	421-471	443.75
Rb	46	39	52	14	14-52	37.75
Sr	660	883	481	856	481-883	720
Zr	433	397	469	429	397-469	432
Y	97	46	61	58	46-97	65.5
Nb	96.3	82.7	104.8	89.3	82.7-104.8	93.275
Ga	36	30	39	35	30-39	35
Cu	0	2	0	0	0-2	0.5
Zn	163	154	188	167	154-188	168
Pb	7	3	7	6	3-7	5.75
La	86	68	62	87	62-87	75.75
Ce	141	121	144	161	121-161	141.75
Th	7	7	8	6	6-8	7

* total iron

Analyst: Dr. Peter R. Hooper, Dept. of Geology, Washington State University, 16-17 October 1989.

EDXRF analysis of Tatagamatau, Mako Ridge, and Fa'ala'aga source rock are presented in tables 12.8-10; mean and range for sources are summarized in table 12.11. Elemental values are presented with one standard deviation which represents the uncertainty of counting statistics at 300 seconds livetime. A comparison of EDXRF and fused disk samples for source means and the Tatagamatau source envelopes is illustrated in figure 12.2. Zr/Sr values are very comparable, whereas Nb/Sr ratios are higher for fused disk values. This probably corresponds to the greater detection efficiency (machine sensitivity) for niobium by the Rigaku spectrometer (Hooper and Johnson 1989); or it could be a sample thickness problem since niobium x-rays are excited as deep as 5-7 mm into the specimen (David Clague, written

Table 12.6
Geochemistry of Fa'ala'aga Source Rock (Fused Disks)

	Sample No.			Range	Mean
	89-14	89-15	89-16		
Oxide (Weight %)					
SiO2	46.89	46.69	46.79	46.69-46.89	46.79
Al2O3	13.68	13.79	13.80	13.68-13.80	13.76
TiO2	5.412	5.426	5.335	5.335-5.426	5.391
FeO*	13.04	12.93	13.06	12.93-13.06	13.01
MnO	0.172	0.178	0.174	0.172-0.178	0.175
CaO	10.54	10.56	10.75	10.54-10.75	10.62
MgO	4.72	4.8	4.76	4.72-4.80	3.16
K2O	1.68	1.73	1.60	1.60-1.73	1.67
Na2O	3.00	3.13	2.97	2.97-3.13	3.03
P2O5	0.674	0.684	0.627	0.627-0.684	0.662
Total	99.808	99.918	99.866		98.268
Element (PPM)					
Ni	57	88	72	57-88	72.3
Cr	24	25	38	24-38	29
Sc	21	25	19	19-25	21.7
V	344	357	359	344-359	353.3
Ba	300	305	307	300-307	304
Rb	45	46	42	42-46	44.3
Sr	644	642	651	642-651	645.7
Zr	323	330	313	313-330	322
Y	34	36	35	34-36	35
Nb	68	71.1	66.6	66.6-71.1	68.57
Ga	28	30	29	28-30	29
Cu	104	117	101	101-117	107.3
Zn	128	138	129	128-138	131.7
Pb	5	7	6	5-7	6
La	40	45	31	31-45	38.7
Ce	115	108	104	104-115	109
Th	4	6	3	3-6	4.3

* total iron

Analyst: Dr. Peter R. Hooper, Dept. of Geology, Washington State University, 16-17 October 1989.

communication, 1990). The larger source envelope for EDXRF may relate to the greater variability in specimen surface.

After selecting elements for analysis (based on analytical precision, accuracy, and sufficient elemental concentrations), assigning artifacts to source was facilitated initially by trial and error. Figure 12.3 illustrates a wide dispersion of data points with most artifacts plotting outside the source envelope when Rb/Sr and Y/Sr ratios are used. Figure 12.4, however, using ratios of Zr/Sr and Nb/Sr, is much more useful for assigning artifacts to the Tatagamatau source. The source envelope is delimited by taking into account the variability in analytical precision.

Table 12.7
Geochemistry of Fa'ala'aga, Mako Ridge, and Tatagamatau Source Rock (Fused Disks)

	Fa'ala'aga (n=3)		Mako Ridge (n=4)		Tatagamatau (n=8)		Tatagamatau sub-source (n=1)
	Range	Mean	Range	Mean	Range	Mean	
Oxide (Weight %)							
SiO2	46.69-46.89	46.79	43.44-49.84	46.97	49.56-50.56	50.02	49.32
Al2O3	13.68-13.80	13.76	17.22-19.72	18.35	15.35-15.62	15.45	13.86
TiO2	5.335-5.426	5.391	3.238-3.886	3.537	3.385-3.467	3.413	3.649
FeO*	12.93-13.06	13.01	10.68-13.20	11.87	12.34-12.90	12.68	12.40
MnO	0.172-0.178	0.175	0.193-0.210	0.211	0.173-0.179	0.177	0.167
CaO	10.54-10.75	10.62	5.50-7.29	6.966	7.56-7.70	7.63	7.80
MgO	4.72-4.80	3.16	4.24-4.44	4.38	4.55-4.77	4.69	7.06
K2O	1.60-1.73	1.67	1.37-1.98	1.76	1.54-1.62	1.58	1.79
Na2O	2.97-3.13	3.03	2.55-4.18	3.51	3.95-4.09	4.02	3.45
P2O5	0.627-0.684	0.662	0.897-1.070	0.979	0.783-0.814	0.800	0.710
Element (PPM)							
Ni	57-88	72.3	0	0	0	0	173
Cr	24-38					1.1	181
Sc	19-25					18.8	27
V	344-359					207.8	233
Ba	300-307					290.5	331
Rb	42-46	44.3	14-52	37.8	42-43	42.9	50
Sr	642-651	645.7	481-883	720	694-708	702.9	683
Zr	313-330	322	397-469	432	348-362	355.6	325
Y	34-36	35	46-97	65.5	45-49	47.6	37
Nb	66.6-71.1	68.57	82.7-104.8	93.3	52.4-56.0	54.5	47.9
Ga	28-30	29	30-39	35	27-31	29.4	26
Cu	101-117	107.3	0-2	0.5	0-9	1.5	31
Zn	128-138	131.7	154-188	168	165-178	171.3	153
Pb	5-7	6	3-7	5.8	4-8	6.1	5
La	31-45	38.7	62-87	75.8	13-50	35.3	43
Ce	104-115	109	121-161	141.8	88-110	100.3	99
Th	3-6	4.3	6-8	7	3-7	5.25	2

* = total iron

Analyst: Dr. Peter R. Hooper, Dept. of Geology, Washington State University, 16-17 October 1989.

Nine artifacts fall within the envelope and four others are very close. Taken together, fifty percent of the adzes and other artifacts with one or more polished surfaces (adz flakes) can be assigned to the Tatagamatau quarry on Tutuila. Weathered surfaces of these specimens were gray (2.5Y 5/0; 2.5YR 5/0; 7.5YR 5/0), dark gray (2.5Y 4/0), to very dark gray (7.5R 3/0; 2.5Y 3/0; 7.5Y 3/0). Freshly broken surfaces on two specimens were very dark gray (2.5Y 3/0; 7.5Y 3/0).

Additional samples from this quarry will undoubtedly define a much larger source envelope since the Tatagamatau sub-source is well outside the limits of the eight samples used to define the geochemical dimensions of the quarry. This underscores the need to collect sufficient samples to define the geochemical variability of adz quarry sources.

The diagonal line in figure 12.4 separates

Table 12.8
Geochemistry of Tatagamatau Source Rock (Whole Specimen)

	Sample									Range
(PPM)	**89-5**	**89-6**	**89-7**	**89-8**	**89-9**	**89-10**	**89-11**	**89-12**	**89-13**	
Oxide										
TiO2	33934.8	33134.9	33311.1	31595.3	32801.2	31746	34162.6	34135	34899.3	31595.3-
	± 249.3	± 237.2	± 234.6	± 230	± 231.5	± 257.6	± 249.5	± 240.4	± 250.3	34899.3
FeO	164927.6	160026.7	161479.5	153319.4	160936.1	146043.9	164807.9	155495.7	168513.3	146043.9-
	± 1134.6	± 1078.8	± 1067.5	± 1043.8	± 1064.3	1104	1127.7	± 1025.4	± 1135	168513.3
MnO	2294.8	2369.2	2271.7	2224.9	2314.5	2062	2432	2204.9	2367.8	2062-2432
	± 44.2	± 43.1	± 42	± 42.2	± 42.2	± 46.1	± 44.7	± 41.2	± 44	
Element										
Ni	0	0	0	0	0	0	0	188 ± 9	0	0-188
Ba	228.7 ± 6.4	222.5 ± 6.8	223.1 ± 5.9	223.5 ± 7.7	209.2 ± 6.4	262.4 ± 10.6	219.9 ± 6.7	259.2 ± 6.3	220.9 ± 6	209.2-262.4
Rb	36.4 ± 2.5	37.5 ± 2.3	42.8 ± 2.4	36.9 ± 2.5	43.4 ± 2.4	41.3 ± 3.2	46 ± 2.6	56.5 ± 2.4	41.4 ± 2.4	36.4-56.5
Sr	740.5 ± 7	762.5 ± 6.5	769.7 ± 6.5	718.1 ± 6.8	767.9 ± 6.5	748.4 ± 8.4	744.9 ± 7	738.6 ± 6.2	750.4 ± 6.4	718.1-769.7
Zr	385.4 ± 5.9	401 ± 5.5	409.6 ± 5.5	387.5 ± 5.9	409.5 ± 5.5	376.4 ± 7	401.4 ± 6	357 ± 5.1	395.3 ± 5.4	357-409.6
Y	48 ± 3.1	50 ± 2.9	52.2 ± 2.8	48.1 ± 3.1	53.1 ± 2.9	47.1 ± 3.7	48.7 ± 3.1	38.8 ± 2.6	50.1 ± 2.8	38.3-53.1
Nb	44.9 ± 3.9	41.1 ± 3.6	46.4 ± 3.5	44.5 ± 3.9	47.3 ± 3.6	43.8 ± 4.7	41 ± 3.9	32.7 ± 3.4	45.9 ± 3.6	32.7-47.3
Ga	30.8 ± 2.7	29.7 ± 2.7	31 ± 2.7	28.6 ± 2.7	36.8 ± 2.6	30 ± 3.2	27.3 ± 2.6	28.3 ± 2.4	31.2 ± 2.8	27.3-36.8
Cu	22.9 ± 4.2	59.6 ± 5	19.1 ± 4.1	95.3 ± 5.8	26.3 ± 3.9	55 ± 6.1	22.4 ± 3.7	61.2 ± 4.6	35 ± 4.5	19.1-95.3
Zn	183.1 ± 5.9	178.1 ± 5.6	190.2 ± 5.7	170.2 ± 5.8	170.5 ± 5.2	159 ± 6.9	179.1 ± 5.6	149.2 ± 4.9	191.1 ± 5.9	149.2-191.1
Pb	0	6.3 ± 1.9	8.6 ± 1.8	10.8 ± 2	7.9 ± 1.8	13.1 ± 2.3	9.7 ± 1.9	0	7.8 ± 1.8	0-13.1
La	28.3 ± 3.4	29 ± 3.6	41.4 ± 3.4	33.9 ± 4.3	40.4 ± 3.6	34.5 ± 6	30.4 ± 3.6	33.1 ± 3.2	35.6 ± 3.3	28.3-41.4
Ce	84.5 ± 4.2	70.5 ± 4.4	81.1 ± 3.9	70.6 ± 5	72.7 ± 4.1	75 ± 6.7	75 ± 4.2	75.9 ± 3.8	76.1 ± 3.9	70.5-84.5
Nd	45.5 ± 4.2	42.6 ± 4.5	49.5 ± 4	34.1 ± 5	40.5 ± 4.2	49.1 ± 6.8	46.9 ± 4.4	38.3 ± 3.9	52.3 ± 4	34.1-52.3
Cs	0	0	0	0	0	0	0	0	0	0
Fr	12.8 ± 3.8	6.9 ± 4	0	9.9 ± 4.5	10.5 ± 3.7	19.4 ± 6.1	5.9 ± 3.9	0	5.9 ± 3.5	0-19.4
Th	0	0	0	13.1 ± 4.1	0	0	0	0	0	0-13.1
Co	0	0	0	0	0	0	0	0	0	0
As	1.6 ± 0.4	1.5 ± 0.4	1 ± 0.5	1.4 ± 0.5	1.4 ± 0.4	2.1 ± 0.5	0.8 ± 0.4	1.5 ± 0.4	0.9 ± 0.5	0.8-2.1

Analyst: Marshall Weisler, September 1989.

Table 12.9
Geochemistry of Mako Ridge Source Rock (Whole Specimen)

	Sample No.				Range	Mean
(PPM)	89-1	89-2	89-3	89-4		
Oxide						
TiO2	32214.3 ± 219.1	30327.9 ± 207	30691.3 ± 199.4	32630.1 ± 225.2	30327.9-32630.1	31465.9
FeO	147154 ± 943.5	136482.1 ± 876.9	141893.9 ± 872.1	147794.6 ± 960.2	136482.1-147794.6	143331.2
MnO	2847.8 ± 44.3	2384.2 ± 40.6	2470.6 ± 39	2605.8 ± 43.5	2384.2-2847.8	2577.1
Element						
Ni	0	0	0	0	0	0
Ba	327.1 ± 7.2	347.9 ± 7.3	354.2 ± 7.4	330.7 ± 7	327.1-354.2	339.96
Rb	52.2 ± 2.3	44.3 ± 2.3	50.3 ± 2.3	14.6 ± 1.9	14.6-52.2	40.35
Sr	752.4 ± 6	959.7 ± 7.1	551.6 ± 5.1	903.9 ± 6.8	551.6-959.7	791.9
Zr	475.4 ± 5.4	466.1 ± 5.6	497.1 ± 5.4	472.1 ± 5.6	466.1-497.1	477.68
Y	94.8 ± 3	48.2 ± 2.8	57.6 ± 2.7	63.6 ± 2.8	48.2-94.8	66.05
Nb	70 ± 3.5	66.4 ± 3.6	75.3 ± 3.5	73.1 ± 3.6	66.4-75.3	71.2
Ga	32.1 ± 2.3	32.7 ± 2.4	33.2 ± 2.1	33.9 ± 2.7	32.1-33.9	32.98
Cu	19 ± 3.4	11 ± 3.4	8.3 ± 2.8	26.4 ± 4.1	8.3-26.4	16.18
Zn	178.3 ± 4.9	163.9 ± 5.1	161.6 ± 4.6	171.1 ± 5.3	161.6-178.3	168.73
Pb	5.9 ± 1.9	7.7 ± 1.8	9.8 ± 1.8	7.7 ± 1.8	5.9-9.8	7.78
La	66.5 ± 4.2	47.2 ± 3.7	54.7 ± 3.9	60.6 ± 4	47.2-66.5	57.25
Ce	122.4 ± 4.6	118.1 ± 4.4	115.2 ± 4.5	131.3 ± 4.6	115.2-131.3	121.75
Nd	75.3 ± 4.5	60.2 ± 4.2	66.3 ± 4.4	73.2 ± 4.4	60.2-75.3	68.75
Cs	2.4 ± 0.7	0	0	0	0-2.4	0.6
Fr	15.1 ± 3.8	10.2 ± 3.8	10.1 ± 4	11 ± 3.8	10.1-15.1	11.6
Th	0	13.8 ± 3.8	0	0	0-13.8	3.45
Co	0	0	0	0	0	0
As	1.3 ± 0.4	1.2 ± 0.4	1.8 ± 0.3	2.2 ± 0.5	1.2-2.2	1.63

Analyst: Marshall Weisler, September 1989.

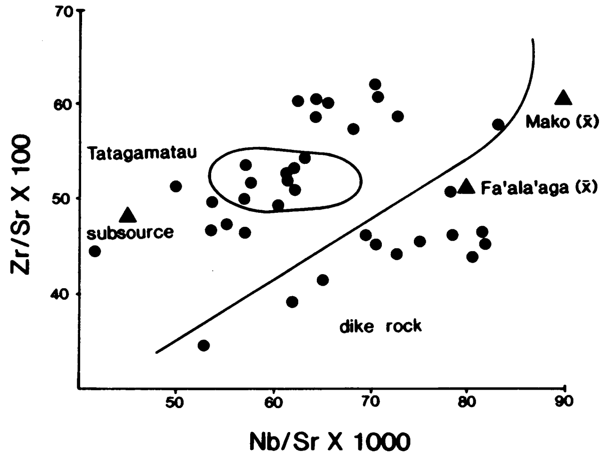

Figure 12.4 Artifacts and source rocks plotted by ratios of zirconium, strontium, and niobium resulting in many specimens plotting within the Tatagamatau source envelope.

Tatagamatau source rock from adz material deriving from the dike sources of Fa'ala'aga and Mako Ridge on Ofu and from all unmodified flakes. The source for the flakes was probably the scree slope below the Fa'ala'aga dike swarm. There are indeed several flakes that plot close to this source mean. The dike source rock and flakes recovered from the site are all medium- to coarse-grained, and eight specimens (61.5% of the total flakes) have one or more naturally flat surfaces characteristic of dike rocks. Several flakes, however, exhibit retouching and one distal margin is smoothed from use. These medium- to coarse-grained rocks were probably not conducive to adz manufacture, and it is perhaps noteworthy that all fine-grained rocks were manufactured into, or are

Table 12.10
Geochemistry of Fa'ala'aga Source Rock (Whole Specimen)

	Sample No.			Range	Mean
(PPM)	89-14	89-15	89-16		
Oxide					
TiO2	50476.8 ± 358	50757.1 ± 366.8	47928.1 ± 334	47928.1-50757.1	49720.7
FeO	168791.1 ± 1153.7	171686.3 ± 1191.4	156480.4 ± 1047.1	156480.4-171686.3	165652.6
MnO	2391.4 ± 44.6	2396 ± 45.5	1978.4 ± 40	1978.4-2396	2255.3
Element					
Ni	84.6 ± 7.9	103.2 ± 8.1	89.7 ± 7.1	84.6-103.2	92.5
Ba	234.4 ± 6.1	230.3 ± 7.1	233.3 ± 6.1	230.3-234.4	232.67
Rb	45.4 ± 2.4	48.4 ± 2.6	42.9 ± 2.4	42.9-48.4	45.57
Sr	691.6 ± 6.2	675.3 ± 6.6	704.8 ± 6.3	675.3-704.8	690.57
Zr	362.4 ± 5.3	359.2 ± 5.7	341.7 ± 5.2	341.7-362.4	354.43
Y	40 ± 2.8	36.1 ± 3	39.1 ± 2.7	36.1-40	38.4
Nb	51.8 ± 3.7	60 ± 4	52.3 ± 3.6	51.8-60	54.7
Ga	25.7 ± 2.7	30.1 ± 2.6	33.9 ± 2.5	25.7-33.9	29.9
Cu	135.9 ± 6.5	134.7 ± 6.4	134.4 ± 5.7	134.4-135.9	135
Zn	143.1 ± 5.5	137.6 ± 5.4	115.9 ± 4.6	115.9-143.1	132.2
Pb	7 ± 1.8	7.4 ± 2	7.6 ± 1.8	7-7.6	7.33
La	40.1 ± 3.3	39.7 ± 3.9	26.8 ± 3.2	26.8-40.1	35.53
Ce	70.2 ± 3.9	81.3 ± 4.5	91.2 ± 3.9	70.2-91.2	80.9
Nd	43.7 ± 3.9	40.8 ± 4.4	34.4 ± 3.9	34.4-43.7	39.63
Cs	0	0	0	0	0
Fr	8.3 ± 3.5	7.9 ± 4	9.2 ± 3.5	7.9-9.2	8.47
Th	0	0	0	0	0
Co	0	0	0	0	0
As	1.7 ± 0.5	1.8 ± 0.4	1.6 ± 0.4	1.6-1.8	1.7

Analyst: Marshall Weisler, September 1989.

Table 12.11
Geochemistry of Fa'ala'aga, Mako Ridge, and Tatagamatau Source Rock (Whole Specimen)

	Fa'ala'aga (n=3)		**Mako Ridge (n=4)**		**Tatagamatau (n=8)**		**Tatagamatau sub-source (n=1)**
(PPM)	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	
Oxide							
TiO2*	4.793-5.076	4.972	3.033-3.393	3.147	3.160-3.490	3.320	3.414
FeO*	15.65-17.17	16.57	13.65-14.78	14.33	14.60-16.85	16.00	15.55
MnO*	0.198-0.240	0.226	0.238-0.285	0.258	0.206-0.243	0.230	0.220
Element							
Ni	84.6-103.3	92.5	nd	nd	nd	nd	188.0
Ba	230.3-234.4	232.6	327.1-354.2	340.0	209.2-262.4	226.7	259.2
Rb	42.9-48.4	45.6	14.6-52.2	40.4	36.4-46.0	40.7	56.5
Sr	675.3-704.8	690.6	551.6-959.7	791.9	718.1-769.7	750.3	738.6
Zr	341.7-362.4	354.4	466.1-497.1	477.7	376.4-409.6	395.8	357.0
Y	36.1-40.0	38.4	48.2-94.8	66.1	47.1-53.1	49.7	38.8
Nb	51.8-60.0	54.7	66.4-75.3	71.2	41.0-47.3	44.4	32.7
Ga	25.7-33.9	29.9	32.1-33.9	33.0	27.3-36.8	30.8	28.3
Cu	134.4-135.9	135.0	8.3-26.4	16.2	19.1-95.3	42.0	61.2
Zn	115.9-143.1	132.2	161.6-178.3	168.7	159.0-191.1	177.7	149.2
Pb	7.0-7.6	7.3	5.9-9.8	7.8	0.0-13.1	8.0	nd
La	26.8-47.6	38.0	47.2-66.5	57.3	28.3-41.4	33.9	33.1
Ce	70.2-81.3	77.6	115.2-131.3	121.8	70.5-84.5	75.7	75.9
Nd	34.4-43.7	39.6	60.2-75.3	68.8	34.1-52.3	45.1	38.3
Cs	nd	nd	0.0-2.4	0.6	nd	nd	nd
Fr	7.9-9.2	8.5	10.1-15.1	11.6	0.0-19.4	8.9	nd
Th	nd	nd	0.0-13.8	3.5	0.0-13.1	1.6	nd
Co	nd	nd	nd	nd	nd	nd	nd
As	1.6-1.8	1.7	1.2-2.2	1.6	0.8-2.1	1.3	1.5

* x 10^{-4}

Analyst: Marshall Weisler, September 1989.

the by-products of, adz production. Geochemical data for all artifacts are presented in table 12.12.

Nine artifacts assigned to the Tatagamatau adz quarry complex on Tutuila are from three archaeological sites on Ta'u Island and two localities within the large To'aga coastal habitation area (see table 12.1). Unfortunately, only three artifacts are from excavated contexts, and the remaining are surface finds. All stylistically diagnostic specimens are quadrangular-sectioned adzes or fragments dating to the late prehistoric period (Green 1974; Green and Davidson 1969). By connecting the six sites with adz material that originated from the Tatagamatau quarry, we can document several nodes of an interaction sphere between the islands of Tutuila, Ta'u, and Ofu. These results seem quite promising for additional provenance studies of the kind employed here.

Table 12.12
Geochemistry of To'aga and Ofu Island Basalt Artifacts (Whole Specimen)

Artifact Number	Lab Number	Trace Element Concentrations (PPM)						
		Pb	Th	Rb	Sr	Y	Zr	Nb
Fiti'uta 1	89-22	11.3 ± 1.3	0.0	65.4 ± 2.4	832.5 ± 6.3	52.0 ± 2.7	438.8 ± 5.2	50.5 ± 3.3
11-1-S-4	89-25	11.1 ± 2	0.0	68.1 ± 6	724.0 ± 6	51.9 ± 2.7	449.1 ± 5.4	51.1 ± 3.4
11-2-S-1	89-26	11.0 ± 1.6	0.0	52.4 ± 2.2	812.8 ± 6.1	49.6 ± 2.6	397.6 ± 5	49.4 ± 3.2
11-2-S-2	89-31	7.7 ± 1.7	0.0	49.0 ± 2.2	782.3 ± 6	41.1 ± 2.6	369.4 ± 4.9	43.2 ± 3.2
11-2-S-3	89-30	11.1 ± 1.7	0.0	50.5 ± 2.3	816.8 ± 6.2	40.3 ± 2.6	422.8 ± 5.2	46.9 ± 3.3
11-2-S-8	89-28	0.0	0.0	30.2 ± 2.1	578.0 ± 5.3	39.2 ± 2.6	339.1 ± 4.8	36.7 ± 3.3
11-2-9	90-30	10.4 ± 2.1	0.0	57.8 ± 2.4	815.7 ± 6.4	51.1 ± 2.8	427.4 ± 5.4	49.9 ± 3.5
11-52-S-9	90-33	8.9 ± 1.8	0.0	59.3 ± 2.5	750.7 ± 6.2	48.0 ± 2.8	457.0 ± 5.5	53.1 ± 3.5
13-S-3	89-18	6.5 ± 1.6	0.0	48.7 ± 2.3	823.3 ± 6.5	43.7 ± 2.7	406.9 ± 5.3	44.3 ± 3.4
13-S-5	89-34	11.7 ± 1.8	0.0	49.0 ± 2.2	824.4 ± 6.1	50.4 ± 2.6	438.0 ± 5.1	50.9 ± 3.3
13-S-6	89-33	6.6 ± 2	0.0	43.0 ± 2.3	772.1 ± 6.2	44.0 ± 2.7	413.1 ± 5.3	43.9 ± 3.4
13-S-9	89-32	7.6 ± 2	0.0	46.3 ± 2.4	691.2 ± 6	34.7 ± 2.7	322.5 ± 5	37.4 ± 3.4
13-1-S-36	89-19	5.3 ± 1.9	0.0	38.9 ± 2.4	635.8 ± 6.2	39.1 ± 2.9	365.1 ± 5.6	53.0 ± 3.8
13-1-3-1-1	89-17	9.2 ± 1.6	0.0	58.9 ± 2.4	854.1 ± 6.5	50.9 ± 2.7	464.6 ± 5.5	54.3 ± 3.4
13-1-9-2-4	90-22	0.0	0.0	48.9 ± 2.5	894.5 ± 7.2	49.0 ± 3	527.1 ± 8.2	64.5 ± 3.8
13-1-13-87	90-23	12.0 ± 2.1	0.0	26.4 ± 2.2	660.0 ± 5.8	31.6 ± 2.6	292.1 ± 4.8	27.8 ± 3.3
13-1-16-1-84	90-42	8.3 ± 1.8	0.0	31.5 ± 2.3	545.5 ± 5.6	33.6 ± 2.8	329.7 ± 5.1	34.1 ± 3.6
13-1-16-11	90-46	9.6 ± 2	0.0	32.5 ± 2.2	638.5 ± 5.8	32.4 ± 2.6	293.2 ± 4.8	49.7 ± 3.5
13-1-16-11-81	90-45	9.6 ± 2.2	0.0	40.8 ± 2.6	856.3 ± 7.5	35.3 ± 3.1	333.8 ± 5.7	53.0 ± 4
13-1-16-12-83	90-38	9.7 ± 1.8	0.0	37.3 ± 2.3	967.8 ± 7.3	34.7 ± 2.6	331.0 ± 5.2	51.1 ± 3.5
13-1-20-4-118	90-27	6.9 ± 1.7	0.0	48.5 ± 2.3	772.8 ± 6.2	40.8 ± 2.7	386.0 ± 5.1	44.4 ± 3.4
13-1-20-5-121	90-37	10.9 ± 2.1	0.0	33.5 ± 2.3	691.7 ± 6	36.8 ± 2.6	317.7 ± 4.9	48.3 ± 3.5
13-1-20-5-122	90-41	0.0	0.0	38.7 ± 2.4	733.0 ± 6.7	29.3 ± 2.8	321.3 ± 5.4	58.5 ± 3.8
13-1-20-5-123	90-34	9.1 ± 1.7	0.0	37.2 ± 2.2	700.9 ± 5.9	33.9 ± 2.6	324.5 ± 4.9	56.6 ± 3.5
13-1-20-6-139	90-48	8.0 ± 1.8	0.0	40.1 ± 2.4	739.8 ± 6.5	33.2 ± 2.7	335.7 ± 5.2	52.1 ± 3.7
13-1-20-6-140	90-29	7.4 ± 1.6	0.0	46.4 ± 2.1	724.4 ± 5.5	35.7 ± 2.4	368.9 ± 4.6	36.0 ± 3
13-1-20-6-141	90-36	11.8 ± 2	0.0	31.1 ± 2.3	758.6 ± 6.6	37.0 ± 2.8	342.1 ± 5.3	61.7 ± 3.8
13-1-20-7-143	90-40	9.1 ± 1.7	0.0	35.6 ± 2.2	694.4 ± 6.2	27.9 ± 2.7	314.2 ± 5.1	52.0 ± 3.6
13-1-20-9-147	90-43	11.4 ± 1.9	0.0	69.0 ± 2.8	969.8 ± 7.9	44.7 ± 3.1	401.7 ± 6	63.4 ± 4
13-1-21-7-151	90-49	8.7 ± 2	0.0	49.8 ± 2.5	524.1 ± 5.5	24.4 ± 2.8	264.6 ± 4.9	41.4 ± 3.7
13-1-22-2-171	90-44	8.8 ± 1.7	0.0	52.3 ± 2.4	786.8 ± 6.3	37.5 ± 2.7	385.8 ± 5.2	49.6 ± 3.5
13-1-22-2-173	90-25	8.7 ± 1.9	0.0	46.1 ± 2.7	722.4 ± 7	45.2 ± 3.1	335.4 ± 5.7	40.8 ± 3.9
13-1-22-2-174	90-24	12.8 ± 2.4	0.0	41.5 ± 2.7	712.3 ± 6.8	49.6 ± 3.1	361.9 ± 5.8	43.6 ± 3.9
13-1-23-7-194	90-26	7.6 ± 1.9	0.0	48.2 ± 2.2	689.7 ± 5.6	47.1 ± 2.6	415.3 ± 5	45.4 ± 3.3
13-1-27-5-39	90-31	8.6 ± 1.9	0.0	49.6 ± 2.3	793.6 ± 6.2	50.2 ± 2.7	455.4 ± 5.4	53.7 ± 3.4
13-1-27-5-40	90-39	7.6 ± 1.6	0.0	50.5 ± 2.2	729.7 ± 5.7	50.0 ± 2.6	440.0 ± 5.1	47.3 ± 3.2
13-1-27-5-41	90-47	7.1 ± 1.9	0.0	38.1 ± 2.2	676.3 ± 5.7	30.8 ± 2.5	298.1 ± 4.6	48.9 ± 3.3
13-1-27-6-42	90-35	9.1 ± 1.8	0.0	43.4 ± 2.4	703.6 ± 6.4	40.7 ± 2.8	392.7 ± 5.6	43.0 ± 3.6

Analyst: Marshall Weisler, September 1989 to February 1990.

SUMMARY AND CONCLUSIONS

Defining the spatial and temporal dimensions of intra- and inter-island communication is an important precursor for evaluating historical developments on insular landscapes. Because Polynesia generally lacks the "footprints of pottery" throughout sequences of most island groups, and large quantities of obsidian are absent in this geologic province, fine-grained basalt manufactured into adzes and widely distributed must of necessity form an important basis for tracking regional interaction. Knowledge of the "provenance environment" or geologic features and their chemical signatures are essential aspects for identifying and predicting the occurrence of fine-grained, stone-tool-quality basalt. Two material characterization and provenance techniques have been described and evaluated, and geochemical analysis is argued to be the most profitable for long-term and regional-scale distributional studies as: (1) the results are reproducible; (2) instrument operating conditions can be reported in full facilitating comparison of regional databases; (3) identification of elements is not subject to human error as with thin-section descriptions; (4) elemental abundances can be reported with precision and accuracy values for specimens and standards; and (5) geochemical sampling locales on specimens more closely represent the population rather than petrographic thin-sections which are limited by two-dimensional surfaces. The efficacy of non-destructive x-ray fluorescence spectroscopy has been demonstrated and its continued use for distributional studies of Polynesian adz material is warranted. Although the technique, as applied here, is limited to elements that can be analyzed with high precision and accuracy (those in the mid-z range), future applications should seek to expand these limits. A major benefit of EDXRF is the wide range of specimen sizes that can be analyzed *without destruction*. In this study, artifacts ranged from as small as 2.1 grams up to 421.9 grams with lengths of 22 to 136 mm. Accommodating a wide range of specimen sizes can be advantageous when analyzing assemblages with a high proportion of small adz flakes, a common situation with most collections of adz material. In fact, with nearly 1000 m^2 of archaeological excavations on the island of Moloka'i, small adz flakes outnumber whole or stylistically diagnostic adzes by more than 10 to 1. Moreover, most adzes are surface finds whereas adz flakes are more often from excavated contexts.

Application of the non-destructive, energy-dispersive technique to source material and artifact assemblages from several sites on Ta'u and Ofu islands has permitted delineation of an interaction sphere during late prehistory that links habitation complexes on these islands to the large adz quarry complex at Tatagamatau, Tutuila Island, some 100 km to the west. Local dike rock from Ofu Island is chemically similar to most of the non-polished and unground flakes. Geochemical analysis has shown that these medium- to coarse-grained rocks were not fashioned into adzes, but this material was restricted to a few retouched, "awl-like" tools and one flake with use-wear along a distal margin. The vast majority, however, were unmodified.

EDXRF is not the answer to all provenance studies, but the results reported here suggest that the technique merits further use and refinement with adz material from Polynesia and possibly throughout Oceania (e.g., Weisler 1993; Weisler et al. In prep.). As the ownership and preservation of archaeological sites and museum collections become increasingly the focus of controversy between the scientific and native communities, discovering more about the past without destroying the evidence itself, may help to bridge our common goals.

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13

FAUNAL ASSEMBLAGES FROM THE TO'AGA SITE

LISA NAGAOKA

THE CALCAREOUS SAND depositional environment at To'aga favored the preservation of faunal material (table 13.1). Over 165 kilograms of invertebrate remains were recovered, representing more than forty families. The To'aga fish-bone sample—the largest in Western Polynesia—contains 2,196 identified bones across twenty-two taxa. Pig, chicken, rat, marine mammal, turtle, and bird comprise the 687 bones of the non-fish vertebrate sample. Each component of the faunal assemblage is described in detail below.

The problem of recovery bias is addressed here through the analysis of bulk sediment samples from the To'aga excavation. Generally, the use of smaller-sized screens increases the size of the faunal sample and the number of taxa recovered. The To'aga bulk samples were sieved through different screen sizes to determine the effects of screen size on the composition of the faunal assemblage.

Current knowledge of Western Polynesian subsistence practices is limited since few zooarcheological studies have been conducted in the region. In this context, the To'aga faunal assemblage is important for adding new information to our understanding of regional subsistence trends. The long temporal sequence at To'aga allows for an assessment of changing subsistence patterns. Despite the small sample of Western Polynesian sites, comparisons of the To'aga assemblage with other regional faunal assemblages may yield information about subsistence patterns.

METHODS

The faunal remains were recovered by dry-screening all excavated earth (except the clayey colluvial sediment) through 1/4" mesh. To determine the feasibility of screening the colluvium, Layer I of Unit 20 was screened through 1/4" screens. Only one poorly preserved *Turbo* shell was recovered from the 0.8 m^3 sieved. A decision was made not to screen the colluvial layer in other units because of the difficulty in dry-screening the matrix, and because of the low density and poor preservation of faunal and other material in this clayey deposit. (See chapter 7 for further discussion of the pH and other aspects of the To'aga site sediments.) During the 1987 field season, most of the shell recovered was identified, weighed, and discarded in the field. Voucher samples and the remaining unidentified shell and bone were shipped back to the laboratory. All faunal materials recovered from the 1989 field season were washed in the field and returned to the laboratory for identification and analysis.

Fish remains were identified to the family level using reference collections from the Bishop Museum, and the personal collections of Patrick Kirch (U.C. Berkeley), Melinda Allen (University of

Table 13.1
Summary of To'aga Site Faunal Remains

Faunal Class	Excavation Units 1-14	Excavation Units 15-30	Total
Total Shell (kg)	50.291	118.367	168.658
Identified Shell (kg)	50.291	115.669	165.960
Total Non-fish (NISP)	322	365	687
Total Fish (NISP)	3462	6062	9524
Identified Fish (NISP)	723	1473	2196

Washington) and the author. Reference collections from the Bishop Museum were used to identify rat, dog, pig, marine mammal, and marine turtle. The bird component was identified by David Steadman of the New York State Museum (see chapter 14).

Although many Pacific faunal analysts use MNI (minimum number of individuals) to quantify vertebrate remains (e.g., Leach 1986; Anderson 1986; Green 1986), we use NISP (number of identified specimens) for the To'aga vertebrate assemblage. The problems with both measures have been discussed extensively elsewhere (see Chaplin 1971; Grayson 1979, 1984; Payne 1972). NISP was chosen here because the effects of aggregation make MNI an inconsistent measure. Although the problem of interdependence affects NISP, the measure is constant across aggregation units.

The invertebrate faunal component was identified using standard shell identification guides (Abbot and Dance 1986; Hinton 1972; Eisenberg 1981). Tentative identifications were confirmed using reference collections at the Burke Museum in Seattle and at the Bishop Museum in Honolulu. Invertebrate remains were quantified by weight. As with MNI and NISP, use of weight has its drawbacks because of variations in size and density of different shell taxa. For example, *Tridacna maxima*, the giant clam, has a very dense shell, and one large individual may weigh more than 1 kg. On the other hand, shells such as limpets (Patellidae) are very light, so that many individuals may account for a small amount of weight. As a result, heavy shells may be overrepresented and light shells underrepresented in any sample. Post-depositional alterations such as leaching and fossilization also may distort shell weight.

RESULTS

The To'aga faunal data are presented in three categories: the vertebrate component, which is subdivided into fish and nonfish, and the invertebrate component. Of the thirty excavation units, complete data by stratigraphic layer from three areal excavations (1987 Main Trench, Units 20/23, and Units 15/29/30) are presented in the text for comparison. These units were chosen to represent the site because they comprise a larger sample than the individual units. Data for the remaining excavation units are presented only in the summary tables for the separate faunal categories. The complete faunal data by stratigraphic layers from all excavation units are available from the author on request.

Fish Remains

The To'aga excavations yielded 2,196 identified fish bones representing twenty taxa (tables 13.2-6). Although this is the largest archaeological fish bone assemblage from Western Polynesia, an average of only 73 bones were identified for each excavation unit. Acanthuridae (surgeonfish), Diodontidae

Table 13.2
Fish Fauna Recovered from the 1987 Excavations
(NISP)

	Excavations Units								
Taxa	**1, 4-9**	**2**	**3**	**10**	**11**	**12**	**13**	**14**	**Total**
Diodontidae	289	1	--	4	15	--	--	19	328
Holocentridae	64	--	--	--	3	--	4	9	80
Acanthuridae	48	1	--	--	4	--	1	13	67
Serranidae	47	--	--	1	2	--	2	15	67
Scaridae	24	1	--	1	6	--	1	5	38
Carangidae	22	--	--	1	3	--	--	6	32
Balistidae	24	--	--	--	2	--	--	2	28
Muraenidae	15	--	--	--	--	--	1	1	17
Labridae	9	1	1	--	--	--	--	2	13
Ostraciidae	5	--	--	--	--	--	--	7	12
Lutjanidae	9	--	--	--	1	--	--	1	11
Aulostomidae	8	--	--	--	--	--	--	--	8
Congridae	5	--	--	--	2	--	--	--	7
Elasmobranchii	3	--	--	--	--	2	--	--	5
Lethrinidae	2	--	--	--	--	--	--	1	3
Belonidae	2	--	--	--	--	--	--	--	2
Kyphosidae	1	--	--	--	--	--	--	--	1
Sphyraenidae	--	--	--	--	--	1	--	--	1
Scombridae	--	--	--	--	--	--	--	1	1
Bothidae	--	--	--	--	--	--	1	--	1
TOTAL IDENTIFIED	577	4	1	7	38	3	10	82	722
UNIDENTIFIED	2003	16	--	45	190	2	19	464	2739
TOTAL	2580	20	1	52	228	5	29	546	3461

(spiny puffers), Holocentridae (squirrelfish), Serranidae (groupers/cods) and Scaridae (parrotfish) comprise approximately 78% of the identified fish remains (fig. 13.1). These taxa are usually the most abundant across time and space at the To'aga site.

The structure and composition of the To'aga fish-bone data probably reflect a combination of methodological, environmental, and cultural factors. Methodological factors include recovery bias and problems in identification and quantification. Bias

Table 13.3
Fish Fauna Recovered from the 1989 Excavations
(NISP)

	Excavation Units											
Taxa	16	18	19	21	22	24	25	26	27	28	20/23	15/29/30	Total
Diodontidae	14	1	--	481	6	1	--	--	8	5	44	35	595
Acanthuridae	36	--	1	28	9	--	1	--	3	5	53	32	168
Serranidae	31	--	2	34	7	--	--	2	4	6	53	23	162
Scaridae	42	--	4	5	1	--	--	--	7	8	25	15	107
Holocentridae	15	--	--	26	3	--	--	--	3	6	27	18	98
Muraenidae	--	--	2	10	3	--	--	1	3	1	38	3	61
Labridae	13	--	1	6	2	--	--	--	2	1	22	9	56
Ostraciidae	1	--	--	10	1	--	--	--	--	--	22	4	38
Carangidae	6	--	--	9	--	--	--	1	1	3	14	2	36
Lutjanidae	2	--	--	8	3	--	--	--	1	--	12	10	36
Balistidae	4	--	1	12	4	--	--	--	--	2	5	2	30
Congridae	--	--	--	9	--	--	--	--	--	1	10	1	21
Aulostomidae	2	--	--	8	--	--	--	--	2	--	7	--	19
Lethrinidae	--	--	1	1	--	--	--	--	--	2	6	2	12
Elasmobranchii	1	--	--	--	4	--	--	1	1	--	3	--	10
Mullidae	1	--	--	5	--	--	--	--	--	1	1	2	10
Scombridae	1	--	--	1	--	--	--	--	--	--	4	--	6
Bothidae	1	--	--	1	--	--	--	--	--	--	1	1	4
Kyphosidae	--	--	--	--	--	--	--	--	1	--	1	1	3
Batoidea	1	--	--	--	--	--	--	--	--	--	--	--	1
TOTAL IDENTIFIED	171	1	12	654	43	1	1	5	36	41	348	160	1473
UNIDENTIFIED	583	--	148	1310	230	--	--	16	100	144	1294	764	4589
TOTAL	754	1	160	1964	273	1	1	21	136	185	1642	924	6062

Table 13.4
Fish Fauna from the 1987 Main Trench (Units 1, 4-9)

Taxa	**Layers**				**Total**
	IIA-1	**IIA**	**IIB**	**IIC**	
Diodontidae	4	25	154	106	289
Holocentridae	3	17	25	19	64
Acanthuridae	3	13	20	12	48
Serranidae	5	11	17	14	47
Scaridae	2	1	21	1	25
Balistidae	4	8	10	2	24
Carangidae	2	4	10	6	22
Muraenidae	---	4	4	7	15
Labridae	2	3	2	2	9
Lutjanidae	2	1	5	1	9
Aulostomidae	---	1	4	3	8
Ostraciidae	---	1	3	1	5
Congridae	---	1	1	3	5
Elasmobranchii	---	2	---	1	3
Lethrinidae	---	---	2	---	2
Belonidae	1	1	---	---	2
Kyphosidae	---	---	1	---	1
TOTAL IDENTIFIED	28	93	279	178	578
UNIDENTIFIED	191	535	827	450	2003
TOTAL	219	628	1106	628	2581

in the recovery process is shown to affect the sample size and the taxa represented in the assemblage (see "Bulk Samples" section). Problems in the identification process include the quality of the reference collection, which can limit the accuracy of the identifications and the number of taxa represented. For the To'aga assemblage, several distinctive mouth parts could not be identified using the reference collection at hand. With a better reference collection, subfamily identifications may also be possible.

Another methodological problem is the inclusion of "special bones" in the NISP count. A few taxa are identified mainly by special bones that can number up to 300 per individual, thus greatly inflating the NISP count. This is especially true for Diodontidae, which can have more than 250 spines per individual, and to a lesser extent for Ostraciidae, Elasmobranchii, and Balistidae. Of the 923 Diodontidae bones identified at To'aga, 901 were spines and only 22 were mouth parts, most being concentrated in Unit 21 and in the 1987 main excavation trench. If the Diodontidae spines are removed from the NISP count, the ranking of diodonts drops from one to thirteen, and the shape of the graph changes (fig. 13.2). Although the presence of this poisonous fish may seem odd, its remains are common in middens across the Pacific (e.g., Allen 1990; Butler 1987; Masse 1989). Moreover, the fish is still eaten by some modern Pacific populations (Bagnis 1972, Masse 1986).

Table 13.5
Fish Fauna from Transect 5, Units 15/29/30
(NISP)

	Layers				
Taxa	**II**	**IIIA-1**	**IIIB**	**IIID**	**Total**
Diodontidae	9	1	9	16	35
Acanthuridae	9	---	8	15	32
Serranidae	11	1	4	7	23
Holocentridae	3	---	10	5	18
Scaridae	3	1	3	8	15
Lutjanidae	3	---	2	5	10
Labridae	6	---	2	1	9
Ostraciidae	---	---	1	3	4
Lethrinidae	2	---	---	---	4
Muraenidae	---	---	---	3	3
Carangidae	---	---	1	1	2
Mullidae	---	---	---	2	2
Balistidae	---	---	2	---	2
Kyphosidae	1	---	---	---	1
Bothidae	1	---	---	---	1
Congridae	---	---	---	1	1
TOTAL IDENTIFIED	48	3	42	67	160
UNIDENTIFIED	201	16	250	297	764
TOTAL	249	19	292	364	924

The structure of the To'aga fish-bone data also may reflect natural distributions and abundances of fish taxa. Most of the To'aga assemblage can be classified as inshore fishes, although a few families such as Serranidae, Lutjanidae, and Carangidae cover a wide range of habitats. Reef ecosystems are generally more diverse and have a higher productivity rate than open ocean environments; therefore, the abundance of inshore versus pelagic fish may reflect the natural diversity of the different environments.

Fishing strategies may also be reflected in the fish-bone data. The fishhooks recovered from the site (see Kirch, chapter 11) may have been used to catch serranids, holocentrids, and lutjanids, but probably not scarids or acanthurids which are more likely to be caught by netting or spearing. A comparison of modern Samoan reef exploitation (Hill 1986) and the To'aga fish data shows that the most abundant taxa in the archaeological assemblage can be caught by several fishing techniques (table 13.7). These taxa may have had more opportunity to be caught than taxa for which only one strategy was used.

Table 13.6
Fish Fauna from Transect 9 (Units 20/23)
(NISP)

Taxa	Layers IIB	IIIA	IIIB	IIIC	IV	Total
Acanthuridae	3	2	30	18	---	53
Serranidae	2	5	37	9	---	53
Diodontidae	3	14	13	12	2	44
Muraenidae	3	3	23	9	---	38
Holocentridae	1	3	14	8	1	27
Scaridae	---	1	14	9	1	25
Labridae	---	1	15	6	---	22
Ostraciidae	---	---	3	6	13	22
Carangidae	1	2	9	2	---	14
Lutjanidae	1	2	9	---	---	12
Congridae	2	1	5	2	---	10
Aulostomidae	---	---	7	---	---	7
Lethrinidae	---	---	5	1	---	6
Balistidae	---	---	1	4	---	5
Scombridae	---	---	2	2	---	4
Elasmobranchii	---	---	3	---	---	3
Bothidae	---	---	---	1	---	1
Kyphosidae	---	---	---	1	---	1
Mullidae	---	---	1	---	---	1
TOTAL IDENTIFIED	16	34	191	90	17	348
UNIDENTIFIED	63	161	610	414	46	1294
TOTAL	79	195	801	504	63	1642

Non-Fish Vertebrate Remains

The non-fish vertebrate sample of 687 bones is small, averaging only 23 bones per excavation unit (tables 13.8, 13.9). About half the sample consists of *Rattus exulans*, the Pacific Rat, with nearly half the rat bones coming from Layer II of the 1987 Main Trench. Bird bones were the second most abundant, with 139 bones. Steadman presents an analysis of the 72 identified bird bones in chapter 14. Fifty-six marine turtle-bone fragments were scattered throughout the excavations with one-third of the sample concentrated in Layer IIIB of Unit 20, dating to about 2900-2400 B.P. From this same time period,

Table 13.7
Modern Samoan Fishing Methods (after Hill 1986)

Taxa	Gleaning	Line-fishing	Diving/ Spearing	Gill-netting	Throw-netting
Holocentridae	***	***	***	***	
Serranidae	***	***	***	***	
Acanthuridae	***		***	***	
Mullidae	***	***		***	
Lutjanidae	***	***			
Muraenidae	***		***		
Lethrinidae		***		***	
Carangidae		***			
Scaridae			***		
Mugilidae					***
Labridae				***	

three-fourths of the marine mammal bones were recovered from Layer IIIC of Unit 15. Another concentration of marine mammal bones was associated with the *'ili'ili* paving found in Layers I and II of Unit 22. No fruit bat bones (*Pteropus* sp.) were identified from the site, although the fruit bat is present on Ofu Island today.

Of the domesticated animals, only 1 pig (*Sus scrofa*) tooth and 15 chicken (*Gallus gallus*) bones were identified. The chicken bones are concentrated in Layer IIIB of Unit 20/23. Generally, the non-fish vertebrate bones were very fragmented and difficult to identify to species or even class. Thus, 44 bones were placed in the "general vertebrate" category and 40 in the "general mammal" category. Many of the bones placed in the mammal category may be either pig or dog, but a distinction between the two could not be made.

Invertebrate Remains

As is true for most Pacific island faunal assemblages, the invertebrate component dominated the To'aga faunal assemblage. The densest concentrations of shell midden were recovered from layers that dated to two periods of time and contained either *'ili'ili* paving or features interpreted as food preparation areas. For the period of 2500-1900 cal B.P., the instances of concentrated midden are dispersed across the site. Unit 28, Layer IIC of Transect 5 had a shell density of over 7.8 kg/m^3. Along Transect 9, about 27 kg of shell midden with a density of 11.9 kg/m^3 were recovered from Layer III of Unit 20/23 (table 13.10), along with one-third of the marine turtle remains for the site and half the chicken bones. The upper portion of this layer contained a large earth oven. The extension of Layer III into Unit 21 contained over 13 kg of shell midden (8.2 kg/m^3). The densest midden in the 1987 Main Trench, in Layers IIB and IIC, also dated to this time period (table 13.11).

In Transect 5, Layer II of Unit 15/29/30, interpreted as a cookhouse activity area dating to the period 1641-1477 cal B.P., contained nearly 12 kilograms of midden, a density of 7.4 kg/m^3 (table 13.12). This layer is contemporaneous with Layer I of Unit 16 of the same transect, which was associated with a dispersed distribution of *'ili'ili* gravel and

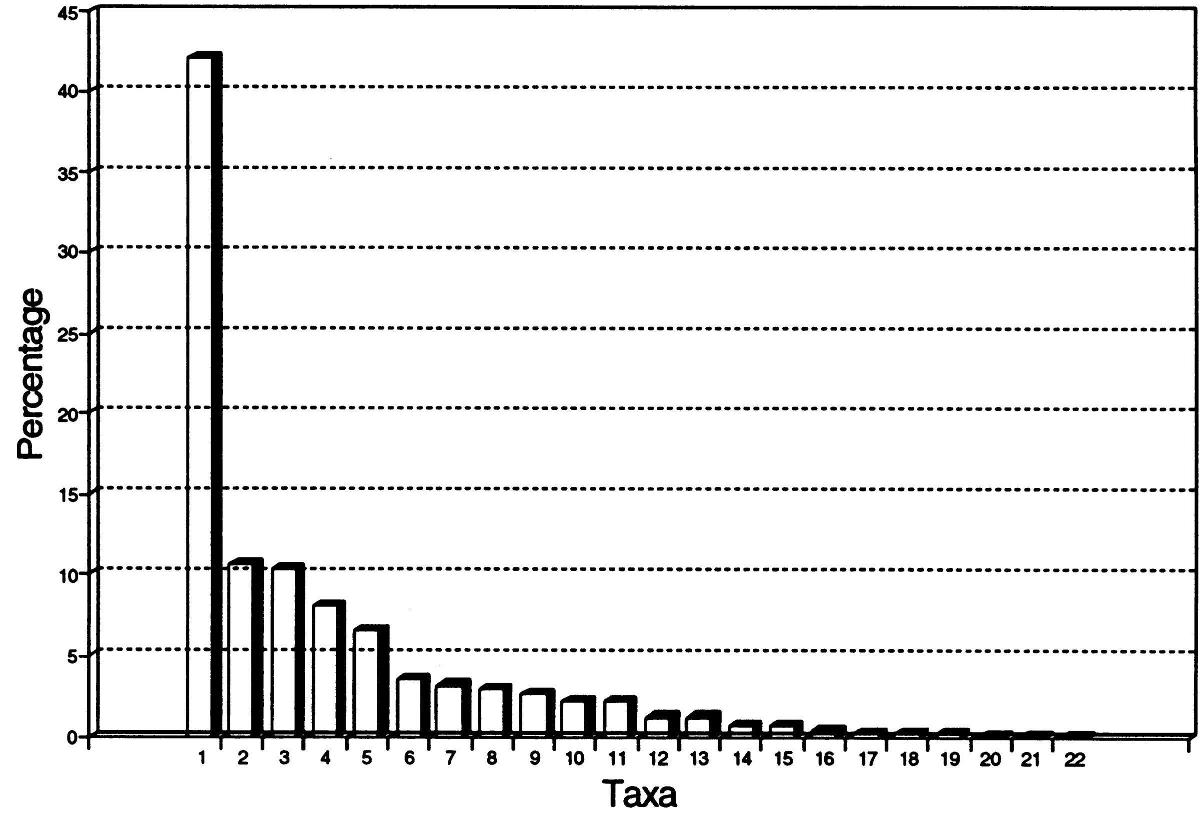

Figure 13.1 Relative frequency of fish taxa from the To'aga site, including Diodontidae.

contained the densest concentration of midden in the site (13.4 kg/m^3). A midden with 7.9 kg/m^3 density was also present in Layer IIC of Unit 28, Transect 5.

Only a few families make up the majority of the invertebrate assemblage. Over 76% of the 165 kilograms of identified shell consisted of three families, Turbinidae, Trochidae, and Tridacnidae, with *Turbo setosus* by far the most abundant species. Besides the shell, more than 14 kilograms of slate-pencil sea urchin (*Heterocentrotus mammilatus*), comprising over 8.5% of the invertebrates, were recovered from the site. Most of the sea urchins were concentrated in Units 20-24 along Transect 9; about half were associated with the earth oven in Layer III, Units 20/23.

The rank order of the invertebrate taxa varies little across time and space. Turbinidae is by far the major taxon in the assemblage with Echinoidea, Trochidae, Tridacnidae, Conidae, Cypraeidae, Muricidae, and Neritidae as secondary taxa. The remaining thirty-seven taxa are minor components, contributing less than 1% each to the assemblage. This high diversity may reflect both cultural and environmental factors. Food choice in foraging often reflects the natural abundance and distribution of resources. However, some of the most abundant taxa in the assemblage, such as Turbinidae, Tridacnidae, Echinoidea, and Conidae, were also used as raw material in the manufacture of artifacts. The abundance of these taxa therefore may reflect these dual uses and species may have been selected disproportionately to their natural distributions. A comparison of natural and archaeological invertebrate distributions through modern marine survey information would be useful in sorting out the influence of environment versus cultural effects on the invertebrate taxa represented archaeologically at To'aga.

ANALYSIS OF BULK SAMPLES

Archaeologists screen sediments in order to increase comparability within and between sites by systematically sampling the archaeological record.

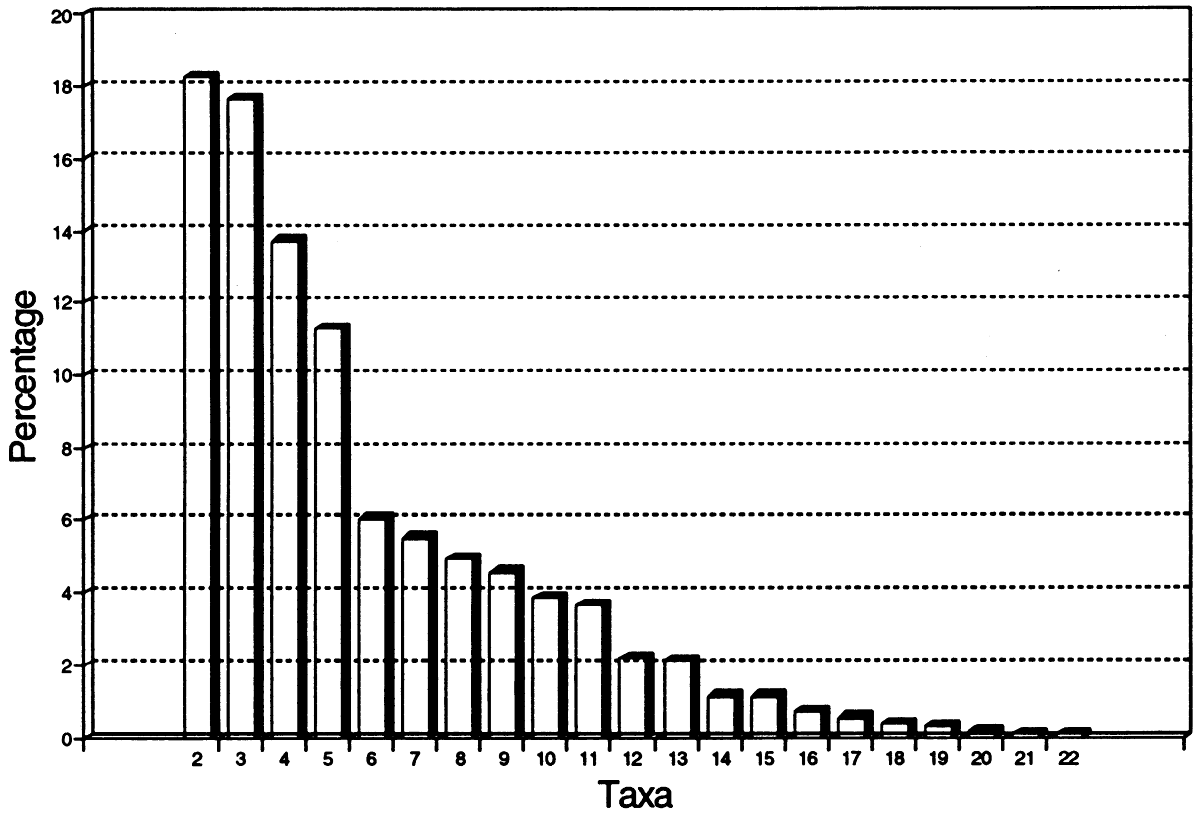

Figure 13.2 Relative frequency of fish taxa from the To'aga site, excluding Diodontidae.

Recovery methods can greatly influence the kinds and the amount of material retrieved from excavation (Grayson 1984). As with other sampling techniques, the size of the screen used is determined by the research problem. Pacific island archaeology has been oriented toward the recovery of artifacts, such as pottery, that can be readily recovered by 1/4" screens. Unfortunately, the consistent use of 1/4" screens does not always sufficiently sample other classes of archaeological material such as smaller faunal remains.

Experiments on the differential recovery of faunal material show that screen size affects the sample size and the number and kind of taxa represented (Thomas 1969; Casteel 1972; Butler 1987). Larger screen sizes bias the sample toward taxa with larger body sizes. The use of smaller screens increases the sample size and retrieves smaller taxa that would otherwise be lost through the larger screens.

To determine how our recovery methods influenced the composition of the To'aga faunal assemblage, bulk samples of ca. 5 kilograms (ca. 500 cm^3) was taken from Layer IIIA/B of Units 20/23 and from Layer II of Unit 30. These layers were chosen because they contained dense midden concentrations. Thus the two samples may not represent the site in general since the recovery rate may be less for areas with a lower midden density.

The bulk samples were wet-sieved through window screen in the field to reduce the bulk of the sediment for shipping. They were dry-screened in the laboratory through nested -3 phi (8mm), -2 phi (4mm), -1 phi (2mm), and 0 phi (1mm) geological sieves. The contents from each phi size were separated into gross categories (rocks, coral, shell, sea urchin, crab, and bone) and weighed (tables 13.13 and 13.14). The bone was then identified and quantified using NISP.

The recovery of bone was affected by screen size more than shell. Almost all the bone was recovered in phi sizes -2 and smaller. The shell recovered by screen sizes less than -3 phi was difficult to identify. Furthermore, the weight of the

Table 13.8 A
Vertebrate Fauna from the 1987 Excavations (NISP)

Taxa	Excavation Units													Total
	1	2	3	4	5	6	7	8	9	10	11	12	14	
Rattus exulans	1	1	---	41	27	55	41	2	21	3	7	---	20	219
Mammal	---	---	---	---	---	---	2	---	1	---	3	---	---	6
Gallus gallus	---	---	---	---	---	---	---	---	---	---	1	---	1	2
Bird	2	---	---	5	10	7	5	1	24	3	5	---	10	72
Marine Turtle	---	---	---	---	1	1	1	---	---	---	2	---	---	5
Other Vertebrate	---	---	5	---	---	---	1	---	2	---	---	7	5	20
TOTAL	3	1	5	46	38	63	50	3	48	6	18	7	36	324

Table 13.8 B
Vertebrate Fauna from the 1989 Excavations (NISP)

Taxa	Excavation Units																Total
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Rattus exulans	19	29	---	---	1	22	22	2	12	2	1	1	9	13	18	10	161
Sus scrofa	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	1
Marine Mammal	18	---	---	---	---	---	---	7	---	---	---	---	---	---	---	2	27
Mammal	7	1	---	---	---	3	3	2	1	---	---	1	8	7	---	1	34
Gallus gallus	---	1	---	---	---	6	2	---	1	---	---	---	---	---	2	---	12
Bird	3	7	---	---	2	16	18	2	6	---	---	---	1	2	6	4	67
Marine Turtle	1	3	---	---	---	19	1	9	3	---	2	---	6	---	2	5	51
Other Vertebrate	11	6	---	2	1	---	---	---	2	---	---	2	---	---	---	---	24
TOTAL	59	47	1	2	4	66	46	22	25	2	3	4	24	22	28	22	377

Table 13.9
Non-Fish Vertebrate Fauna from the To'aga Site

A. 1987 Main Trench, Units 1, 4-9

Taxa	Layers IIA-1	IIA	IIB	IIC	III	Total
Rattus exulans	9	63	88	28	--	188
Mammal	--	--	2	1	--	3
Bird	5	13	21	14	1	54
Marine turtle	--	1	2	--	--	3
Vertebrate	--	1	--	2	--	3
TOTAL	14	78	113	45	1	251

B. Transect 5, Units 15/29/30

Taxa	Layers II	IIIA-1	IIIB	IIIC	IIID	Total
Rattus exulans	10	2	22	12	1	47
Mammal	8	--	--	--	--	8
Marine mammal	--	--	--	18	2	20
Gallus gallus	--	--	2	--	--	2
Bird	4	--	1	--	6	11
Marine turtle	3	--	--	1	4	8
Vertebrate	--	--	--	11	--	11
TOTAL	25	2	25	42	13	107

C. Transect 9, Units 20/23

Taxa	Layers IIB	IIIA	IIIB	IIIC	IV	Total
Rattus exulans	5	2	5	20	2	34
Mammal	--	4	--	--	--	4
Gallus gallus	1	--	7	--	--	8
Bird	6	2	4	2	1	15
Marine turtle	--	1	18	3	--	22
Vertebrate	--	2	--	--	--	2
TOTAL	12	11	34	25	3	85

Table 13.10
Invertebrate Fauna from Transect 9 (Units 20/23)
(weight in grams)

	Layers						
Taxa	**I**	**IIB**	**IIIA**	**IIIB**	**IIIC**	**IV**	**Total**
GASTROPODA							
Patellidae	---	0.3	---	0.2	0.4	---	0.9
Trochus maculatus	32.5	118.4	235.8	642.6	394.6	1.2	1425.1
Trochus niloticus	---	---	1.2	0.5	---	---	1.7
Trochus spp.	---	---	3.9	23.8	4.7	---	32.4
Tectus pyramis	---	---	21.1	46.5	---	---	67.6
Turbo crassus	48.2	276.4	932.9	1734.6	500.2	58.4	3550.7
Turbo setosus	263.9	792.8	1561.0	3980.6	2275.0	100.9	8974.2
Turbo spp.	8.3	114.6	140.8	135.1	125.3	0.7	524.8
Turbo operculae	89.9	138.1	228.7	1632.0	894.4	10.6	2993.7
Astrea stellare	---	2.0	7.5	34.1	8.9	---	52.5
Lunella cinereus	---	0.4	1.0	9.1	11.8	---	22.3
Nerita albicilla	---	---	---	---	1.1	---	1.1
Nerita picea	---	---	0.9	2.8	2.7	1.2	7.6
Nerita plicata	1.0	0.6	1.2	23.2	29.3	8.0	63.3
Nerita polita	5.2	3.3	1.5	47.4	44.9	5.6	107.9
Nerita spp.	1.0	2.2	4.3	38.0	11.4	---	56.9
Neritina spp.	---	---	---	---	---	0.1	0.1
Tectarius grandinatus	---	---	---	---	---	1.6	1.6
Cerithium nodulosum	---	---	---	54.8	13.7	---	68.5
Cerithium spp.	7.5	---	51.5	19.0	0.6	---	78.6
Clypeomorus spp.	---	---	---	1.7	2.4	---	4.1
Strombus mutablis	---	9.8	---	21.9	1.3	---	33.0
Strombus spp.	---	9.4	37.1	15.1	12.7	---	74.3
Hipponix spp.	---	---	11.3	4.7	6.0	---	22.0
Cypraea annulus	---	2.2	9.0	26.4	14.4	---	52.0
Cypraea arabica	---	---	---	---	19.2	---	19.2
Cypraea caputserpentis	---	7.7	9.2	16.0	68.7	---	101.6
Cypraea mappa	---	9.0	6.5	89.9	66.3	---	171.7
Cypraea moneta	---	3.1	29.9	62.0	80.4	---	175.4
Cypraea tigris	---	---	---	---	10.9	---	10.9
Cypraea spp.	41.3	23.8	57.6	206.6	141.9	2.0	473.2
Natica spp.	---	---	---	---	0.5	---	0.5
Tonna spp.	---	6.3	6.6	30.2	7.5	---	50.6
Cassidae	---	---	---	11.0	---	---	11.0
Cymatium nicobarium	---	---	2.5	---	---	---	2.5
Cymatium spp.	---	3.6	4.2	4.0	1.0	---	12.8
Bursa granularis	---	---	70.1	19.6	---	---	89.7
Bursa spp.	---	3.3	17.1	10.2	40.3	---	70.9
Drupa ricina	---	---	0.6	12.9	5.9	---	19.4
Drupa morum	---	---	---	6.9	---	---	6.9
Drupa spp.	5.9	2.4	15.9	25.4	1.4	0.8	51.8
Morula uva	---	---	---	---	1.2	---	1.2
Nassa spp.	---	---	---	16.9	---	---	16.9
Thais armigera	13.1	18.0	67.8	91.6	48.0	---	238.5
Thais tuberosa	---	8.1	---	29.6	---	---	37.7

(continued next page)

Table 13.10 (continued)

	Layers						
Taxa	**I**	**IIB**	**IIIA**	**IIIB**	**IIIC**	**IV**	**Total**
Thais spp.	---	6.3	46.9	43.4	17.1	---	113.7
Cantharus undosa	---	1.3	5.1	10.9	16.7	2.2	36.2
Nassarius spp.	---	0.3	2.9	1.6	6.7	---	11.5
Vasum ceramicum	27.0	12.6	22.4	40.9	14.5	---	117.4
Conus argus	---	---	---	---	38.2	---	38.2
Conus chaldeus	---	---	---	2.3	13.9	---	16.2
Conus eburneus	---	---	1.2	20.3	19.8	---	41.3
Conus cf. *maculifera*	---	---	---	0.5	---	---	0.5
Conus spp.	4.8	27.4	110.1	147.1	55.2	3.4	348.0
Bulla spp.	---	0.2	1.4	18.3	3.2	---	23.1
Dolabella spp.	---	---	0.8	5.5	5.7	---	12.0
Melampus spp.	0.4	1.6	11.9	21.3	28.0	3.6	66.8
Pythia spp.	---	---	---	3.3	6.8	11.1	21.2
PELEYCYPODA							
Mytilidae	---	20.0	6.7	23.9	1.9	---	52.5
Isognomon spp.	---	---	0.7	---	1.6	---	2.3
Chama spp.	---	---	---	1.1	7.2	---	8.3
Chlamys spp.	---	15.1	---	---	1.8	---	16.9
Cardiidae	---	14.9	---	---	---	---	14.9
Periglypta reticulata	---	4.7	---	---	0.8	---	5.5
Tridacna maxima	81.1	17.9	283.5	234.4	205.4	---	822.3
Quidnipagus palatam	---	10.6	18.1	70.3	31.8	1.8	132.6
Scutarcopagia scobinata	2.2	9.0	5.1	75.4	29.8	---	121.5
Trapezium oblongum	---	---	13.7	---	---	---	13.7
Asaphis violaceus	---	3.4	12.5	35.4	2.6	7.6	61.5
Pinna spp.	---	---	---	0.3	0.2	---	0.5
ECHINOIDEA	25.0	919.8	3052.9	3742.2	395.5	34.1	8169.5
CRUSTACEA	---	6.8	30.7	39.3	54.4	1.8	133.0
Unidentified	14.2	48.8	116.4	38.4	67.9	---	285.7
TOTAL (g)	672.5	2676.5	7281.7	13703.0	5875.7	256.7	30466.1
VOLUME (m^3)	1.90	0.85	0.40	0.95	0.90	0.30	5.30
DENSITY (kg/m^3)	0.35	3.15	18.20	14.24	6.53	0.86	5.75

Table 13.11
Invertebrate Fauna from the 1987 Main Trench, Units 1, 4-9
(weight in grams)

	Layers							
Taxa	**IC**	**IIA-1**	**IIA**	**IIB**	**IIC**	**III**	**IV**	**Total**
GASTROPODA								
Haliotis ovina	---	---	---	---	13.9	---	---	13.9
Patellidae	---	---	---	---	2.0	1.1	---	3.1
Trochus maculatus	---	36.7	66.8	145.4	136.9	20.5	---	406.3
Trochus spp.	5.0	---	20.0	65.0	71.3	1.0	---	162.3
Turbo crassus	20.0	498.0	383.1	1274.5	667.7	44.9	4.6	2892.8
Turbo setosus	60.0	2072.3	973.1	4646.3	2850.6	185.8	---	10788.1
Turbo spp.	---	215.2	235.0	313.1	189.5	32.0	8.1	992.9
Turbo operculae	---	347.3	872.3	1116.1	2045.2	18.1	4.5	4403.5
Astrea stellare	---	---	4.3	7.6	12.9	---	---	24.8
Astrea rhodostoma	---	---	---	---	5.0	---	---	5.0
Lunella cinereus	---	3.2	---	---	1.1	---	8.7	13.0
Nerita plicata	---	0.3	0.7	0.9	---	---	---	1.9
Nerita polita	---	6.7	4.3	7.9	16.8	1.0	14.9	51.6
Nerita spp.	---	20.0	9.0	65.4	43.4	1.3	---	139.1
Cerithium nodulosum	---	---	---	20.0	166.5	---	---	186.5
Cerithiidae	---	2.0	9.2	34.9	2.7	---	---	48.8
Strombus cf. *maculatus*	---	15.0	9.0	60.0	65.0	---	---	149.0
Strombus cf. *mutablis*	---	1.2	---	---	1.4	2.4	---	5.0
Strombus spp.	---	---	---	2.2	---	---	---	2.2
Hipponix conicus	---	11.0	3.0	15.3	15.9	---	---	45.2
Cypraea arabica	---	---	---	25.6	---	---	---	25.6
Cypraea annulus	---	11.6	0.5	---	8.4	---	---	20.5
Cypraea caputserpentis	---	2.6	4.1	---	3.3	---	---	10.0
Cypraea mappa	---	---	---	---	---	24.3	---	24.3
Cypraea moneta	---	1.0	---	---	31.6	9.7	---	42.3
Cypraea cf. *tigris*	---	0.4	---	---	---	---	---	0.4
Cypraea spp.	1.0	53.4	69.8	276.0	255.4	0.7	3.9	660.2
Policines spp.	---	---	---	5.0	---	---	---	5.0
Cymatium nicobarium	---	5.9	1.1	3.7	6.8	2.0	---	19.5
Cymatiidae	---	25.2	---	24.1	---	---	---	49.3
Tonnidae	---	---	1.5	4.2	17.2	---	---	22.9
Bursidae	---	---	15.2	19.5	16.1	13.2	---	64.0
Drupa grossolaria	---	---	---	---	1.7	---	---	1.7
Drupa ricina	---	2.3	---	6.5	---	---	---	8.8
Drupa spp.	---	1.6	2.7	5.9	---	---	---	10.2
Nassa spp.	---	---	---	1.4	---	---	---	1.4
Thais armigera	---	---	13.7	48.8	2.2	---	---	64.7
Thais spp.	---	0.9	---	---	1.8	---	---	2.7
Muricidae	---	79.2	70.0	183.0	285.0	---	---	617.2
Cantharus undosus	---	1.6	0.5	---	5.5	---	---	7.6
Nassarius spp.	---	---	---	---	6.4	---	---	6.4
Vasum ceramicum	---	---	9.3	64.4	68.1	---	---	141.8
Conidae	---	11.5	14.5	48.7	82.5	4.8	---	162.0
Bulla sp.	---	1.1	1.4	9.5	1.2		---	13.2
Melampus fasciatus	---	0.5	---	0.2	1.2	0.9	---	2.8
Melampidae	---	15.0	11.0	30.0	37.0	---	---	93.0
Pythia scarabeus	---	---	---	---	---	---	1.5	1.5

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Table 13.11 (continued)

Taxa	Layers IC	IIA-1	IIA	IIB	IIC	III	IV	Total
PELECYPODA								
Anadara sp.	---	---	---	1.0	---	---	---	1.0
Arca spp.	---	---	---	---	6.0	---	---	6.0
Mytilidae	2.0	75.4	69.5	38.5	40.2	1.0	---	226.6
Isognomon spp.	---	---	---	---	0.7	---	---	0.7
Chama spp.	---	---	---	30.0	1.1	---	---	31.1
Codakia divergens	---	---	---	---	0.9	---	---	0.9
Gafrarium spp.	---	---	---	65.0	---	---	---	65.0
Lucinidae	---	---	3.0	7.0	---	---	---	10.0
Periglypta reticulata	---	---	---	59.2	0.6	---	---	59.8
Tridacna maxima	---	303.5	22.3	1320.4	1698.8	40.7	---	3385.7
Hippopus hippopus	---	---	---	121.4	215.0	---	---	336.4
Quidnipagus palatam	---	0.3	1.9	10.3	13.2	---	---	25.7
Scutarcopagia scobinata	---	3.3	---	7.5	10.9	4.8	---	26.5
Tellinidae	---	8.0	10.0	57.0	75.0	---	---	150.0
Asaphis violaceus	---	3.1	---	0.9	---	1.4	---	5.4
ECHINOIDEA	---	21.6	32.8	27.5	52.2	17.9	---	152.0
CRUSTACEA	---	4.8	5.1	28.4	1.9	0.3	5.3	45.8
TOTAL	88.0	3862.7	2949.7	10305.2	9255.7	429.8	51.5	26942.6
VOLUME (m^3)	0.10	0.65	0.95	1.85	1.85	1.75	1.05	8.20
DENSITY (kg/m^3)	0.88	5.94	3.10	5.57	5.00	0.25	0.05	3.29

shell recovered by the smaller screens added relatively little to the shell recovered from the larger screens.

The bulk samples show that the size of the vertebrate sample greatly increases as the screen size decreases. Only one unidentifiable bone was recovered from the -3 phi screen. The -2 phi screen recovered only a fraction of the material recovered from the -1 and 0 phi screens (tables 13.15 and 13.16). Comparisons of the density of identifiable fish bone obtained from the bulk samples to that from the excavation unit illustrate the amount of material being lost through the 1/4" screens (tables 13.17 and 13.18). While the standardization of the volume to a cubic meter exaggerates the recovery rate for the bulk samples, it shows that a significant amount of bone may be lost through 1/4" screens.

The smaller screen sizes also increase the sample's richness through the addition of new taxa. Balistidae and lizard were not recovered in either excavation unit. Along with Balistidae, four other fish families (Ostraciidae, Muraenidae, Carangidae, and Apogonidae) were added to the Unit 30 data through fine screening. Most of these are small-bodied taxa with small diagnostic skeletal elements that are less likely to be recovered by 1/4" screens.

Although the To'aga fish sample is the largest in Western Polynesia, the analysis of the bulk samples shows that sample size, taxonomic richness, and thus sample representativeness can greatly increase through the consistent use of smaller screens and bulk samples. This point is especially relevant for Pacific island archaeology where the vertebrate samples from most sites have been small. Because the representativeness of the 1/4" sample is suspect, the validity of interpretations based on measures of diversity, such as richness (the number of taxa present) and evenness (the distribution of abundance

Table 13.12
Invertebrate Fauna from Transect 5, Units 15/29/30
(weight in grams)

	Layers				
Taxa	**II**	**IIIA-1**	**IIIB**	**IIID**	**Total**
GASTROPODA					
Haliotis spp.	---	---	---	2.7	2.7
Patellidae	0.8	---	2.2	0.4	3.4
Trochus maculatus	504.5	43.4	40.9	95.4	684.2
Trochus niloticus	42.5	---	---	1.3	43.8
Tectus pyramis	12.4	---	---	1.9	14.3
Turbo crassus	988.0	45.0	145.6	151.6	1330.2
Turbo setosus	4213.8	170.0	408.5	872.8	5665.1
Turbo spp.	172.8	13.6	47.4	138.9	372.7
Turbo operculae	2721.2	153.6	163.2	396.5	3434.5
Astrea stellare	21.3	3.2	1.2	57.4	83.1
Lunella cinereus	2.9	---	0.4	7.8	11.1
Nerita albicilla	4.0	---	---	---	4.0
Nerita picea	1.9	---	0.3	8.5	10.7
Nerita plicata	29.1	---	2.5	13.8	45.4
Nerita polita	36.0	1.1	3.9	82.6	123.6
Nerita spp.	23.7	---	16.1	51.7	91.5
Cerithium nodulosum	56.8	---	26.0	17.4	100.2
Cerithium columna	---	---	---	2.6	2.6
Cerithium spp.	5.0	---	0.2	9.2	14.4
Clypeomorus spp.	19.9	0.5	6.5	8.6	35.5
Strombus mutablis	---	---	5.2	5.2	10.4
Strombus spp.	29.8	2.7	8.4	11.2	52.1
Hipponix conicus	5.4	---	---	2.9	8.3
Hipponix sp.	7.8	---	1.0	1.8	10.6
Cypraea annulus	1.7	---	0.5	0.3	2.5
Cypraea caputserpentis	37.5	1.3	6.7	8.6	54.1
Cypraea eburneus	9.8	---	---	---	9.8
Cypraea mappa	24.8	0.8	3.8	63.5	92.9
Cypraea mauritania	0.8	---	---	---	0.8
Cypraea moneta	10.1	---	---	17.5	27.6
Cypraea tigris	---	---	0.9	---	0.9
Cypraea spp.	241.6	9.8	22.6	109.7	383.7
Policines spp.	---	---	2.3	0.8	3.1
Naticidae	0.3	---	1.8	4.6	6.7
Tonna spp.	11.6	---	0.1	5.4	17.1
Cymatium nicobarium	7.2	---	7.3	3.5	18.0
Cymatium spp.	6.2	---	---	4.5	10.7
Bursa granularis	42.5	---	---	---	42.5
Bursa spp.	5.8	---	---	---	5.8
Drupa ricina	34.9	9.7	---	9.7	54.3
Drupa morum	29.0	---	---	6.8	35.8
Drupa rubusidaceus	13.6	---	---	---	13.6
Drupa spp.	8.3	---	1.1	4.5	13.9
Morula sp.	2.8	---	---	1.2	4.0

(continued next page)

Table 13.12 (continued)

Taxa	Layers II	IIIA-1	IIIB	IIID	Total
Nassa sp.	2.3	---	1.0	2.2	5.5
Thais armigera	88.2	7.6	---	60.2	156.0
Thais tuberosa	111.7	---	12.9	17.4	142.0
Thais spp.	124.5	10.0	25.4	33.6	193.5
Cantharus undosa	11.0	---	1.9	21.4	34.3
Nassarius gaudiosis	---	---	---	0.6	0.6
Latirus filamentosa	66.8	---	---	---	66.8
Vasum ceramicum	42.2	---	3.6	7.6	53.4
Conus chaldeus	---	---	---	0.5	0.5
Conus eburneus	11.2	---	---	0.8	12.0
Conus spp.	349.5	0.4	15.0	36.6	401.5
Terebra sp.	5.7	---	---	---	5.7
Bulla spp.	15.7	0.8	7.2	5.3	29.0
Dolabella spp.	1.4	---	---	---	1.4
Pythia spp.	---	0.4	3.0	48.0	51.4
Melampus spp.	1.0	0.2	3.5	10.2	14.9
PELECYPODA					
Arca spp.	1.3	0.7	---	1.6	3.6
Mytilidae	8.9	1.2	9.7	14.8	34.6
Isognomon spp.	0.3	---	---	1.4	1.7
Chama spp.	2.7	---	1.0	26.4	30.1
Codakia spp.	---	---	0.3	---	0.3
Periglypta reticulata	26.9	---	11.0	3.6	41.5
Tridacna maxima	1170.1	7.7	215.2	310.8	1703.8
Hippopus hippopus	---	---	---	13.6	13.6
Quidnipagus palatam	28.9	1.6	4.2	3.6	38.3
Scutarcopagia scobinata	51.2	2.4	13.1	10.3	77.0
Trapezium oblongum	4.2	---	---	---	4.2
Asaphis violaceus	50.7	1.5	1.1	7.1	60.4
POLYPLACOPHORA	---	---	---	5.3	5.3
ECHINOIDEA	72.6	5.0	28.7	215.6	321.9
CRUSTACEA	17.7	1.0	11.1	8.8	38.6
Unidentified	198.4	19.4	30.5	162.4	410.7
TOTAL (g)	11853.2	514.6	1326.0	3212.5	16906.3
VOLUME (m^3)	1.60	0.10	1.50	1.85	5.05
DENSITY (kg/m^3)	7.41	5.15	0.88	1.74	3.35

Table 13.13
Units 20/23 Bulk Sample Analysis (weight in grams)

	Screen Size			
Class	**>-3 ϕ**	**-2 ϕ**	**-1 ϕ**	**0 ϕ**
Rock	522.5	30.7	133.6	103.3
Coral	234.4	34.1		
Shell	56.6	19.6		
Crab	8.6	---		
Bone	0.4	1.0	2.9	2.5
TOTAL	950.2	104.5	136.5	105.8

Table 13.14
Unit 30 Bulk Sample Analysis (weight in grams)

	Screen Size			
Class	**>-3 ϕ**	**-2 ϕ**	**-1 ϕ**	**0 ϕ**
Rock	138.4	49.7	10.9	30.4
Coral	102.2	68.5		
Shell	57.8	24.5		
Bone	---	0.8	3.9	2.5
TOTAL	299.4	143.5	14.8	32.9

values) is also questionable (Gordon 1991). Ideally, a faunal assemblage should reflect the larger target population of the archaeological record, not simply the archaeological recovery techniques used.

TEMPORAL TRENDS IN THE TO'AGA ASSEMBLAGE

One goal of faunal analysis is the description and interpretation of temporal change in prehistoric subsistence patterns. A pattern of subsistence change which has been described for some Pacific island sites is a quantitative shift from the exploitation of wild or naturally occurring resources to a dominance on horticultural production (e.g., the Tikopia case documented by Kirch and Yen [1982] or the Mangaia case described by Steadman and Kirch [1990]). Temporal increases in the frequency of pig, dog, and chicken and decreases in wild vertebrate taxa such as birds, turtle, and marine mammal are taken to indicate this trend. In contrast, the character of the To'aga assemblage changes little over time and does not strongly reflect this kind of shift. Wild taxa are found throughout the site, and the sample of domesticated animals is too small to draw any firm conclusions. Although much of the wild taxa (especially the birds) are represented in early contexts, most of the chicken bone is also found in those early layers. Thus, there is no clear cut shift from one type of resource use to the other.

A corollary of the wild to domesticated fauna hypothesis is the reduction of marine resources with increasing reliance on horticulture (e.g., Janetski 1976, 1980; Kirch 1982, 1988). Resource exploitation and environmental degradation by humans are also suggested to contribute to the decline in marine resources, with decreases in the density of shellfish used to support this hypothesis. Invertebrate density varies at To'aga, increasing then decreasing over time (tables 13.10-13.12). However, the use of density measures may be misleading since changes in density may result from other factors, such as changing rates of sedimentation or shifts in settlement pattern.

In sum, the composition of the To'aga assemblage changes little over time. The invertebrate assemblage best illustrates this with a few taxa dominating the assemblage across time and space. A similar trend appears to be evident for the fish assemblage as well. At present, the cause of this pattern is not evident. Some possible causes include the exploitation of naturally abundant taxa from a temporally stable environment, a lack of change in subsistence practices, or a combination of both factors.

REGIONAL COMPARISONS

Comparisons of faunal assemblages from different areas or islands allow for the assessment of

Table 13.15
Vertebrate Taxa Represented in the Bulk Sample From Units 20/23 (NISP)

	Screen Size		
Taxa	**-2 ϕ**	**-1 ϕ**	**0 ϕ**
Balistidae*	---	7	5
Ostraciidae	---	3	4
Serranidae	---	3	2
Labridae	---	1	2
Holocentridae	---	1	2
Diodontidae	---	1	---
Muraenidae	---	1	---
Acanthuridae	---	---	1
Scaridae	1	---	---
Rattus sp.	---	---	2
Bird	---	1	---
Lizard*	---	---	1
TOTAL IDENTIFIED	1	18	19
UNIDENTIFIED	10	196	456
TOTAL	11	214	475

* Not found in regular 0.25 inch screened samples from this excavation unit.

regional trends. To'aga may be compared with other faunal assemblages from well-documented sites in Western Samoa (Green and Davidson 1969, 1974; Janetski 1976, 1980; Lohse 1980; Smith 1976), Tonga (Kirch 1988; Poulsen 1987), and Fiji (Best 1981, 1984; Hunt 1980; Kay 1984). First, the issue of data comparability is addressed to determine the quality of the regional data base. Differences in recovery, identification, and quantification techniques can seriously affect the comparability of data across assemblages (Butler 1988; Nagaoka 1988). If data sets are not comparable, differences between them may reflect methodological rather than regional differences. Once these issues have been addressed, the faunal data are then examined for the invertebrate, fish, and non-fish vertebrate categories.

For Western Polynesian faunal assemblages, recovery and quantification techniques vary considerably across sites (table 13.19). As was shown in the analysis of the bulk samples from To'aga, screen size influences the kind and the size of the faunal sample. Screen size differences can even change data at a nominal level since smaller screen sizes add taxa. Quarter-inch screens have been the most commonly used although for some sites screen size was not reported. In other cases, several screen sizes were used, but when and where the different sizes were used was not reported. This lack of information makes it difficult to evaluate the comparability of the data.

Table 13.16
Vertebrate Taxa Represented in the Bulk Sample from Layer II, Unit 30 (NISP)

	Screen Size		
Taxa	**-2 ϕ**	**-1 ϕ**	**0 ϕ**
Balistidae*	---	6	7
Diodontidae	---	8	---
Labridae	2	4	---
Ostraciidae*	---	5	---
Serranidae	---	3	---
Muraenidae*	---	2	---
Scaridae	---	1	---
Lutjanidae	---	1	---
Carangidae*	---	---	1
Apogonidae*	---	---	1
Rattus sp.	2	3	3
Lizard*	---	---	1
TOTAL IDENTIFIED	4	34	13
UNIDENTIFIED	18	246	532
TOTAL	22	280	546

* Not found in 0.25 inch screened samples from this excavation unit.

NISP was the common technique for quantification of the vertebrate component, except for the Fiji sites where MNI was used. For the invertebrates, weight was used except for Lakeba and Naigani. These differences in quantification may not be as severe as screen size differences since, in many cases, there is little difference between quantification techniques at an ordinal level (Grayson 1984; Janetski 1980). If the data are considered in terms of the rankings of taxa, it may still be possible to make valid comparisons.

In the identification process, differences in the reference collections and the diagnostic elements used can also affect the data. Kirch (1988) and Best (1984) noted that their fish reference collections were inadequate, limiting the number of possible taxa that could be identified. This problem also exists for the To'aga assemblage. Publication of reference collections and the elements used would help evaluate how these factors have biased the data.

Some differences among the faunal samples may be due to the range of diagnostic elements used to identify the assemblages, especially for the fish assemblages. Kirch, Poulsen, and Best used mainly the premaxilla, dentary, and special bones for their fish identifications. For the To'aga assemblage three additional elements, the articular, maxilla, and quadrate, were used. This increased the size of the To'aga sample about fifteen percent and added two taxa.

Table 13.17
Density of Identified Fish Bone from Layer III A/B, Units 20/23

	No. of Identified Fish	Sample Volume (m^3)	Density (NISP/m^3)
Excavation Unit	221	1.3	170
Bulk Sample	34	0.0005	68,000

Given the problems in data comparability of the Western Polynesian faunal assemblages, only general comparisons between the data sets can be made. The issue of comparability is important for future faunal work in the area. Ideally, a faunal data base would be created in which data from different sites could be easily assimilated into one body of knowledge with new data continually adding to our knowledge of subsistence patterns.

Fish

For many of the Western Polynesian sites either little faunal material was recovered or the data are poorly reported. The data on fish bones from Western Samoa consists of brief notes on their presence in the sites. Janetski (1976, 1980) mentions 10 fish bones identified from Potusa and an unknown quantity from Falemoa and Jane's Camp. Over 174 grams of fish bone were recovered from Lotofaga (Davidson 1969), but no other data are presented.

The best reported and largest samples of fish come from Tongatapu, Niuatoputapu, Lakeba, and To'aga. Kirch (1988) recovered a sample of 231 NISP across 11 taxa from Niuatoputapu. From Tongatapu, Poulsen (1987) identified 15 fish taxa containing 179 NISP. Lakeba produced 323 MNI or 1782 NISP, and 21 taxa from the four sites for which the fish component was analyzed (Best 1984). The To'aga assemblage is comparable in size to Lakeba with 2196 NISP and 22 taxa represented.

The most abundant fish taxa are inshore/reef fishes, and a few taxa make up the majority of the assemblage (fig. 13.3). The cause of this distribution of fish taxa may be cultural (fishing strategies, food preferences) or environmental (natural abundances and distributions). Unfortunately, the biases created by the recovery techniques, differential preservation, and identifiability may have influenced these distributions.

The most common fish families across sites are Scaridae, Lethrinidae, Serranidae, Acanthuridae, and Diodontidae. The dominance of taxa, such as Scaridae, Lethrinidae, and Diodontidae, may be due to preservation and identification bias as much as subsistence patterns. The diagnostic elements of these taxa are very robust and easily identified. It is

Table 13.18
Density of Identified Fish Bone from Layer II, Unit 30

	No. of Identified Fish	Sample Volume (m^3)	Density (NISP/m^3)
Excavation Unit	29	0.8	36
Bulk Sample	52	0.0005	104,000

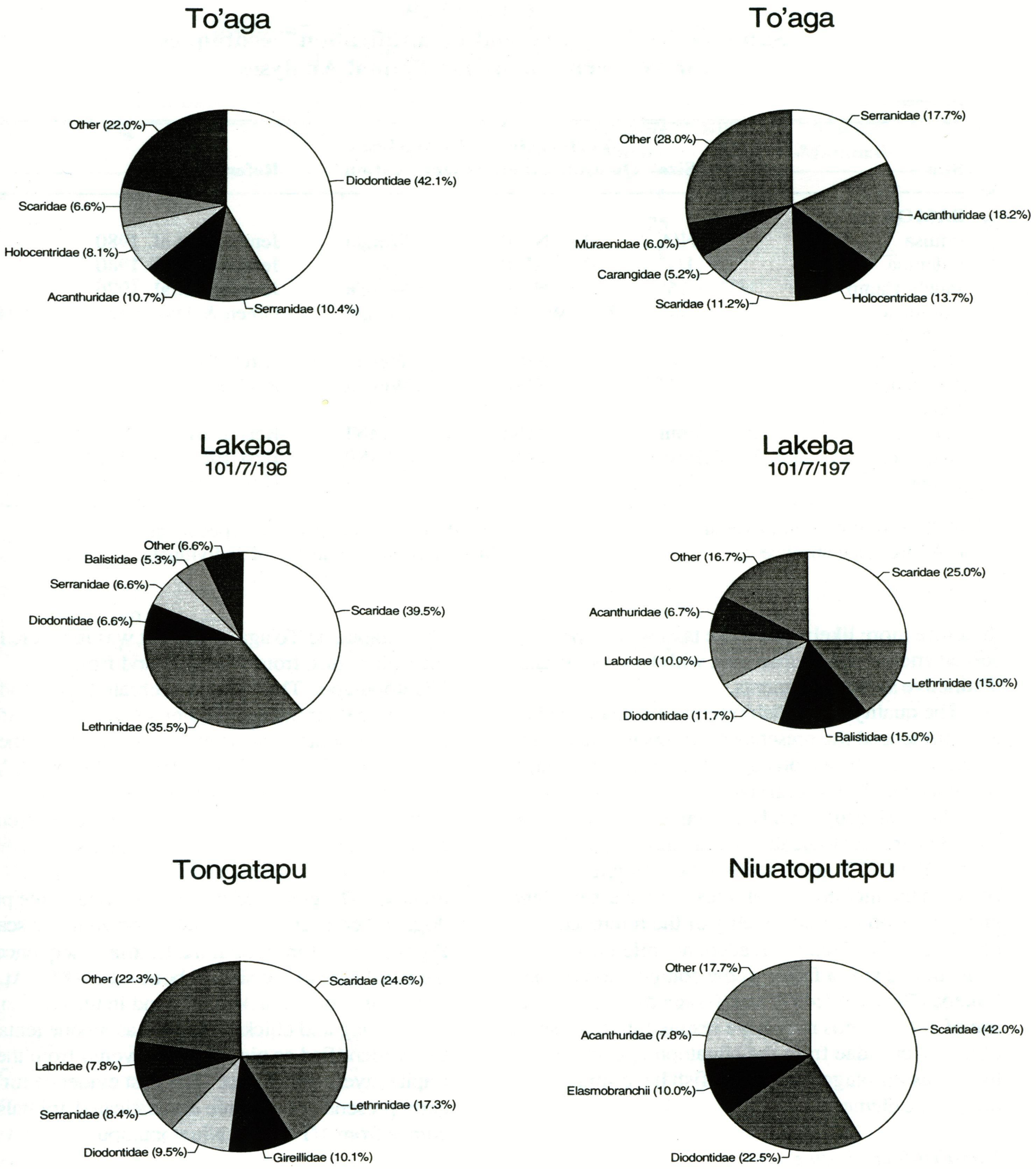

Figure 13.3 Percentage composition of fish faunal assemblages from major Western Polynesian and Fijian sites; the two diagrams for the To'aga site are with and without Diondontidae.

Table 13.19
Summary of Recovery and Quantification Techniques for Western Polynesian Faunal Analyses

Site	Screen Size	Vertebrate Quantification	Invertebrate Quantification	Reference
SAMOA				
Potusa	N/A	P/A, NISP	Weight	Jennings et al. 1980
Falemoa	1/4"	P/A, NISP	Weight	Jennings et al. 1980
Jane's Camp	1/2", 3/16"	P/A, NISP	Weight	Jennings et al. 1976
Lotofaga	1/4"	P/A, Weight	Weight	Green & Davidson 1969, 1974
TONGA				
Niuatoputapu	1/4"	NISP	Weight	Kirch 1989
Tongatapu	1/4"	NISP	Weight	Poulsen 1987
FIJI				
Lakeba	2.5, 5, 9mm	MNI	MNI	Best 1984
Naigani	2.5, 3.5, 7.1mm	MNI	NISP	Best 1981; Kay 1984
Yanuca	N/A	MNI	---	Hunt 1980

N/A, information not available
P/A, presence/absence
NISP, number of identified specimens
MNI, minimum number of individuals

therefore more likely that these taxa will be preserved and identified than taxa with less robust and distinctive skeletal elements.

The quality of the fish reference collections has also influenced the presence or absence of taxa in the assemblages. Based on ethnoarchaeological data, Mullidae and Pomacentridae are among the most abundant fish caught on Niuatoputapu, but none are recorded archaeologically (Kirch and Dye 1979). Kirch (1988:225) suggests that the differences between the modern and archaeological assemblages may be due to the poor quality of the reference collection. The lack of an adequate reference collection is also a factor in the composition of the Lakeba (Best 1981:497) and To'aga data. Finally the use of 1/4" screens may have resulted in the absence of Pomacentridae from the Niuatoputapu archaeological assemblage since these fish have small diagnostic elements.

Non-Fish Vertebrates

Compared to the fish, the non-fish vertebrate sample is smaller, but better reported (table 13.20). Rat, bird, and marine turtle are found at most sites. Marine mammal was identified at only two sites, Tongatapu and To'aga. Fruit bat was recovered from the Fijian sites, from Falemoa, and from Niuatoputapu. The 'wild' vertebrate fauna tend to be from earlier instead of later sites. Some of the largest amounts of turtle and bird were from the Lapita sites, TO-2, NT-90, 101/7/196 and 101/7/197.

Chicken is the most common of the three domesticated animals. Dog and pig are less abundant, possibly due to the problem of distinguishing between the two species when the bone is fragmented. The evidence for the presence of the pig, dog, and chicken from initial colonization is scant. Pig is present throughout the Lotofaga sequence, but the basal date of the site is about A.D. 1000. At Tongatapu, only chicken is found in the early site, TO-2. Dog and chicken, as well as a bone tentatively identified as pig, were recovered from the Lapita layers of Yanuca. The best evidence for the early presence of all three domesticated animals comes from NT-90, on Niuatoputapu.

Invertebrates

The invertebrate component comprises a large proportion of Western Polynesian faunal assemblages. The most abundant taxa vary across sites,

Table 13.20
Summary of Western Polynesian Vertebrate Faunal Assemblages (NISP)

Site	Pig	Dog	Chicken	Rat	Fruit Bat	Marine Turtle	Bird	Marine Mammal	Fish
To'aga	1	---	15	380	---	56	139	27	2196
Jane's Camp	---	---	P	---	---	25	P	---	87
Falemoa	2	---	---	---	P	P	P	---	P
Potusa	37	---	P	---	---	---	---	---	10
Lotofaga									
Locus A	P	P	---	P	---	---	P	---	>39g
Locus B	P	P	---	P	---	---	P	---	>74g
Locus C	P	P	---	P	---	---	P	---	>61g
Tongatapu									
TO-1	10	---	47	294	---	17	125	---	72
TO-2	---	---	7	9	---	404	109	2	43
TO-3	3	---	1	2	---	19	42	---	1
TO-4	---	---	---	---	---	1	2	---	---
TO-5	---	---	3	2	---	18	73	1	27
TO-6	189	---	16	198	---	15	167	1	36
Total	202	---	74	505	---	474	504	4	179
Niuatoputapu									
NT-90	2	4	12	1	1	71	31	---	10
NT-91	---	---	---	---	---	---	---	---	1
NT-93	3	---	6	---	---	6	1	---	15
NT-100	5	---	7	16	---	10	3	---	46
NT-110	---	7	1	---	---	---	1	---	11
NT-112	3	---	37	---	---	2	7	---	4
NT-113	---	---	---	---	---	---	---	---	1
NT-135	19	3	3	---	---	3	4	---	12
NT-163	1	---	26	---	---	1	5	---	34
Total	33	14	92	17	---	93	52	---	231
Lakeba									
101/7/196	---	---	19	---	---	28	2	---	76
101/7/197	---	---	2	20	11	8	69	---	60
101/7/47	1	2	---	---	---	22	1	--	180
101/7/132	3	1	---	---	---	3	---	---	7
101/7/135	---	---	---	---	---	---	1	---	---
101/7/2b	---	1	---	---	---	---	---	---	---
101/7/166	---	1	---	---	---	---	---	---	---
Total	4	5	21	20	11	61	72.	---	323
Naigani	---	1	---	3	5	12	4	---	18
Yanuca	4	2	2	4	2	9	11	---	23

P = present in unknown quantities

but the dominant taxa tend to reflect the marine environment near the site. For example, the exploitation of a sheltered lagoon is reflected in the abundance of bivalves in the Tongatapu assemblage. Other sites contain mainly *Turbo* or other taxa reflecting the exploitation of a fringing reef environment. Changes in the dominant taxa at Niuatoputatpu, Tongatapu, and Lakeba are also used to indicate changing marine environments.

While it appears that the most abundant taxa are good indicators of environment, the influence of environmental versus cultural factors still needs to be determined. As at To'aga, the bulk of the invertebrate assemblages is concentrated in a few taxa. Whether this uneven distribution reflects the exploitation of naturally abundant taxa or cultural preferences will need to addressed in future studies.

CONCLUSIONS

The analysis of the To'aga faunal assemblage has generated a number of new questions. Despite the time depth represented at the To'aga site, there is a striking lack of change in the resources exploited. A few taxa comprise a large percentage of the fish and invertebrate components of the assemblage. The overall pattern of high diversity may reflect the exploitation of naturally abundant taxa or culturally preferred taxa. Population studies of marine environments off To'aga would be useful for creating a baseline of natural distributions which could then be compared to the archaeological data.

Addressing these and other faunal questions requires data robust enough to compile into a cumulative data base and to use at a level higher than nominal. The To'aga analysis has shown that methodological biases introduced during excavation and analysis can severely affect the data, reducing its robustness. Thus, interpretations must be made cautiously. The problems created by these biases are compounded when data are compiled from different sites into a regional data base. Variability in and among data sets may be attributed to differences in recovery or analytical techniques rather than prehistoric cultural patterning. Faunal analysis can be a useful tool for understanding subsistence practices, an important aspect of prehistoric culture. Its utility in future studies, however, depends upon the commitment of faunal analysts and archaeologists to create quality faunal data.

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14

BIRD BONES FROM THE TO'AGA SITE: PREHISTORIC LOSS OF SEABIRDS AND MEGAPODES

DAVID W. STEADMAN

INTRODUCTION

As PART OF A LONG-TERM program to reconstruct the natural distribution and diversity of birdlife in the South Pacific (figure 14.1), I have sought bird bones from archaeological sites in many different archipelagos. Until recently, the islands of Samoa have not been represented in this data base. In 1987, T. L. Hunt and P. V. Kirch conducted excavations at the To'aga site (AS-13-1), Ofu Island, American Samoa yielding a small sample of bird bones representing at least six taxa (Steadman 1990). This first glimpse of the prehistoric avifauna of Samoa showed that at least two species (a shearwater and petrel) had been lost on Ofu since the first arrival of humans more than 3000 years ago. Hunt and Kirch expanded the excavations at To'aga in 1989. This paper reports the entire bird bone assemblage from both the 1987 and 1989 field seasons. The sample of bird bones from To'aga now consists of at least fifteen taxa (table 14.1) and provides a more thorough, although still far from complete, portrayal of the birdlife of ancient Samoa.

The bird bones from To'aga have been catalogued in the University of Washington Burke Museum (UWBM) Fossil Bird Collection. Comparative skeletal or oological specimens are from UWBM, the British Museum (Natural History) (BMNH), the New York State Museum (NYSM), and the United States National Museum of Natural History, Smithsonian Institution (USNM). In the species accounts that follow, "Unit" refers to meter square excavations (designated with Arabic numerals). Roman numerals refer to stratigraphic layers. For details of the stratigraphy, chronology, material culture, and non-bird faunal assemblages of the To'aga site, see Hunt and Kirch (1988), Kirch et al. (1989, 1990), and various chapters in this volume.

Unless stated otherwise, the modern distributions of species within American Samoa are taken from the excellent surveys conducted in 1975-1976 by Amerson et al. (1982a,b) and in 1986 by Engbring and Ramsey (1989). Modern distributions for elsewhere in Polynesia are taken from Pratt et al. (1987). The prehistoric records are from Steadman (1989a) and from unpublished data from my recent research; islands preceded by an asterisk (*) represent extirpated populations.

SPECIES ACCOUNTS

Order Procellariiformes
Family Procellariidae

Puffinus pacificus (Wedge-tailed Shearwater)

MATERIAL. Humerus (UWBM 1680), T9/500E, Unit 21, IIB. Five ulnae (UWBM 1244, 1251,

Table 14.1
Bird Bones from the To'aga Site

Taxa	Number of Identified Bones
Seabirds	
**Puffinus pacificus*	11
**Puffinus lherminieri*	2
**Puffinus griseus*	15
**Pterodroma rostrata*	6
**Pterodroma* sp., size of *P. heraldica*	2
(*)Procellariidae sp.	9
**Sula sula*	1
Fregata sp.	2
Anous stolidus	1
Gygis alba	1
Sterninae sp.	1
Landbirds	
Egretta sacra	1
Numenius tahitiensis (M)	1
Gallus gallus (I)	16
**Megapodius* sp.	2
Gallicolumba stairii	3
TOTAL	15/74
Total Seabirds (species/bones)	10/51
Total Landbirds (species/bones)	5/23
Total Native Landbirds, without I,M (species/bones)	4/7
% of Bones from Extirpated Species (without I,M)	85%

I=Introduced species
M=Migrant Species
* Extirpated on Ofu
(*) represents extirpated species, but not necessarily different from those already listed.

1256, 1678, 1679), Unit 9, IIB; Unit 5, IIC; Unit 14, IIIa-4; T9/500E, Unit 21, IIB (2 bones). Radius (UWBM 1664), T9/500E, Unit 20, IIIB. Carpometacarpus (UWBM 1630), T3/200W, Unit 27, IIIA. Tibiotarsus (UWBM 1642), T5/100E, Unit 28, IIB. Two pedal phalanges (UWBM 1246, 1248), Unit 4, IIB; Unit 1, IIB.

REMARKS. This tropical shearwater is rarely noted at sea today in American Samoa. It may nest on Pola Islet (off Tutuila) and on Ta'u, but this has not been confirmed. There are no previous records from Ofu. It is widespread in Polynesia today, although nesting islands are few. Other Polynesian archaeological records of *Puffinus pacificus* are from *Ua Huka and *Tahuata (Marquesas), *Huahine (Society Islands), *Lifuka and *'Eua (Tonga), and Tikopia and Anuta (Solomon Islands).

Puffinus lherminieri (Audubon's Shearwater)

MATERIAL. 2 ulnae (UWBM 1651, 1671), T9/500E, Unit 23, IIB; T9/500E, Unit 21, IIB.

REMARKS. Within American Samoa, *Puffinus lherminieri* nests only on Ta'u, where at least 200 birds breed in the cloud forest, and on Tutuila (colony size unknown). It is uncommon at sea and has not been recorded previously on Ofu. Like *P. pacificus*, *P. lherminieri* nests today on relatively few islands scattered across Polynesia. Other Polynesian archaeological records of *P. lherminieri* are from *Nuku Hiva, Ua Pou, *Ua Huka, *Hiva Oa, and *Tahuata (Marquesas), *Huahine (Society

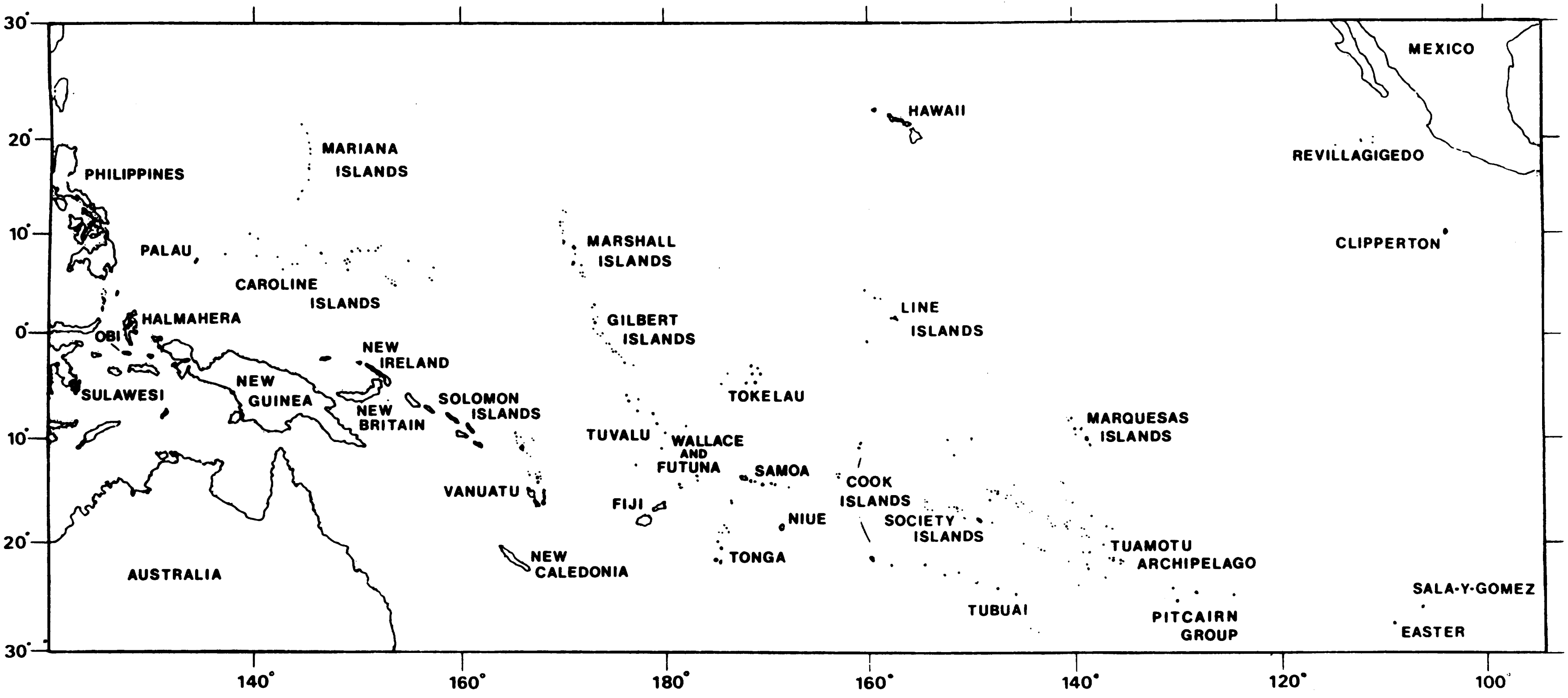

Figure 14.1 Map of the Pacific Islands, showing localities mentioned in the text.

Islands), *Mangaia (Cook Islands), 'Eua (Tonga), and Tikopia and *Anuta (Solomon Islands).

Puffinus griseus (Sooty Shearwater)

MATERIAL. Sternum (UWBM 1681), T9/500E, Unit 21, IIB. Coracoid (UWBM 1645), T5/100E, Unit 29, IIIB. Scapula (UWBM 1245), Unit 9, IIB. Three humeri (UWBM 1641, 1643, 1659), T5/100E, Unit 29, II; T5/100E, Unit 28, IIB; Unit 20, IIB. Three ulnae (UWBM 1240, 1241, 1647), Unit 11, II-8 (2 bones); T5/100E, Unit 30, II. Carpometacarpus (UWBM 1259), Unit 7, IIA. Manus digit (UWBM 1260), Unit 7, IIA. Pelvis (UWBM 1674), T9/500E, Unit 21, IIB. Three tibiotarsi (UWBM 1252, 1253, 1652), Unit 6, IIA (2 bones); T9/500E, Unit 23, IIIA.

REMARKS. As reported by Steadman (1990), these bones are larger than those of any species of shearwater that resides today in tropical Polynesia. They agree in all osteological details with bones of *Puffinus griseus*, a species that probably migrates through the Samoan region today (Harrison 1983:260, 420; Pratt et al. 1987:55), although there are no records from American Samoa. The Sooty Shearwater nests today only on islands off New Zealand, southern Australia, and extreme southern South America (Harrison 1983:260, 420). Most of the nesting localities of *P. griseus* are temperate or subantarctic, although in Australia nesting occurs at least as far north as 32° 40' S on the subtropical Broughton Islands.

Three possible explanations for the unexpected presence of *Puffinus griseus* on Ofu were proposed by Steadman (1990): (1) the bones represent migrant birds taken at sea by fishermen; (2) *P. griseus* once resided on Ofu and, like other procellariids, was extirpated through predation in their nesting burrows by humans and rats; (3) the bones represent an extinct, resident shearwater that differs specifically or subspecifically from modern *P. griseus* but is osteologically very similar. Regarding the first explanation, I am aware of no ethnographic accounts of Polynesians capturing seabirds while fishing. The data now available, particularly that fifteen bones (nine different skeletal elements) are osteologically indistinguishable from modern skeletons of *P. griseus*, suggest that the second explanation may be correct, even though the oceanographic conditions near Ofu are warmer than those of the warmest localities where *P. griseus* nests today. That this large shearwater (or an osteologically indistinguishable subspecies [explanation 3 is not necessarily incompatible with explanation 2]) was once resident rather than migrant on Ofu is indicated by the presence at To'aga of two bones of *P. griseus* (UWBM 1645, 1653) that, based upon porosity of the external surface, are from volant juveniles unlikely to have dispersed far from their place of birth. The former residency of *P. griseus* on Ofu is supported further by the abundance of its bones at To'aga (15 of 74, or 20% of identifiable bones). Sooty Shearwaters are represented as well among the few bird bones from a Lapita site on *Niuatoputapu (Tonga), southwest of American Samoa (Steadman 1990).

Pterodroma rostrata (Tahiti Petrel)

MATERIAL. Two mandibles (UWBM 1250, 1682), Unit 4, IIB; T9/500E, Unit 21, IIB. Scapula (UWBM 1684), T9/500E, Unit 21, IIB. Humerus (UWBM 1657), T9/500E, Unit 20, IIB. Ulna (UWBM 1242), Unit 5, IIA. Tarsometatarsus (UWBM 1247), Unit 4, IIB.

REMARKS. This large petrel nests today at a few widely scattered localities in the Marquesas Islands, Tahiti, New Caledonia, and American Samoa. Its presence on the latter is based upon a colony of about 500 individuals discovered in 1976 in the montane cloud forest of Ta'u, a single nesting bird discovered on Tutuila in 1986, and a few birds heard on Olosega in 1986. An onshore record in 1972 from Taveuni (Clunie et al. 1978) suggests that *Pterodroma rostrata* may nest in Fiji as well. Elsewhere in Polynesia, *P. rostrata* has been identified from archaeological sites on *Ua Huka and Tahuata (Marquesas), *Huahine (Society Islands), *Aitutaki (Cook Islands), *Lifuka and *'Eua (Tonga), Tikopia (Solomon Islands), and New Caledonia.

Pterodroma sp. (unknown petrel, size of *P. heraldica*)

MATERIAL. Radius (UWBM 1670), T9/500E, Unit 21, IIB. Femur (UWBM 1676), Unit 21, IIB.

REMARKS. These specimens, although not adequate for species-level identification, represent a species of *Pterodroma* in the approximate size range of *P. heraldica* (Herald Petrel, which often is considered conspecific with *P. arminjoniana*) or perhaps the slightly larger *P. externa* (Juan Fernandez Petrel), both of which are significantly smaller than *P. rostrata*. In American Samoa, *P. externa* is known only from uncommon sightings at sea, while *P. heraldica* nests on Ta'u. Regardless of species-level identification, UWBM 1670 and 1676 indicate that a species of petrel other than *P. rostrata* probably once nested on Ofu.

Procellariidae sp. (unknown petrel/shearwater)

MATERIAL. Coracoid (UWBM 1633), T5/100E, Unit 16, II. Five ulnae (UWBM 1243, 1258, 1634, 1662, 1669), Unit 9, IIB; Unit 5, IIB; T5/100E, Unit 16, I; T9/500E, Unit 20, IIIB; T9/500E, Unit 21, IIB. Radius (UWBM 1249), Unit 4, IIB. Two carpometacarpi (UWBM 1239, 1677), Unit 9, IIB; T9/500E, Unit 21, IIB.

REMARKS. These fragmentary bones cannot be identified beyond the family level. They do not represent a taxon separate from those already identified.

Order Pelecaniformes
Family Sulidae

Sula sula (Red-footed Booby)

MATERIAL. Radius (UWBM 1656), T9/500E, Unit 20, IIIC.

REMARKS. *Sula sula* nested on Ofu as recently as 1975-76 (only twenty-five birds), but the small colony no longer existed in 1986. This booby still nested in 1986 on Tutuila and Rose islands. It is widespread in tropical oceans. Other Polynesian archaeological records of *S. sula* are from *Henderson (Pitcairn Group); *Ua Huka, *Hiva Oa, and *Tahuata (Marquesas); *Huahine (Society Islands); *Aitutaki (Cook Islands); Niuatoputapu (Tonga); and *Tikopia and *Anuta (Solomon Islands).

Family Fregatidae

Fregata sp. (unknown frigatebird)

MATERIAL. Humerus (UWBM 1254), Unit 14, IIIa-4. Ulna (UWBM 1675), T9/500E, Unit 21, IIB.

REMARKS. These specimens cannot be distinguished from those of *Fregata minor* or *F. ariel*, both of which visit but do not nest on Ofu today (total of thirteen birds counted in 1975-76; still recorded as a visitor in 1986). The bones of *F. minor* males and *F. ariel* females are similar in size and difficult to distinguish from each other (Steadman et al. 1990). Both species of *Fregata* occur fairly commonly in Polynesian archaeological sites.

Order Charadriiformes
Family Laridae

Anous stolidus (Brown Noddy)

MATERIAL. Humerus (UWBM 1668), T9/500E, TP 21, IIB.

REMARKS. This tern is common and widespread today in American Samoa as well as most of Polynesia. The Ofu population was ca. 500 in 1975-76 and was not accurately estimated in 1986. Other Polynesian archaeological records of *Anous stolidus* are from Henderson (Pitcairn Group); Ua Pou, Ua Huka, and Tahuata (Marquesas); Huahine (Society Islands); Mangaia and Aitutaki (Cook Islands); Niuatoputapu, Lifuka, and 'Eua (Tonga); 'Upolu (Western Samoa); Tikopia and Anuta (Solomon Islands); and Mussau (Papua New Guinea).

Gygis alba (Common Fairy-Tern)

MATERIAL. Humerus (UWBM 1631), T5/100E, Unit 16, I.

REMARKS. This distinctive tern is common and widespread today in most of Polynesia including American Samoa. The Ofu population was ca. 100 in 1975-76, and at least 500 in 1986. Other Polynesian archaeological records of *Gygis alba* are from Henderson Island (Pitcairn Group), Ua Huka and Tahuata (Marquesas), Huahine (Society Islands), Mangaia (Cook Islands), and Niuatoputapu and 'Eua (Tonga).

Sterninae sp. (unknown tern)

MATERIAL. Ulna (UWBM 1257), Unit 14, IIIb-5.

REMARKS. This eroded, fragmentary specimen represents a tern smaller than either of the above species. UWBM 1257 is approximately the size of the ulna in *Sterna sumatrana* or *Anous minutus*, both of which occur today in American Samoa, although only the latter nests on Ofu (just ten birds in 1975-76, and perhaps about the same in 1986).

Order Ciconiiformes
Family Ardeidae

Egretta sacra (Pacific Reef-Heron)

MATERIAL. Coracoid (UWBM 1655), T9/500E, Unit 22, I.

REMARKS. *Egretta sacra* resides throughout American Samoa and most of Polynesia today. It is uncommon on Ofu, where only dark-phase birds have been recorded. Other archaeological records are from Nuku Hiva and Ua Huka (Marquesas), Huahine (Society Islands), Mangaia and Aitutaki (Cook Islands), and 'Eua (Tonga).

Order Charadriiformes
Family Scolopacidae

Numenius tahitiensis (Bristle-thighed Curlew)

MATERIAL. Coracoid (UWBM 1635, 1636; originally believed to be two separate bones), T5/100E, Unit 15, IIID.

REMARKS. This widespread but rather uncommon migrant shorebird has not been recorded previously from Ofu, although undoubtedly it still occurs there occasionally. American Samoan records of *Numenius tahitiensis* are confined to Tutuila, Ta'u, Swains, Rose, and Olosega. Other Polynesian archaeological records for *N. tahitiensis* are from Henderson Island (Pitcairn Group), Ua Huka (Marquesas), Huahine (Society Islands), Mangaia and Aitutaki (Cook Islands), and Tikopia (Solomon Islands).

During the autumn wing molt, thirteen of twenty-nine individuals of *N. tahitiensis* captured on Laysan (Leeward Hawaiian Islands) were flightless (Marks et al. 1990). This adaptation would seem to be viable only in a predator-free setting. It may have led to reductions in the distribution and abundance of *N. tahitiensis* following the human colonization of Polynesia.

Order Galliformes
Family Megapodiidae

Megapodius sp. (Unknown Megapode)

MATERIAL. Ulna (UWBM 1637), T5/100E, Unit 15, IIID. Femur (UWBM 1649), Unit 30, IIID.

REMARKS. These two fragmentary specimens (fig. 14.2) are most similar quantitatively and qualitatively to modern specimens of *Megapodius freycinet*, a widespread species that now reaches its eastern limit in Vanuatu. UWBM 1649 is indistinguishable qualitatively from the femur in modern *M. freycinet*, while UWBM 1637 differs from the ulna of *M. freycinet* in having a slightly deeper sulcus radialis and in lacking a diagonal trough on the cranial surface of tuberculum carpale.

Like the archaeological specimens of *Megapodius freycinet* from *Tikopia (Solomon Islands; Steadman et al. 1990), the specimens of *Megapodius* from To'aga are at the extreme small end of the size range *of M. freycinet* (table 14.2). Among living subspecies of *M. freycinet*, there is no indication that individual body size decreases eastward in Oceania. For example, the tarsus (in skins) of the Vanuatu population is not smaller than that from Australia (table 14.3). The bones from To'aga are larger than in *M. pritchardi* (confined to Niuafo'ou, Tonga) and *M. laperouse* (found only in Palau and Mariana Islands), but much smaller than in two extinct species recently described from late Holocene archaeological and paleontological sites—*M. molistructor* of New Caledonia and Lifuka and *M. alimentum* of Lifuka and 'Eua (Balouet and Olson 1989; Steadman 1989b, pers. obs.). *Megapodius pritchardi* is the only species of megapode that survives east of Vanuatu.

Both To'aga specimens of *Megapodius* are from one of the site's deepest and oldest strata, Layer IIID in units 15/29/30. This suggests that megapodes may have been lost from Ofu not long after prehistoric colonization of the island. These bones provide the first unequivocal, well-documented record of a megapode from Samoa. There is, however, complicated historical evidence that a megapode, described as *M. stairi* by Gray (1861), may have existed in the mid-1800s on 'Upolu or Savai'i (Western Samoa). Gray (1861) also described *M. burnabyi* from

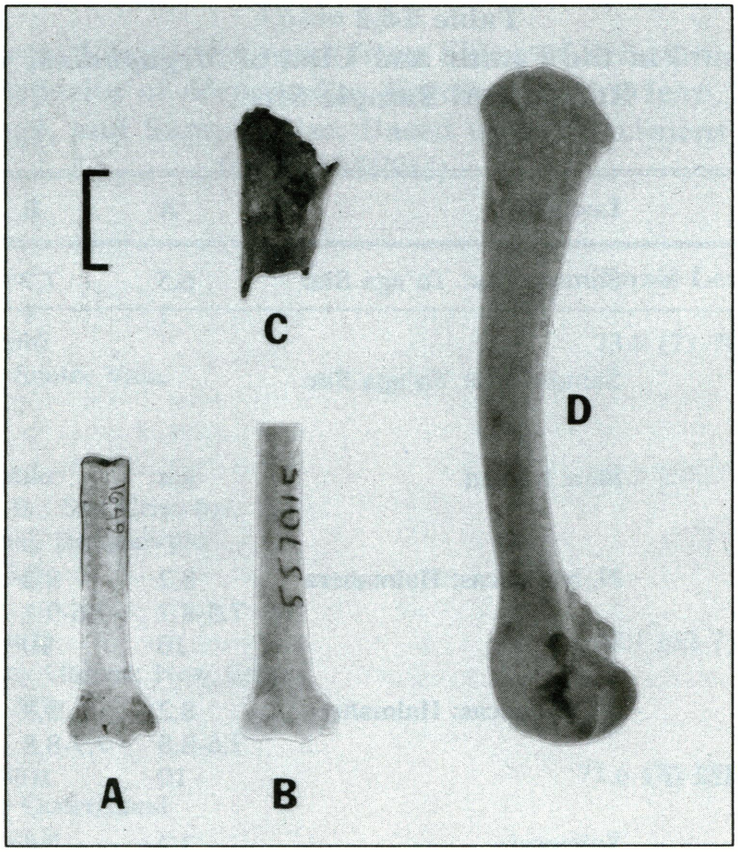

Figure 14.2 Comparison of megapode bones: ulna in ventral aspect (A, B) and femur in lateral aspect (C, D). A, C. *Megapodius* cf. *freycinet*, archaeological specimens (UWBM 1637, 1649), To'aga site, Ofu, American Samoa. B, D. *M. freycinet*, modern specimen, USNM 557015, male, Halmahera, Northern Moluccas. Scale = 20 mm.

Ha'apai (Tonga). The true identities of *M. stairi* and *M. burnabyi* are uncertain because only a single egg ever was collected of each, and these two eggs cannot be assigned unequivocally to *M. pritchardi*, *M. freycinet*, or any other species of megapode (Steadman 1991). One or both of these eggs may represent the same species as the bones from Ofu, which also are at the very lower limit of the size range of *M. freycinet* and larger than, or at the uppermost size limit of, *M. pritchardi*.

The original, handwritten data slip with the holotypical egg of *Megapodius burnabyi* in the British Museum notes that this egg was "called the 'chief's egg' as they are only allowed to eat them." Such a chiefly tabu might suggest rarity of the bird and a knowledge that overexploitation, which probably was the cause of the rarity, would eventually lead to extinction. Alternatively, being called the "chief's egg" could suggest that megapode eggs were prestigious trade items brought to Ha'apai from another island. An extensive exchange network operated among Fiji, Tonga, and Samoa in late prehistoric and early historic times (Kirch 1984:238-42; 1988:257-60). The Samoan voyages recorded by Stair (1895) included Fiji and Tonga as well as much of East Polynesia. Bennett (1862:247) noted that the nesting grounds of *M. pritchardi* on Niuafo'ou were "under the protection of the king or chief, and by his permission only can the birds or eggs be procured." Even if megapodes of the Fiji/Tonga/Samoa region were confined by the nineteenth century to Niuafo'ou, they would have been known to Tongans in Ha'apai, as well as to Samoans.

Unless additional evidence comes forth, neither

Table 14.2
Measurements (in mm) of the Femur and Ulna of *Megapodius*, with Mean, Range, and Sample Size

Specimen	Locality	A	B	C	D	E
Megapodious sp.	Samoa: Ofu: To'aga Site	6.5	7.7	-	-	-
UWBM 1637 (U)		1	1			
Megapodius sp.	Samoa: Ofu: To'aga Site	-	-	4.4	3.3	6.8
UWBM 1649 (U)				1	1	1
M. f. cf. *eremita*	New Ireland	8.4	-	4.9	-	7.3
Lab #: 66, 68 (U)		1		1		1
M. f. freycinet	N. Moluccas: Halmahera	8.2	8.2	5.0	3.8	7.4
USNM 556995-557002		7.5-8.7	7.6-9.1	4.7-5.3	3.3-4.1	7.0-7.9
557016, 557017 (M)		10	10	10	10	10
M. f. freycinet	N. Moluccas: Halmahera	8.2	8.3	4.9	3.7	7.3
USNM 557006-557008		7.6-8.8	7.7-8.8	4.6-5.4	3.5-4.1	7.0-7.8
557010-557013, 557019-557022 (F)		10	10	10	10	10
M. f. gilberti	Sulawesi	7.2	7.4	4.3	3.2	6.5
USNM 226175, 226176 (F, M)		6.9-7.5	7.3-7.6	4.3	3.2-3.3	6.5
		2	2	2	2	2
M. f. cumingi	Philippines: island	8.1	8.0	5.2	4.1	7.4
BM(NH) 1862.2.10.2 (U)	unknown	1	1	1	1	1
M. f. nicobariensis	Nicobar Islands	8.3	8.3	5.0	3.8	7.8
USNM 19686, 19700 (M)		8.0-8.6	8.2-8.4	4.9-5.0	3.6-4.0	7.6-7.9
		2	2	2	2	2
M. pritchardi	Tonga: Niuafo'ou	5.6	6.0	3.4	2.8	5.2
USNM 319633, 319634 (U)		5.4-5.7	5.9-6.1	3.3-3.5	2.8-2.9	5.0-5.3
		2	2	2	2	2
M. laperouse	N. Mariana Islands:	-	-	3.4	2.5	5.4
USNM unnumbered (U)	Rota: Payapai Cave			1	1	1
M. alimentum	Tonga: 'Eua:	-	-	6.0	4.4	-
UWBM 2100 (U)	'Anatu (Ground-Dove Cave)			1	1	

F = Female, M = Male, U = Sex unknown

Column Headings:

A. Femur: width at deepest proximo-lateral muscle scar
B. Femur: depth at deepest proximo-lateral muscle scar
C. Ulna: minimum width of shaft
D. Ulna: minimum depth of shaft
E. Ulna: width of distal end

Table 14.3
Tarsal Length (in mm) from Skins of Selected Subspecies of *Megapodius freycinet*, with Mean, Range, and Sample Size. Based upon Specimens from BM(NH).

Subspecies	Tarsal Length
M. f. layardi Vanuatu: Santo, Vate (F, 5M)	73.8 (71-76), 6
M. f. eremita Solomon Is.: San Cristobal, Guadacanal, Bouganville (3F, 2M, U)	72.2 (67-77), 6
M. f. eremita Papua New Guinea: New Britain (3F, 2M, 3U)	67.1 (62-71), 8
M. f. yorki Australia: Queensland (2F, 4M, 4U)	71.6 (70-74), 10

F = female, M = male, U = sex unknown

Megapodius stairi or *M. burnabyi* should be regarded as certain records of indigenous populations of megapodes in nineteenth century Samoa or Ha'apai, although this cannot be ruled out. The survival of *M. pritchardi* on Niuafo'ou has been due to chiefly control of exploiting eggs and birds at the conspicuous nest mounds, as first described by Bennett (1862). The people of Niuafo'ou must have realized that conserving megapodes, which probably occurred nowhere else in the region, would help to maintain their share of commerce in the Samoa-Tonga-Fiji trade network.

Family Phasianidae

Gallus gallus (Chicken)

MATERIAL. Sternum (UWBM 1261), Unit 11, II. Coracoid (UWBM 1654), T9/500E, Unit 23, IIIB. Scapula (UWBM 1663), T9/500E, Unit 20, IIIB. Ulna (UWBM 1255), Unit 14, IIIa-4. Radius (UWBM 1660), T9/500E, Unit 20, IIIB. Two pelves (UWBM 1665, 1686, 1688; the last two originally believed to be separate bones), T9/500E, Unit 20, IIIB; T9/500E, Unit 21, IIB. Two femora (UWBM 1666, 1667), T9/500E, Unit 20, IIIB. Four tibiotarsi (UWBM 1632, 1644, 1658, 1661), T5/100E, Unit 16, I; T5/100E, Unit 29, IIIB; T9/500E, Unit 20, IIB; T9/500E, Unit 20, IIIB. Two tarsometatarsi (UWBM 1646, 1683), Unit 29, IIIB; Unit 21, III.

REMARKS. Feral and/or domestic populations of *Gallus gallus* occur nearly throughout Polynesia, including all inhabited Samoan islands. All chickens recorded on Ofu in 1986 were near human habitation and not from deep within forests. This non-native species has been found through virtually all of Polynesia in archaeological sites of any age, except that it is absent from all sites on Henderson Island (Schubel and Steadman 1989). Chicken bones occur throughout the To'aga sequence, but are especially well represented in the Layer IIIB occupation in Units 20/23 along Transect 9. This indicates that *G. gallus* was a commonly eaten bird during the Ancestral Polynesian phase, ca. 2500 yr B.P.

Order Columbiformes
Family Columbidae

Gallicolumba stairii (Shy Ground-Dove)

MATERIAL. Humerus (UWBM 1638), T5/100E, Unit 15, IIID. Ulna (UWBM 1658), Unit 30, IIID. Tarsometatarsus (UWBM 1690), T5/100E, Unit 29, IIID.

REMARKS. This species occurs only in very old deposits at To'aga, primarily Layer IIID in Units 29/30. *Gallicolumba stairii* is extremely rare on Ofu today, with a very roughly estimated 100 birds surviving in 1975-76. Only two or three ground-doves were seen on Ofu during the 1986 surveys; no population estimate was made. Within American Samoa, only perhaps on Olosega does another small population of *G. stairii* survive. Similar declines or losses of populations of *G. stairii* have occurred in Tonga, where the only other archaeological record of *G. stairii* is from *'Eua.

DISCUSSION

Virtually all of the bird bones from To'aga are broken, often with both articular ends missing. Most of these breaks are not fresh, although often it is difficult to distinguish whether human or sedimentary processes have caused the breakage. A few bones are rounded, suggesting some post-mortem sedimentary transport. The breakage and rounding might indicate that the calcareous sands at To'aga represent a somewhat higher energy deposit than the calcareous sands at certain other Polynesian archaeological sites, such as Hane (Ua Huka, Marquesas) or Tongoleleka (Lifuka, Tonga). Among the shearwaters and petrels, however, a systematic butchering technique is suggested by the fairly consistent pattern of both ends of the humerus, ulna, and tibiotarsus being broken off. Two of the chicken bones had been chewed by rats. None of the bird bones seems to have been modified into recognizable artifacts.

Among indigenous, resident species recorded from the To'aga site, five of ten seabirds and one of three landbirds are extirpated on Ofu (table 14.1). At least two of the surviving species (Sterninae sp., *Gallicolumba stairii*) exist today on Ofu only in very small, threatened populations. Should these species be lost from Ofu, the proportion of bones of extirpated species at To'aga would increase from 85% (table 14.1) to 93%.

The majority of bird bones from To'aga (46 of 74, or 62%) are of at least five species of petrels or shearwaters (table 14.1), none of which nests on Ofu today (Amerson et al. 1982a:90). Only two of these species (Audubon's Shearwater and Tahiti Petrel) are known certainly to nest today anywhere in American Samoa. As seems to be case throughout Polynesia (Steadman 1989a, Dye and Steadman 1990), the island of Ofu had a diverse and probably abundant seabird fauna when humans first arrived. In the case of Ofu, not a single species of procellariid has survived the three millennia of human occupation.

Compared to avian assemblages from other Polynesian archaeological sites, the dominance of procellariids at To'aga would characterize a fairly early site, i.e., one that dates to within the first thousand years of human occupation (Dye and Steadman 1990). When compared to sites that seem to represent the initial human occupation of an island, however, such as the Hane site (Ua Huka, Marquesas; Steadman 1989a) or Tongoleleka site (Lifuka, Tonga; Steadman 1989b), the To'aga site's lower percentage and diversity of bones from native landbirds and higher percentage of chicken bones would suggest that this site may not represent the first 500 years of human occupation of Ofu. This suggestion is compatible with the radiocarbon chronology at To'aga which indicates occupation of the site from about 2800 to 1900 yr B.P. (see Kirch, chapter 6).

Although the bird bones from To'aga provide much new data on the prehistoric distribution of Samoan birds, a bone sample about an order of magnitude larger would be necessary to provide a fairly complete picture of the past birdlife of Ofu. That six of the fifteen taxa of birds from To'aga are represented by only a single bone indicates that more species await discovery if a larger bone sample were available. The 1987 sample of twenty-three bones yielded six taxa, which increased to fifteen taxa with the addition of fifty-one bones from the 1989 excavations. The point of diminishing returns is difficult to determine, however, from comparison with assemblages from other sites. For example, thirty-five species of birds are represented in a sample of ca. 350 bones from the Fa'ahia site (Huahine, Society Islands; Steadman and Pahlavan

1992), while thirty-nine species of birds are represented in a sample of ca. 12,000 bones from the Hane site (Ua Huka, Marquesas) (Steadman 1989a, pers. obs.). Twelve of the species from Hane are known from either one or two bones. Another gauge of the incompleteness of the To'aga avifauna is the low percentage of species in the modern avifauna of Ofu that are represented at the site. In this case, only two of sixteen possible species of resident landbirds (12.5%) are represented.

The To'aga site has given us an intriguing introduction to Samoa's prehistoric birdlife. Our understanding of the relationship between native birds and the first human inhabitants of Samoa undoubtedly will improve as more early archaeological sites are discovered and carefully excavated.

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SYNTHESIS AND INTERPRETATIONS

P. V. KIRCH AND T. L. HUNT

PRIOR TO THE MANU'A PROJECT in 1986, our knowledge of the archaeology and prehistory of the most easterly Samoan islands—Ta'u, Olosega, and Ofu—was rudimentary indeed. Limited reconnaissance survey had revealed the presence of stone-and-earth monuments, especially house platforms, typical of Samoan settlement patterns on the larger islands (Kikuchi 1963). Attempts at excavation on Ta'u Island by a Bishop Museum expedition in 1962 (in one cave site and two open "cooking-house sites") were disappointing (Emory and Sinoto 1965:40-48), and no stratified materials were discovered that might be used to outline a cultural sequence. Although the Bishop Museum team collected 201 basalt adzes and coconut graters from Manu'a, these were all from surface contexts (Emory and Sinoto 1965, table 2). In short, at the commencement of our project, knowledge of Manu'an archaeology was limited to brief descriptions of surface sites and stone tools, with no time depth.

Against this background, our 1986 reconnaissance work throughout the Manu'a Group yielded a number of significant advances (Hunt and Kirch 1988). The number and range of surface monuments were extended considerably. Perhaps most importantly, several stratified sites were discovered, two of which on test excavation yielded ceramic assemblages radiocarbon dated to between 1950-1850 cal B.P. (Hunt and Kirch 1987). These results confirmed our initial expectations that the Manu'a Group would prove to have a deep prehistoric sequence extending back to the Ancestral Polynesian phase, quite probably in parallel with the sequence defined for Western Samoa (Green and Davidson 1969, 1974).

The preceding fourteen chapters have presented the detailed results of two subsequent seasons of concentrated field and laboratory research at the most promising of the ceramic-bearing sites discovered during the 1986 reconnaissance: the To'aga site on Ofu Island. In 1987 and again in 1989 we carried out a program of systematic subsurface sampling of the To'aga area, producing an areal and stratigraphic definition of what is currently the largest and most deeply stratified early site known for the entire Samoan archipelago. Although our research design was of necessity oriented first and foremost to considerations of cultural resource management (i.e., the spatial definition of the site and assessment of its significance), we have also been able to use this research opportunity to expand on certain aspects of our knowledge of Manu'an—and indeed general Samoan—prehistory. For example, we have formulated and tested a model of morphodynamic landscape change with implications for other coastal sites throughout the archipelago. Similarly, our various analyses of artifactual and faunal materials from the systematic transect excavations have enhanced the reconstructions of early Samoan material culture, subsistence economy, and inter-island exchange. In this concluding chapter, we attempt to integrate these significant new results from the To'aga site with the existing reconstructions and interpretations of Samoan prehistory, deriving primarily from work in Western Samoa (Green and Davidson 1969, 1974; Jennings et al. 1976; Jennings and Holmer 1980) and to a limited extent from recent work on Tutuila Island (e.g., Clark and Herdrich 1988; Clark 1989; Leach and Witter 1987; Best et al. 1989).

In presenting this synthesis, we are acutely aware that our fieldwork at To'aga has barely begun to tap the immense archaeological potential of this large and complex site. Our excavated sample of 31 m^2, while sufficient to give some idea of the extent and range of subsurface deposits and assemblages, represents a very small portion of the estimated 21,000 m^2 of buried, ceramic-bearing deposits present in the To'aga area. It will take a much larger effort, including the application of time-consuming and costly horizontal excavation methods, to begin to exploit fully the potential of this site to reveal unknown aspects of the Samoan past.

CHRONOLOGY AND CULTURAL SEQUENCE

The suite of fourteen radiocarbon age determinations from the To'aga site (see Kirch, chapter 6) constitutes the largest set of dates from a single excavation locality anywhere in the Samoan archipelago. These ^{14}C dates define a two-millennium long sequence of coastal terrace formation and occupation beginning ca. 3600 cal B.P. and continuing without pause up to ca. 1000 cal B.P. Although no radiocarbon dates younger than about 1000 cal B.P. were obtained during our fieldwork, this does not necessarily imply site abandonment during the last millennium. Rather, the distribution of radiocarbon dates from To'aga reflects our emphasis on testing and dating the earlier, deeply buried occupation deposits, as opposed to later surface features. Given the presence of various aceramic occupation pavements and mounds (*'ili'ili* pavements), grinding stones, *lua'i masi* breadfruit storage pits, other surface features throughout the To'aga area, and the presence of historic artifacts (see Hunt, chapter 3), it seems likely that To'aga was in fact continuously occupied by prehistoric Polynesians for a full three millennia. Indeed, this is the only site recorded to date in the archipelago that appears to encapsulate the entire prehistoric record of the islands, from initial settlement to historic contact.

The timing of initial human settlement in Western Polynesia has been a matter of some contention over the years and is directly relevant to current debates over the rate of dispersal and colonization of the southwestern Pacific by the makers of Lapita pottery (Kirch and Hunt 1988a,b; Spriggs 1990). Kirch (1988:244, table 48) summarized the radiocarbon evidence for initial settlement of Fiji, Tonga, and Samoa, based on such Lapita sites as Natunuku, Yanuca, Lakeba (Site 197), Naigani, To. 2, and Mulifanua. "Almost all of these [^{14}C] ages cluster between about the twelfth and ninth centuries B.C." (1988:244). The only site in Samoa which has yielded dentate-stamped Early Eastern Lapita pottery is Mulifanua, which has a single radiocarbon age of 1280-800 cal B.C. (based on a Δ-R value of 100 ± 24, and correction for the oceanic reservoir effect; see Leach and Green 1989).

The To'aga site provides additional new evidence for the timing of early, if not initial, settlement. (This qualification is necessary, because we cannot be certain whether our systematic transects actually exposed the earliest occupation deposits in the To'aga area. It is a distinct possibility that earlier strata are preserved under the deep colluvium and talus at the inland edge of the site, which could not be penetrated without the use of heavy mechanical equipment.) Our oldest ^{14}C sample in direct, unquestionable association with ceramics is Beta-35601 from Unit 28, at 1308-930 cal B.C. This age is essentially identical with that from the Mulifanua site and entirely consistent with the suite of dates from other early Western Polynesian localities. The radiocarbon sample was associated with thinware and thickware pottery, although no dentate-stamped sherds were present. The absence of dentate-stamping in this early context may simply be a function of sampling error (only 8 percent of the Mulifanua ceramics were decorated). Alternatively, it is possible that a stratum bearing dentate-stamped pottery lies further inland, under the impenetrable talus. A third possibility is that the decoration of pottery with dentate-stamping had ceased prior to the colonization of Ofu. Only further work at the To'aga site will be able to discriminate among these alternative hypotheses.

Despite the absence of "classic" dentate-stamped pottery, it is clear that Ofu Island and the Manu'a Group were colonized within the same general time period, between ca. 1200-900 cal B.C., as were Early Eastern Lapita sites in Western Samoa, Niuatoputapu, Tongatapu, Futuna, and Fiji. Given that Manu'a lies at the eastern extreme of the Western Polynesia region, this finding is quite significant. It implies that the Lapita colonization of the entire Fiji-Western Polynesian region was accomplished rapidly, with no appreciable lag between sites at the western and eastern boundaries. The settlement of Manu'a by the close of the second millennium B.C. also implies that Lapita populations were poised at the threshold of the vast eastern Pacific, thus raising again the question of whether there was truly a "long pause" between the settlement of Western and Eastern Polynesia (Irwin 1981; Kirch 1986; Terrell 1986). If highly successful and rapidly advancing island colonizers had moved as far to the east as Manu'a by 1000 B.C., it seems strange that they did not continue eastward into central Polynesia (the Cook, Society, and Austral archipelagoes) within the next two or three hundred years. Yet, at present we have no confirmed human habitation sites in central Polynesia dated to the first millennium B.C. (The earliest sites are still those in the Marquesas, probably dating to as early as 400-200 B.C., although this remains controversial, see Kirch 1986.) In sum, while our radiocarbon dates from To'aga confirm the pattern of rapid colonization of Western Polynesia by the end of the second millennium B.C., they also heighten the controversy surrounding the subsequent phase of human settlement of the eastern Pacific.

Another chronological issue of some concern within Western Polynesia has been the timing of the cessation of pottery manufacture and use. Poulsen's initial claims for a long sequence of pottery manufacture in Tongatapu have now been revised, and ceramic use appears to have ceased somewhere between about 400 cal B.C. and cal A.D. 50 (Poulsen 1987:83; see also Groube 1971). Based on a large number of ^{14}C dates from several pottery-bearing sites on 'Upolu, Green and Davidson (1974) put the date of pottery disappearance in Samoa after A.D. 300, somewhat later than the Tongatapu sequence. On Niuatoputapu Island, situated between Tonga and Samoa, radiocarbon dates from Sites NT-93 and -100, containing plainwares, may indicate the persistence of ceramic manufacture and use as late as A.D. 800-900 (Kirch 1988:142, 246). Thus, while there is a consistent pattern of pottery decline and eventual loss throughout Western Polynesia, the timing of this process may not be contemporaneous in all locations.

At To'aga, the youngest radiocarbon date in direct association with pottery (predominately coarse, thickware) is Beta-35924, at cal A.D. 319-473. Sample Beta-26463, which comes from the base of an aceramic midden deposit (in Unit 3), dates to cal A.D. 561-663, while Beta-35600 from an aceramic *'ili'ili* pavement, dates to cal A.D. 694-943. Thus, the radiometric evidence from To'aga indicates that the cessation of pottery manufacture and use in the Manu'a Group occurred during the fifth-sixth centuries A.D. If Green and Davidson's dating of pottery cessation in 'Upolu to approximately A.D. 300 is correct, there was a lag of 100-200 years in the Manu'a Group. Such chronological differences are certainly not surprising, especially in light of the known ethnographic differences between Manu'a and the rest of Samoa in historic times (Mead 1930; see Kirch, chapter 2).

The radiometric chronology developed for the To'aga site now allows the Manu'a Group to be incorporated into a cultural sequence for the Samoan archipelago as a whole. The initial settlement of Manu'a was pene-contemporaneous with that at Mulifanua, suggesting that all islands of the archipelago were settled fairly rapidly at the close of the second millennium B.C. Parallel changes in material culture during the following 1500 years are also evidenced (see further discussion below), with the cessation of ceramic manufacture in Manu'a possibly lagging behind 'Upolu by one or two centuries. One chronological issue not addressed at To'aga is the development of large monumental architecture (such as star mounds and tombs). (We were not permitted by the landowners to excavate in or near the Tui Ofu monumental complex situated within the To'aga area.) We suspect, however, that as in Western Samoa, these features will prove to date to the last millennium of Manu'a prehistory.

GEOARCHAEOLOGY AND LANDSCAPE CHANGE

A major thrust of our research program at To'aga has been the application of a geoarchaeological and geomorphological approach, in order to address questions of site formation processes. Given that most of the archaeological deposits and features at To'aga are deeply buried, a geomorphological approach was essential even for such basic objectives as location and subsurface mapping of archaeological deposits. Our aim, however, has been to go further and to explore the evidence for both natural and cultural processes of landscape change at To'aga over the three millennia represented in the prehistoric sequence. To this end, a morphodynamic model for the formation of the To'aga coastal terrace was developed (see Kirch, chapter 4) and has been explicitly tested on (1) stratigraphic relationships (see Kirch and Hunt, chapter 5), (2) radiocarbon dates (see Kirch, chapter 6), and (3) sedimentological analyses (see Kirch, Manning, and Tyler, chapter 7). Here we briefly summarize the major results of this effort, with particular attention to the broader implications for Western Polynesian prehistory.

One specific result of our strategy of systematic transect excavations at To'aga was the areal definition of the extent of subsurface archaeological deposits dating to the ceramic period. Although our excavation sample is admittedly small, the highly consistent distribution of pottery-bearing deposits in a narrow zone at the base of the talus slope allows us to predict with considerable accuracy the probable extent of these subsurface deposits. These early occupation layers are all associated with former beach-ridge environments, at a time when the shoreline was much closer to the cliff and talus, and when sea level was apparently at a +1-2 m stand. The inferred distribution of pottery-bearing occupation deposits (dating to between ca. 3000-1900 cal B.P.) is plotted in figure 15.1, which also depicts the probable location of the Ofu shoreline during the first millennium B.C. It is important to stress, however, that we were unable to determine precisely the *inland* boundary of these pottery-bearing deposits, as this lies somewhere under the modern talus slope. Lacking heavy mechanical equipment, it was impossible for us to penetrate the compact mass of colluvium and talus boulders (estimated to be as thick as 10-15 m in places) which caps the inland portions of these early layers. Probably these deposits do not extend any farther inland than 20-40 m from our inland-most test units.

Based on the distribution depicted in figure 15.1, the total area of buried subsurface archaeological deposits containing ceramics covers a minimum of 21,000 m^2, and a maximum of 35,000 m^2. By any Polynesian standards, this is a large site with considerable potential for future horizontal excavations.

As noted earlier in this volume (see Kirch, chapter 2), the coastal terrace running along the southern side of Ofu from To'aga to Fa'ala'aga comprises an important land use and resource zone for the island's Polynesian occupants. Given the island's very steep and rugged topography, this stretch of flat land is one of the few areas suitable for intensive arboriculture and for habitation. Yet, our geoarchaeological studies at To'aga clearly demonstrate that this coastal terrace is a highly dynamic accumulation form which developed into its present configuration only within the past 2,000 years—well after initial human colonization of the island. At the time of initial settlement, the coastal terrace was very narrow, consisting of little more than a beach ridge situated directly beneath the steep overhanging cliffs and talus. A phase of active progradation of this shoreline did not commence until about 1.9 kyr B.P. This progradation appears to have been initiated by a rapid fall in sea level (presumably a eustatic fall which is evidenced over much of the southwestern Pacific at this time, see chapter 4) equalling or slightly exceeding the rate of local subsidence, and thus exposing the reef flat to erosion and storm surges. The littoral, calcareous contribution to the sediment budget was thereby increased, producing a sufficient volume of sediment to prograde the shoreline between 40-100 meters from its location prior to 1.9 kyr B.P. Following the classification of "accumulation forms" proposed by Zenkovich (1971:95-97, fig. 4.1), the To'aga terrace is an attached form, specifically type c, a "terrace formed by the infilling of a concavity (supplied laterally)." In this case, the concavity was formed by the marine cliff inland of the site, which was deepest at the southwestern end of the coastal strip. The infilling

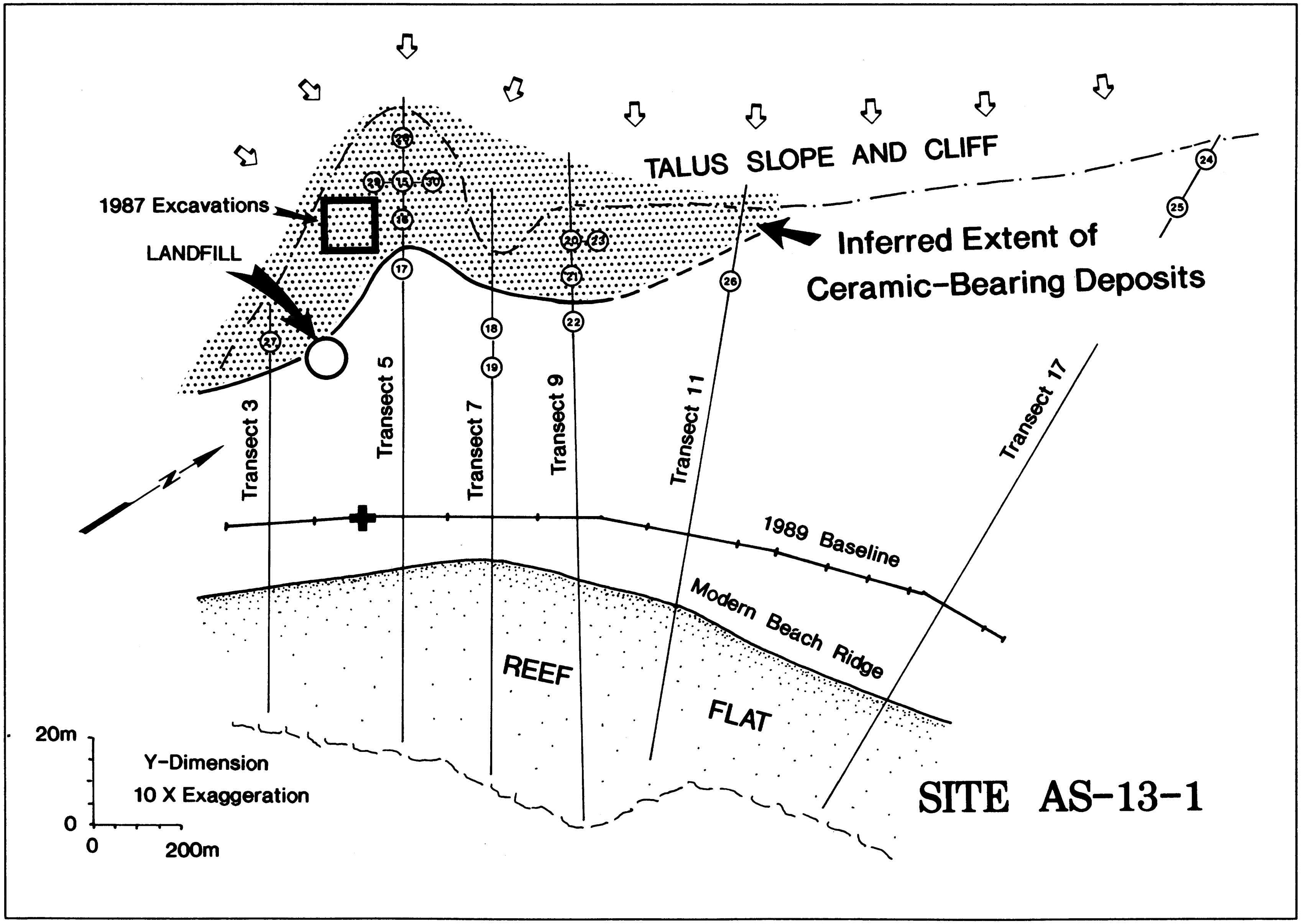

Figure 15.1 Schematic map of the To'aga area, showing the inferred extent of ceramic-bearing archaeological deposits.

and progradation of the coastal terrace proceeded from southwest to northeast. This sequence of infilling is confirmed by our transect excavations and correlates with the early pottery-bearing deposits (dating to 3-1.9 kyr B.P.) which are confined to the southwestern part of the To'aga coastal terrace. The northeastern end of the terrace, in the vicinity of Fa'ala'aga (Transect 17), remained a high-energy beach until relatively recently.

The morphodynamic model developed and tested for the To'aga site has wider implications for coastal archaeology elsewhere in Samoa and, indeed, on other volcanic oceanic islands (i.e., those situated on the Pacific Plate). In Manu'a, we would predict that coastal terraces on Olosega and Ta'u islands (for example, the Faga and Saua areas on Ta'u Island) will prove to have similar dynamic geomorphological histories to that evidenced at To'aga. Thus, any effort to discover occupation sites dating to the period between ca. 3-2 kyr B.P. will require the use of subsurface testing to locate the early beach ridge environments that are predictably buried under later prograded sediments. We believe that it is likely that such buried sites do exist on Olosega and Ta'u. Indeed, a ceramic-bearing site in precisely this kind of buried beach ridge environment was identified by Hunt and Kirch at the base of the marine cliff behind Ta'u Village during our 1986 reconnaissance survey (1988:166-67).

The morphodynamic model of the To'aga site is also likely to apply, perhaps with minor modifications, to Tutuila Island. (One modification to the model which may be required is the rate of subsidence. Tutuila is somewhat older than Manu'a, and thus may already have passed through its phase of rapid subsidence due to point-loading of the thin oceanic crust.) Clark and Herdrich (1988) demonstrated that the 'Aoa Valley has been substantially infilled since initial human occupation, indicated by a pottery-bearing site situated along the interior edge of the modern valley floor and by other geomorphological signs of a former shoreline now well inland of the present coast. They listed several hypotheses to account for this sequence of infilling (1988:173-75), including "a lowering of sea level" of about 1-2 m. We would suggest that this hypothesis is the most likely of the alternatives they list, although the contribution of terrigenous sediment to the 'Aoa sediment budget (resulting from human-induced forest clearance and erosion in the interior valley slopes) was doubtless greater than at To'aga. In any event, the failure of early archaeological efforts to locate ceramic-bearing sites on Tutuila (e.g., Kikuchi 1963; Emory and Sinoto 1965; Frost 1978) was due to the lack of a geomorphologically informed approach to site discovery. It is probable that most if not all of the valley floors as well as the coastal terraces of Tutuila Island have undergone significant infilling and progradation during the past two millennia. Thus, early coastal sites are unlikely to be exposed on the surface. It will be essential to work out local geomorphological sequences of infilling and progradation as an integral part of archaeological survey in these cases.

We also predict that similar sequences of progradation and burial of early archaeological sites will be found throughout many of the volcanic high islands of central Polynesia, particularly in the southern Cooks, Society Islands, and probably the Australs. These are all "hot spot" linear volcanic chains situated on the Pacific Plate, which typically undergo point-loading induced subsidence (Menard 1986:95-99). Stearns (1978:286), for example, points to geological and geomorphological evidence for rapid subsidence of the Society Islands during the late Pleistocene (and probably continuing into the Holocene). Furthermore, there is now considerable radiometrically dated evidence for a +1-2 m higher sea level at ca. 4-2 kyr B.P. throughout French Polynesia with a rapid fall to modern level after about 2 kyr B.P. (see Kirch, chapter 4). In short, both of the major controlling processes that resulted in coastal terrace construction on Ofu (subsidence and sea level change) were probably also operating in central Polynesia. This suggests that early occupation sites will not be easy to discover using conventional archaeological surface survey methods. Indeed, the presence of buried, and even partially submerged, archaeological deposits is known for Huahine (Sinoto 1979) and for Mo'orea (Green et al. 1967) in the Society Islands. On Mo'orea, Lepofsky recently discovered anaerobically preserved coconuts buried under 2 m of recent alluvium in the interior of the Opunohu Valley (Lepofsky, Harries, and Kellum 1992).

These problems of site survey and discovery raise serious issues for Eastern Polynesian prehistory. Specifically, given the probability of deep burial of early coastal sites, the archaeological record for central Polynesia as currently defined is likely to be highly biased toward later prehistoric sites. It is entirely possible that the early phases of occupation in the Societies and Cooks have yet to be discovered. Just how far back in time we may be able to extend these chronologies after a program of geomorphologically informed, systematic subsurface sampling is launched is impossible to say. It seems conceivable, however, that the "long pause" currently identified between the settlement of Western Polynesia and the movement of people into Eastern Polynesia (Irwin 1981; Kirch 1986; Terrell 1986) may prove to be an artifact of archaeological sampling bias. Only a concerted effort to work out the late Holocene dynamics of coastal landforms in central Eastern Polynesia, and to search for early sites in these depositional contexts, will provide a definitive answer to this problem.

Although the sequence of coastal terrace accumulation at To'aga was largely controlled through the interaction of sea level change and subsidence, it would be a mistake to attribute the entire pattern of landscape change to natural processes. At To'aga, as throughout much of the tropical Pacific, humans have played a major role in modifying and shaping island environments (see Kirch 1982, 1983, 1984:123-51). One process which is probably due largely, if not wholly, to human interference in the Ofu ecosystem is the erosion and deposition of substantial volumes of colluvium. Our transect excavations revealed a consistent pattern over most of the To'aga area (except at Transect 17 which has an almost exclusively boulder talus underlying the narrow ridge) of increasing rates of colluvial deposition onto the coastal terrace after about 2 kyr B.P. This deposition occurred as a series of small, overlapping colluvial fans emanating out of intermittent watercourses or small ravines inland of the site. These fans cap the early calcareous beach-ridge deposits containing pottery-bearing occupations, and in our inland-most test units frequently exceeded 1 m in depth. The fans rapidly pinch out as they extend onto the coastal terrace, with the larger angular clastics decreasing in frequency, and thin "tongues" of fine-grained silt and clay extending out onto the coastal flat. That humans played a key role in initiating this increased rate of erosion and deposition of colluvium after about 2 kyr B.P. is suggested by the presence of charcoal in most of these colluvial sediments. Natural forest fires are an extremely rare occurrence in the humid tropics, and thus the presence of charcoal flecking in these sediments is almost certainly a signal of human burning (see Kirch and Yen 1982:154, 351-52 for a discussion of this phenomenon on Tikopia Island). This burning most likely was associated with forest clearance for agriculture, specifically shifting cultivation of root and tuber crops on the steep hillsides inland of the site. Once the native forest was disturbed and opened up, erosion of the youthful volcanic soils on the steep slopes would have increased dramatically.

The effects of this erosion and deposition of colluvium on the newly prograded coastal terrace were by no means negative from the human viewpoint of potential land use. Rather, the addition of highly fertile, young volcanic sediments to the well-drained calcareous terrace created a mixed edaphic environment that was more suited to the cultivation of tuber and tree crops (such as *Dioscorea* yams, *Alocasia* aroids, breadfruit, and coconut), than either the volcanic or calcareous sediments by themselves. Hence, as the coastal terrace itself prograded and expanded in area after about 2 kyr B.P., its potential as a zone of intensive agricultural production was significantly enhanced by the human-induced deposition of volcanic sediments. We can only speculate that the creation of this coastal zone, edaphically well-suited to intensive agriculture as a result of human actions, may have occurred at a time when the island's population was likely to have been increasing after a millennium or so of settlement. Here too, it may not be at all coincidental that the traditional site of chiefly power on Ofu Island—the Tui Ofu monument complex—is situated in the approximate center of this rich resource zone (see Hunt, chapter 3). The emerging chiefly polity of the island could be expected to have exercised its hegemony by seizing control of this newly created and highly productive resource zone.

Other indications of human impacts on the Ofu Island ecosystem in the archaeological record at To'aga include the extinction or extirpation of bird populations (see Steadman, chapter 14) and the introduction of adventive species of terrestrial molluscs associated with Polynesian horticulture (see Kirch, chapter 8). Consideration of this evidence, however, will be deferred to the discussion of the prehistoric subsistence system in a later section of this chapter.

Before closing this discussion of the sequence of landscape change at the To'aga site some brief comparisons with other documented sequences from tropical Polynesia are warranted. The patterns of change that dramatically transformed the lowland environment of To'aga between 3 kyr B.P. and the present are not unique to Ofu Island. Similar sequences have been attested for other islands in the southwestern Pacific, including Tikopia (Kirch and Yen 1982), Aneityum (Spriggs 1986), Lakeba (Hughes et al. 1979; Bayliss-Smith et al. 1988), Futuna (Kirch 1975, forthcoming), Mangaia (Kirch et al. 1992) and Niuatoputapu (Kirch 1988). The specific similarities include: (1) the progradation of coastal lowlands between ca. 3-1.5 kyr B.P., presumably due to sea-level changes in the area; (2) human-induced forest clearance and erosion resulting from shifting cultivation; (3) deposition of alluvial and colluvial sediments in lowland landforms; and (4) edaphic enhancement of lowland environments as a consequence of (3). Also attested in these sequences are human impacts on the endemic and indigenous biota. In short, the To'aga site adds yet another case to the growing catalog of significant human modifications to the island ecosystems of the central Pacific.

ANCESTRAL POLYNESIAN CULTURE

The derivation of Polynesian cultures from a Lapita ancestor is now well attested in the archaeological sequences of Western Polynesia. Kirch (1984) and Kirch and Green (1987) have used the term "Ancestral Polynesian Culture" (or "Society," depending upon the frame of reference) for the culture which emerged in the archipelagoes of Western Polynesia during the middle of the first millennium B.C. The reconstruction of Ancestral Polynesian Culture (which doubtless was not uniform throughout the region) is arguably a key task for Polynesian prehistorians, because it provides the baseline against which subsequent cultural divergence, evolution, or transformation can be measured. Such reconstruction may be attempted from at least three different, but complementary, sources of evidence: comparative ethnography, historical linguistics, and archaeology. Green (1986) has outlined this "triangulation" approach in greater detail using the example of Ancestral Polynesian settlement systems.

The To'aga site is potentially a major source of *archaeological* evidence for the reconstruction of Ancestral Polynesian Culture, because the site's stratigraphic sequence spans the whole of the first millennium B.C., the period during which this Ancestral culture emerged out of its Lapita predecessor. Because our objectives and temporal-fiscal limitations necessitated a *testing* strategy of excavation, our present evidence from To'aga is primarily in the realms of material culture and of faunal material bearing on the subsistence economy. In the future, however, expanded horizontal excavations at To'aga may reveal much new evidence regarding the structure and spatial organization of Ancestral Polynesian settlements.

Ceramic studies have been an important part of understanding prehistory and culture change in Samoa and West Polynesia. The assemblage from the To'aga excavations is especially significant as it is large, excavated from a well-stratified, well-dated deposit, represents the full duration of pottery manufacture in Samoa, and has been studied in detail (chapter 15).

Green (1974) performed the first detailed analysis of Samoan ceramics from the SU-Sa-3 site at Sasoa'a, 'Upolu. He defined one "type" with two varieties of plainware: a coarse-tempered thickware, and a fine-tempered thinware. Green (1974) followed a methodology for classification developed in the culture-historical paradigm of American archaeology (i.e., especially in the work of J. Ford, A. Kreiger, and I. Rouse; see Dunnell 1986a, 1986b). Contrary to criticisms from proponents of the New Archaeology (1950s-60s), classification formulated by culture historians is deductive, problem-oriented, and based largely on a paradigmatic structure (Dunnell 1971). Culture historians understood the explanatory meaning of variability—their methodology was founded in a materialist ontology (Dunnell 1986b). The debate between Ford and Spaulding in the mid-1950s is illustrative of the contrasts between culture history and the aspirations of the New Archaeology (see Dunnell 1986b).

Following the culture historians' lead, Green (1974) defined two classes of pottery by the combination of dimensions in a paradigmatic structure (see Dunnell 1971) for thickness and temper size. Thick- and thinware, as varieties of one type (in the type-variety system; see Dunnell 1986b:174), are *ideational* units or classes. Ideational units "are tools of our construction the purpose of which is to allow us to recognize and describe these things about which empirical claims are made" (Dunnell 1986b:151). Classes are based on intentional definitions, where a specific set of features forms the necessary and sufficient conditions for membership in a unit (Dunnell 1971:16). Once Green (1974) defined classes for analytic purposes, he described the empirical variability within them. His descriptions include observations such as color, paste texture, temper composition, and surface treatments—attributes that were not part of the defining criteria. Dunnell (1971) has distinguished definitions from descriptions as the contrast between *class* and *group*. Classes comprise lists of criteria; groups are sets of things (Dunnell 1986b:181). Thus, defining classes and describing groups (empirical entities), which he called "categories," characterizes Green's analytic approach.

In his analysis, Green (1974) attempted to use the vessel, rather than sherds, as the basic counting unit comprising the archaeological assemblage. This innovative approach to establish a minimum number of vessels based on similarity in sherd color, temper, and other attributes has been attempted by others (e.g., Brose 1970; Sullivan 1983). However, as Feathers (1990:139) explains, attempts to transform sherds into vessels are met with some problems. And, such attempts are not always necessary, since variability between assemblages will be reflected in attributes of sherds as well as vessels. As Feathers (1990:139-40) puts it, "sherd information is not inferior to vessel information. It is just different. And because of the problematic representation of vessels archaeologically, sherd data is [*sic.*] the best source of assemblage information." Green's (1974) minimum number of vessels approach does not lessen the usefulness of his analysis. While later statistical analyses (e.g., Clark and Herdrich 1988; Hunt and Erkelens, chapter 9) revealed problems in the intuitive definition of thick- and thinware, Green's rich descriptions provide data suitable for comparative analysis.

In a subsequent study, Smith (1976) took assemblages from the Mulifanua Lapita site, Jane's Camp, and the Paradise site for ceramic analysis. Smith used principal components analysis, a multivariate grouping procedure, to (1) evaluate Green's conclusions, (2) compare Lapita with later Samoan ceramics, and (3) in his words, "attempt a meaningful and useful classification of the present Samoan ceramic material using a wide range of both stylistic and technological variables" (1976:83-84). Focusing on attributes that appeared to vary temporally, Smith (1976:86) initially sorted sherds into three kinds based on thickness and paste texture: a thick coarse-textured (tempered?) ware; a thinner, finer-textured ware; and an extremely fine textured ware. The distinctions of thickness and paste texture (temper size?) appear identical to those made by Green (1974), with the addition of a finer ware (no doubt due to earlier ceramics in the sample).

Smith's (1976) principal component analysis, like Green's pottery descriptions, is a means to delineate the empirical variability of groups. Smith's principal components analysis is not a *classificatory* tool, however, but a method that analyzes the *grouping* tendency of the sherds studied. His results show that pottery from these assemblages is relatively homogeneous with respect to the attributes of paste and color. The variables of paste and color are represented in components I and II of his analysis. A third component includes thickness, exterior and interior evenness (variance in thickness?), "filler type" (temper composition?), and "filler size" (temper size?) (Smith 1976:90). While Smith (1976:90) states that "it does not appear possible to interpret this combination of variables in any meaningful fashion," these variables clearly relate to the criteria used to define thick- and thinwares (e.g., Green 1974; Hunt and Erkelens, chapter 9).

In analytic terms, Smith (1976) conflates the distinction of *group* and *class* (Dunnell 1971). He has not created a classification, but has only shown the grouping tendency of sherds from three assemblages. Unlike paradigmatic classes, groups (as statistical summaries) change with the addition of every new case (sherd or assemblage). Smith (1976:92) proposes that his groups form the basis for a new "typology" of Samoan ceramics. He points out, however, that his "types" would serve as descriptive categories only as they do not correspond to either chronology or spatial distribution. Smith (1976: 93) implicitly recognizes the problem of conflating class and group as he notes that the discreteness of "types" will disappear with additional analyses of Samoan ceramics (see Dunnell 1971, especially pp. 87-110, figure 8). Clearly, analysis of groups does not provide the basis for a useful classification. Instead statistical grouping techniques allow one to examine variability among defined classes.

Holmer (1980) re-analyzed sherds from Mulifanua, Jane's Camp, and the Paradise site with sherds from two new sites, Potusa and Falemoa, both on Manono Island. He attempted factor analysis on unspecified variables—apparently similar or identical to those used by Smith (1976). When factor analysis failed to produce groups (clusters), a new strategy was attempted. Holmer subjectively (implicitly) classified sherds into seven "types." Variables were then selected for observation/ measurement, and data from the analysis of sherds was used in discriminant function analysis. In this analytic procedure, Holmer (1980) simply confirms (statistically) his "subjective" sorting criteria (implicit *a priori* class definitions). As with Smith's (1976) analysis, the ideational (classes) and empirical entities (groups) are confused. Holmer (1980) is thus left with "types" that will constantly change with every new case analyzed.

These problems with confusing group and class, evident in Smith (1976) and Holmer's (1980) work, are not merely an academic issue. The conflation of these observational and analytic steps is the reason why Smith and Holmer did not succeed in producing classificatory systems, contrary to their stated objectives. This is because: (1) Analysis of objects is necessarily based on an *a priori* (most often implicit) classificatory system (i.e., to observe "x" is to observe "x" *as a case of something*). Grouping procedures are data manipulations performed on unanalyzed and implicit classifications; they are inductive and often formulated as "problem-free." (2) Groups are based on empirical sets (e.g., statistical summaries) that change with every case added, thus an object cannot be assigned to a pre-existing group without altering the "definition" of the unit. (3) Grouping provides descriptions of phenomena, but not definitions stipulating necessary and sufficient conditions for membership (although *post hoc* definitions might be extracted). Group membership is based on similarity which varies in degree. This means that individual objects in a group may share many, some, or in extreme cases, no traits in common (see Dunnell 1971:fig. 8).

Clark and Herdrich (1988) recently called attention to the problem of Green's (1974) original formulation of coarse-tempered thickware and fine-tempered thinware. They point to the lack of explicit criteria for what is thick and thin, fine or coarse. Clark and Herdrich (1988) illustrate the variability of these dimensions in an assemblage from 'Aoa, eastern Tutuila. While preliminary in nature, their examination of ceramics points to the importance of classification as a means to document change in the Samoan sequence.

The To'aga ceramic study reported in this volume is the most intensive analysis of assemblage from Samoa to date. The analytic protocol was designed to support the definition of numerous classes (i.e., from two or more of the dimensions) deduced to address particular research questions of the assemblage. While the To'aga assemblage is especially well-studied, much work remains to answer the larger questions posed by Hunt and Erkelens (chapter 9) for ceramic evolution. Results from To'aga show that thickware is present in the earliest deposits, and its abundance (in actual numbers) over time is relatively stable. Thinware is never clearly dominant at To'aga. Thinware declines in real and relative abundance over time but persists perhaps as long as pottery production itself. At To'aga, as elsewhere in Samoa, pottery declines in abundance early in the Christian era and then disappears entirely.

Results from ceramic compositional analyses show that the bulk of pottery, including both thick- and thinwares, and some carved paddle-impressed ceramics, was produced locally with colluvial "self-tempered" clay source(s) from Leolo Ridge on Ofu. Red-slipped pottery from To'aga does not match the local colluvial clays presently known. Based on this, the red-slipped ware may have an exotic provenance, arriving on Ofu through inter-island exchange. Finally, results also suggest that the diversity of raw materials declined over time. Such a pattern if substantiated with further work, suggests changes in availability and/or procurement of raw material. A decline and eventual end to inter-island exchange of ceramics might also be hypothesized.

The To'aga assemblage, like most others from Samoa, is simple in form and includes very little decoration. Only bowls are represented. Decoration is restricted to impressing and notching on the lip, and on body sherds, red-slip, carved paddle-impression, and incision. This simplicity stands in marked contrast to Lapita assemblages of comparable age from Mulifanua, 'Upolu, and assemblages known from Futuna, Tonga, and Fiji. Isolation of Manu'a from communities beyond Samoa might account for this stylistic divergence.

The To'aga excavations also yielded a small but important set of stone adzes in association with the ceramics just discussed. Significantly, these are all variants of the plano-convex sectioned Type V adz described by Green and Davidson (1969). A dominance of Type V adzes in ceramic-bearing contexts in Western Samoa was noted by Green (1974:257-58). The Manu'a results confirm this pattern for the eastern part of the Samoan archipelago. Indeed, Type V appears to have been a widespread and common form throughout the Ancestral Polynesian region, given the presence of this form in sites in Futuna (Kirch 1981), Niutoputapu (Kirch 1988:192), and Tongatapu (Poulsen 1987:170). Type V was dropped from the Samoan adz inventory early in the first millennium A.D., and our surface collections from Manu'a are dominated by adzes with quadrangular or trapezoidal cross sections. One of these trapezoidal forms was recovered from a late, aceramic depositional context in Unit 3; this particular specimen appears to have been manufactured at the Tatagamatau quarry on Tutuila Island (see Weisler, chapter 12).

Pottery and stone adzes are the best documented classes of Ancestral Polynesian portable artifacts. For both of these artifacts, the development of uniquely Ancestral Polynesian forms out of Lapita prototypes has been archaeologically demonstrated (e.g., Green 1971, 1974). This is not the case, however, with another important Polynesian artifact class: the one-piece fishhook. When archaeologists first commenced stratigraphic excavations in the Eastern Polynesian archipelagoes of Hawaii, the Marquesas, Societies, and New Zealand in the 1950s and 60s, fishhooks proved to be among the most ubiquitous artifacts. Indeed, in the absence of pottery, Polynesian archaeologists applied their skills at classification and seriation to fishing gear, in an effort to establish chronological sequences (e.g., Emory, Bonk, and Sinoto 1959; Suggs 1961). Thus, when efforts were directed at the Western Polynesian islands of Tonga and Samoa, the initial expectation was that similarly rich assemblages of fishing gear would be recovered. These expectations were quickly thwarted by an almost complete absence of fishhooks in Western Polynesian sites. Poulsen recovered only one "certain specimen" of one-piece hook in his excavations of six sites on Tongatapu (1987:186), while the major Samoan archaeological programme of Green and Davidson (1969, 1974) recovered but a single fragment of a Turbo-shell hook from the Lotofaga midden (Green and Davidson 1969, pl. 23). Kirch's excavations on Niutaputapu fared only slightly better, with four one-piece hooks out of thirteen sites sampled (1988:204, fig. 124).

The extreme paucity of fishing gear in Western Polynesian sites—in contrast with the typically high density of fishhooks in Eastern Polynesian sites—raised a number of questions. Given the extensive scope of Western Polynesian excavations, sampling error alone can be ruled out. Rather, it appears that the rarity of hooks in early Western Polynesian sites (i.e., those dating to the Ancestral Polynesian period) is an accurate reflection of the relative unimportance of angling gear (Green 1986:131). The faunal assemblages from these sites, however, clearly indicate that inshore fishing was a major component of the subsistence economy. Were hooks being made of perishable materials (such as wood) and hence not preserved in the archaeological record? Were other fishing strategies, such as netting, spearing, or poisoning, preferred over angling by Ancestral Polynesian fishermen?

To'aga is the first Ancestral Polynesian site to produce a large assemblage of one-piece fishing gear, and thus demonstrates another kind of variability in early Polynesian culture. As described in chapter 11, a total of twenty-eight whole or partial *Turbo*-shell hooks were recovered from our excavations, along with another thirty-one preforms or tabs. This is a fishhook density level much more in keeping with Eastern Polynesian sites. Why should To'aga produce such an assemblage of one-piece hooks when other Samoan and Western Polynesian sites are devoid of these artifacts? We suggest that the answer lies in the differential marine environments of the various islands. The Western Samoan islands of 'Upolu and Savai'i, as well as Niuatoputapu and Tongatapu, are all characterized by extensive barrier reef and lagoon ecosystems. In these kinds of coastal environments, the most effective fishing strategies are usually those involving nets (seines, dip nets, nets used with weirs, and other techniques). This was well documented, for example, in ethnoarchaeological studies of contemporary fishing on Niuatoputapu Island (Kirch and Dye 1979; Dye 1980). In contrast, the marine environment of Ofu is that of a relatively narrow fringing reef, lacking a broad protected lagoon. In such fringing reef environments, angling becomes a far more significant fishing strategy, to exploit the dominant fish populations of the reef crest and outer slope.

The hypothesis that a greater emphasis on angling gear is correlated with fringing reef (as opposed to barrier reef-lagoon) environments receives some support from the general Oceanic picture of archaeological fishing gear distribution. For example, both Tikopia (Kirch and Yen 1982) and Anuta (Kirch and Rosendahl 1973)—small high islands with narrow fringing reefs—yielded high frequencies of one-piece fishhooks in their archaeological sites. The same is true of Hawai'i and the Marquesas, where reefs are fringing or even lacking altogether. On the other hand, the Society Islands which have extensive lagoons have produced relatively low densities of fishing gear in comparison with other Eastern Polynesian sites. Consequently, we would argue that the Manu'a Group is one area within Western Polynesia where the marine ecological conditions favored the use of angling gear.

The *Turbo*-shell fishhook assemblage from To'aga is of some interest from a morphological-stylistic perspective, in addition to its ecological-functional implications. As noted in chapter 11, several of the hooks exhibit morphological features similar to those in early Eastern Polynesian fishhooks. These include the strongly incurved or "bent" shank and the single-notched, line-lashing devices. Thus, the To'aga hooks can readily be identified as a "prototype" stage from which the greater diversity of Eastern Polynesian forms was subsequently developed.

THE SUBSISTENCE ECONOMY OF EARLY SAMOA

The To'aga excavations produced one of the largest and best preserved faunal assemblages ever recovered from a Western Polynesian site: 10,209 vertebrate bones and approximately 166.5 kg of invertebrate materials. Largely due to poor preservation, most previously excavated Samoan sites yielded very poor faunal collections. In Western Samoa, only the late prehistoric Lotofaga midden reported by Davidson (1969) and the three coastal sites analyzed by Janetski (1976, 1980)—ceramic-bearing Potusa, Falemoa, and Jane's Camp—have well-preserved vertebrate and invertebrate faunal materials. Thus, the To'aga materials provide the first extensive sample of fauna from well-stratified and dated contexts spanning the first half of the Samoan sequence. The faunal data have been presented and analyzed by Nagaoka and Steadman in chapters 13 and 14, respectively. Here we expand on their analyses with several general observations and with comparisons to other Samoan and Western Polynesian sites.

One problem that has concerned archaeologists in Western Polynesia is whether the Polynesian triad of domestic animals—pig, dog, and chicken—was introduced at the time of initial settlement and colonization (Groube 1971; Hunt 1981; Best 1984; Kirch 1979, 1988). At To'aga, only the chicken (*Gallus gallus*) is well represented in our faunal suites. Chicken is actually the most frequent bird species represented in the avifaunal material, with 16 NISP (see Steadman, chapter 14). Chicken bones were especially well represented in the Layer III deposits in Units 20/23, dating to ca. 2800-2300 cal B.P. Pig, however, is unambiguously represented only in later contexts (in Layer I of Unit 17). Some of the unidentifiable mammal bone from earlier strata may indeed be of pig or dog—or both—so that the absence of pig and dog in early contexts is not certain. Nonetheless, given the large vertebrate faunal sample and excellent preservation, it is certain that neither of these domestic animals was ever present in large numbers at the To'aga site.

Another adventive species introduced (presumably as an inadvertent "stowaway" on voyaging canoes) at the time of initial colonization is the

Polynesian or Pacific rat, *Rattus exulans*. This species is ubiquitous in the To'aga strata and occurs in the earliest dated depositional context (Layer IIID in Units 15/29/30). Tate (1951) discusses the very widespread dispersal of this synanthropic species.

Another group of human-introduced organisms appearing in the early To'aga deposits is the set of five synanthropic terrestrial molluscs discussed in detail in chapter 8: *Assiminea* cf. *nitida, Lamellidea pusilla, Gastrocopta pediculus, Liardetia samoensis,* and *Lamellaxis gracilis*. These species are closely commensal with humans, their preferred habitats being gardens and disturbed environments adjacent to habitation sites. The species are all minute—visible to the human eye only on close inspection—and can only have been transported inadvertently. Many of these species have also been identified from early, Lapita-associated archaeological contexts on Niuatoputapu Island (Kirch 1988:233-35) and on Tikopia (Kirch and Yen 1982:308-309). As discussed in chapter 8, the most likely mechanism for their inter-island transfer, and introduction to the Manu'a Islands, was with economic plants and adhering soil media. In this regard, these snails provide indirect evidence for early plant introductions to the island. Indeed, in the absence of direct ethnobotanical evidence for cultigens, the suite of synanthropic snails is the best clue that the early Polynesian colonists introduced a complex of economic plants to the island, along with the domestic chicken (and possibly also pigs or dogs). Future excavations at To'aga should test this hypothesis through identification of charcoal, carbonized parenchyma, and other carbonized plant materials from earth ovens, hearths, and other stratigraphic contexts. Recent developments in the identification of such carbonized materials by J. Hather (Institute of Archaeology, London; pers. comm., 1991) and others, not available to us at the time the To'aga excavations were undertaken, now make the possibilities for such paleoethnobotanical studies possible.

Two kinds of larger marine animals are represented in the vertebrate faunal collections: sea turtles and unidentified marine mammal. The sea turtles probably consist mostly (if not exclusively) of the Green Sea Turtle, *Chelonia mydas*, but definite identifications on the post-cranial skeleton are virtually impossible. Turtle bones were fairly common and were especially frequent in Layer IIIB of Units 20/23 and Layer IIB of Unit 19. The marine mammal bone is most likely from one or more species of porpoise. A relatively high frequency (18 NISP) of marine mammal bone was found in the early Layer IIIC deposit in Units 15/29/30.

The bird bones are of particular interest, for they reveal extinctions and extirpations consistent with a pattern of avifaunal change from early sites throughout Polynesia (Steadman 1989; Steadman, Pahlavan, and Kirch 1990; Steadman and Kirch 1990). An unexpected discovery was the presence of two *Megapodius* sp. bones from Layer IIID of Units 15/29/30, the oldest dated layer at the site. Megapodes were not formerly known to have been present in Samoa, and this find thus represents an eastern extension of the prehistoric range of this taxon. Given the restriction of this taxon to the earliest stratum, it is likely that the species was rapidly overexploited—to the point of extinction—by the early colonizers of Ofu. Also striking is the presence of bones of six species of seabirds which no longer occur on Ofu Island, including *Puffinus pacificus, Puffinus lherminieri, Puffinus griseus, Pterodroma rostrata, Pterodroma* sp., and *Sula sula*. The loss of these species from the island within the span of human occupation most likely reflects both direct predation by humans and habitat disturbance.

Ninety-four percent of the vertebrate fauna from To'aga consists of fishbone, of which 2,229 NISP were identifiable to family-level taxa (see Nagaoka, chapter 13). Although there are frequency differences in taxa within different excavation units, there is remarkable consistency overall in the rank-order dominance of particular fishes. Four families dominate the faunal assemblages: Diodontidae, Serranidae, Acanthuridae, and Holocentridae. These families include numerous species, most of which occur on the reef flat or immediately off the reef edge. They may be taken with a variety of fishing strategies including netting, spearing, poisoning, and angling. The acanthurids, holocentrids, and serranids especially, can be taken with hook-and-line, and it is very likely that the small one-piece *Turbo*-shell fishhooks recovered from the To'aga site were used to capture these taxa. Of considerable interest is the high frequency of Diodontidae (primarily *Diodon hystrix*), the porcupinefish. These fishes are known to carry tetradontoxin which can cause severe illness or even death when ingested by humans. That such a dangerous fish should dominate the To'aga faunal assemblages is curious, although not inconsistent with patterns in other early Pacific sites (see Green 1986:132). In Tikopia, *Diodon hystrix* was extremely plentiful in the early middens (Kirch and Yen 1982: 292, table 42), as it was also in the Early Eastern Lapita site of NT-90 on Niuatoputapu Island (Kirch 1988:223, table 29).

A second tier of fish taxa, in terms of their rank-order abundances, comprises the following families: Scaridae (parrotfish), Carangidae (jacks), Labridae (wrasses), Lutjanidae (snappers), Muraenidae (moray eels), Balistidae (triggerfish), and Ostraciidae (boxfish). Again, these are all inshore, reef or reef edge fishes, represented by a large number of species. A variety of fishing strategies were doubtless employed to take these fishes. A number of other taxa are less commonly represented among the fish faunal assemblages from various excavation units. These are again primarily inshore fishes, but several examples from the family Scombridae (tunas and mackerels) are present. This is significant, for it does indicate the practice of pelagic fishing, probably with pearl-shell trolling lures. Trolling for tuna, however, was clearly a minor fishing strategy in terms of its contribution to the total fish catch.

In terms of sheer bulk, invertebrates (and especially molluscs) comprise the majority of the faunal materials from the To'aga site. (Nonetheless, their contribution of meat to the prehistoric Samoan diet was probably less than that of fish.) In terms of rank-order abundances based on weight, a few taxa dominate the assemblages. Consistently the most abundant species is the reef gastropod *Turbo setosus*; the closely related species *T. crassus* is also quite common. Only slightly less common is the bivalve *Tridacna maxima*, which occupies the reef platform. *Turbo* spp. gastropods comprise on average about 62 percent of the invertebrate faunal suite from the To'aga midden deposits, while *Tridacna* bivalves constitute another 7 percent. Other commonly represented taxa include: *Trochus maculatus*, *Tectus pyramis*, *Cypraea* spp., *Conus* spp., *Vasum ceramicum*, *Cerithium nodulosum*, *Strombus maculatus*, *Thais armigera*, *Asaphis violaseus*, and *Nerita* spp. All of these molluscs occur on the reef platform and reef crest fronting the To'aga site.

Sea urchins of several species are also represented in the To'aga middens. The smaller-spined taxa are doubtless underrepresented in our samples, because the spines usually are not retained in the 0.25-inch mesh sieves that we employed. Some indication of their presence was provided by the bulk samples and micro-artifact analyses of selected sediments (see Kirch, Manning, and Tyler, chapter 7; Nagaoka, chapter 13). The Layer IIIA/IIIB occupation in Units 20/23 was noteworthy for an unusually dense concentration of the large slate-pencil sea urchin (*Heterocentrotus mammillatus*). More than 6 kg of these spines and test fragments were recovered from these strata, partly in association with an earth oven feature.

In sum, the To'aga excavations have provided significant new information on which to base reconstructions of Ancestral Polynesian subsistence economy, and of the impacts of these early island colonists to the biota of remote Pacific islands. An economic strategy integrating broad-spectrum exploitation of natural faunal resources (marine and terrestrial) with agricultural production is indicated by the To'aga evidence, reinforcing reconstructions based on other early Fijian and Western Polynesian sites (Kirch 1984; Kirch and Green 1987). The presence of an extinct or extirpated species of megapode, of six species of extirpated seabirds, and of marine turtle, all in the earliest deposits at To'aga (especially in Layer IIIB of Units 20/23), suggest that initial exploitation of the island's larger faunal resources may have exceeded the capacity of these natural populations to survive or reproduce under the pressures of intensive human predation. In addition to these early impacts on the natural biota, however, the Polynesians radically altered the To'aga area, transforming the coastal environment in particular into a thoroughly anthropogenic landscape. The purposive introduction of domestic animals and economic plants, and the inadvertent introduction of rats, terrestrial snails, and other organisms were the first stages in the conversion of the Ofu ecosystem into a cultural landscape capable of supporting a dense human population. Following progradation of the coastal plain after about 1900 B.P., the To'aga area was developed into a highly intensive arboricultural production zone, dominated by economic plants of Polynesian introduction (coconut, breadfruit, aroids, yams, arrowroot, and others). Even the steep volcanic slopes inland were cleared of native forest and converted to zones of shifting cultivation. Such interior slope modification resulted as well in increased rates of soil erosion and deposition onto the coastal flats, enhancing the edaphic condition of the latter zone for crop production. In this regard, the To'aga data add another instance in the rapidly accumulating repertoire of archaeological evidence for prehistoric human transformation of Pacific island environments (Bayliss-Smith et al. 1988; Kirch 1983; Steadman 1989).

INTER-ISLAND CONTACTS AND EXCHANGE

Archaeological research in the Fiji-Western Polynesia region has produced some evidence for inter-island contacts and exchange (e.g., Best 1984; Davidson 1977; Kirch 1988). While inter-archipelago contacts and exchange are known ethnohistorically, extensive exchange of ceramics and other materials appears to have occurred in the earliest period of the region's history. Best (1984), for example, shows that a substantial proportion of early ceramics on Lakeba was imported to the island. While the Tatagamatau basalt quarry site on Tutuila (Leach and Witter 1987; Best et al. 1989) is a likely center for adz export, little is known about potential patterns of exchange in Samoa and the quarry's place in a regional system.

Excavations at To'aga produced a range of materials for which provenance can be deduced or inferred. Compositional analysis of volcanic rock lithics and adzes, temper and clay of ceramics, and raw materials from potential sources offer a means to explore questions of prehistoric exchange.

Weisler (chapter 12) used non-destructive XRF analysis on artifacts and potential source rocks from Manu'a and Tatagamatau. His results show that the composition of rock in finished adzes (and in flakes from adzes showing polish) of fine-grained basalt cluster with those from Tatagamatau on Tutuila. In contrast, a relatively coarse-grained dike stone from Fa'ala'aga on Ofu Island is represented only in debitage and simple flake tools. These results suggest that perhaps much, or all local stone was not suitable for adz production. Exchange, at least with Tutuila some 100 km to the west, brought adzes and probably other materials to Manu'a.

Hunt and Erkelens (chapter 15) conclude that red-slipped ware, and perhaps other pottery made of clay distinctive from the locally known colluvial sources on Ofu, may reflect imports to the island. The decline in compositional diversity hypothesized for the ceramic assemblage might also indicate that exchange diminished in importance over time. Additional research on sherds from Manu'a and elsewhere in the region is necessary, however, to fully test hypotheses for inter-island ceramic exchange.

THE TO'AGA SITE: CULTURAL RESOURCE MANAGEMENT CONSIDERATIONS

As the initial objective of the Manu'a Project was the identification of archaeological sites for purposes of cultural resource management—under contract to the Historic Preservation Office of the Government of American Samoa—it is appropriate to conclude this monograph with a discussion of the significance of the To'aga site, the current status of the site, and the potential impacts which may threaten its integrity in future years.

Site AS-13-1 is unquestionably one of the most significant archaeological sites yet discovered in American Samoa, and indeed, in the Samoan archipelago as a whole. Within American Samoa, it certainly ranks with the extensive Tatagamatau adz quarry complex on Tutuila in terms of its potential to yield information on the prehistory of the archipelago. Some specific aspects of the To'aga site that collectively contribute to its archaeological significance are enumerated below:

1. Site AS-13-1 incorporates the largest continuous area of subsurface archaeological deposits dating to the ceramic phase of Samoan prehistory of any site yet discovered in the archipelago. These deposits are estimated to cover between 21,000 and 35,000 m^2 and appear to represent a series of domestic household units.

2. Site AS-13-1 is well stratified, and thus has the potential to yield a finely-detailed chronological sequence of cultural change for the Manu'a Islands. The remarkably deep stratification in parts of the To'aga site contains three or more meters of cultural deposits. Because of this stratigraphic record, the

To'aga site presents excellent opportunities for recovering a detailed sequence of artifactual, faunal, and settlement information.

3. Site AS-13-1 spans virtually the entire prehistoric sequence of the Samoan archipelago. Initial occupation of the site began around the close of the second millennium B.C., contemporaneous with the Mulifanua Lapita site on 'Upolu Island. The stratigraphic record from ca. 3000 B.C. to A.D. 800 has been well documented by our systematic transect excavations, detailed in this monograph. Other archaeological features dating to the last one thousand years are also present in the area, although they have not yet been intensively investigated or radiocarbon dated. No other single site locality in American Samoa has yet produced such a continuous occupation sequence spanning the whole of regional prehistory.

4. The preservation of both artifacts and faunal materials in Site AS-13-1 is excellent, especially in the deeper stratigraphic units, where calcareous (alkaline) sedimentary conditions prevail. The majority of Samoan archaeological sites are characterized by acidic soil conditions which do not favor the preservation of such organic materials as bone, shell, or sea urchin spines. In such acidic contexts, cultural materials are usually limited to pottery and stone artifacts. At To'aga, the excellent preservation conditions yield not only ceramic and stone artifacts, but extensive assemblages of bone and shell faunal materials, as well as artifacts of shell, bone, and sea urchin spine. As a result, our knowledge of early Samoan material culture and economy has been significantly expanded by the materials from Site AS-13-1. A particular example is the complex of *Turbo*-shell fishing gear, which for the first time has given us some in-depth information on Samoan angling strategies in the first millennium B.C. Similarly, the faunal assemblages from the To'aga site are the largest—in terms of both numbers and taxonomic richness—from any site yet excavated in the archipelago.

5. Site AS-13-1 also incorporates a number of features of considerable cultural significance to the people of Ofu Island. In particular, To'aga is the traditional seat of the Tui Ofu chiefship, represented by the Tui Ofu well and burial mound (see Hunt, chapter 3). These monuments are held in considerable awe by the people of Ofu Island and are directly connected to a body of oral traditions (see Mead 1930).

Together, all of the aspects of Site AS-13-1 enumerated above combine to make this archaeological complex one of the most significant cultural resources in American Samoa, and indeed, in the Samoan Islands as a whole. The site has already yielded much important new information on the prehistory of the Manu'a Group and the Samoan archipelago, and its potential has hardly been tapped. Because of its outstanding significance, we have nominated Site AS-13-1 to the National Register of Historic Places, in conjunction with the Historic Preservation Office of the Government of American Samoa.

From the cultural resource management viewpoint, it is important to assess any potential threats to the To'aga site. As described in chapter 2, the present mode of land use over most of the site is subsistence gardening in a more-or-less traditional manner (arboriculture and *Alocasia* aroid swiddening). This relatively low intensity land use does not seriously threaten the integrity of the site, other than for minor impacts to surface archaeological features such as *'ili'ili* pavements or *lua'i masi* pits.

There has already been some significant damage to the site, however, through the construction of the Public Works Department landfill at the southwestern edge of the site. (Ironically, it was this landfill that led to the original discovery of surface pottery-bearing deposits during the 1986 reconnaissance survey.) It appears that most of the bulldozed landfill pit lay outside of the area of deeply stratified archaeological deposits, but these were disturbed along the inner edge of the bulldozer cut. While the 1986 bulldozing probably did not greatly impact the total site area, it is extremely important that no further expansion of this landfill operation occur without prior consultation with the Historic Preservation Office. It should be possible to plan for future landfill needs by situating such landfill pits in the seaward portions of the To'aga coastal flat that do not contain subsurface archaeological deposits. We strongly recommend that prior to any future landfill operations, the Public Works Department consult with the Historic Preservation Officer and arrange for limited test excavations to assure that landfill bulldozing take place outside of the zone of buried archaeological features.

We are unaware, at present, of any other planned developments or construction in the To'aga area, but if such projects arise, they could also have the potential to threaten the integrity of the site. For this reason, it is important that AS-13-1 be placed on the National Register of Historic Places, and that the American Samoa Historic Preservation Officer attempt to monitor any proposed land use actions in the vicinity of the site.

Over the longer term, the entire archaeological complex at To'aga could be seriously threatened by natural coastal erosion. According to the morphodynamic model developed in chapter 4, and tested through various field and laboratory observations, it would appear that the southern Ofu coastline may have entered a phase of sea level transgression. This appears to be reflected along the modern coastline by active erosion of the beach ridge and associated vegetation line, and by exposure of beach rock. Given that the subsurface archaeological deposits are situated well inland of the present shoreline (between about 40 to 60 m, depending upon the particular locality), such erosion is not at present a serious concern. However, should this transgression phase continue or intensify, for example as a result of global warming and consequent sea level rise (Geophysics Study Committee 1990), the integrity of Site AS-13-1 would ultimately be affected. Continued tectonic subsidence of Ofu Island may itself eventually result in the natural erosion and destruction of the site, but this process could be seriously intensified and quickened by rapid sea level rise. Obviously, these are not problems requiring immediate attention, but they should not be wholly ignored either.

Finally, we wish to conclude by briefly drawing attention to some further research possibilities at the To'aga site. While we have been able to use the opportunity of subsurface testing and site survey at AS-13-1 to address a number of research problems in Samoan archaeology, our investigation of the To'aga site in 1987 and 1989 must be regarded as no more than a pioneering phase. This site has enormous potential to add to our knowledge and understanding of the prehistory not only of Samoa, but of the Western Polynesian region as a whole. The site is also of sufficient size, with an estimated 21,000-35,000 m^2 of stratified deposits dating to the ceramic phase of Samoan prehistory, that even a large scale excavation program would not remove more than a small percentage of the total area, leaving the majority of the site as an "archaeological bank" for future research.

We suggest that the next logical phase of archaeological research at To'aga might be to employ a horizontal excavation strategy to expose one or more larger areas (on the order of 100-150 m^2) within the zone of subsurface deposits dating to the ceramic phase of Samoan prehistory. Our systematic transect sampling suggests that this zone is made up of clusters of domestic or household residential units, probably consisting of series of dwelling, cookhouse, and possibly other special purpose activity areas. Horizontal exposure of one or more of these residential units could provide the first clear picture of the settlement layout and spatial arrangement of an early, Ancestral Polynesian community. Such a project would be of considerable interest not only for Samoan prehistory, but for expanding our knowledge of Ancestral Polynesian culture, which is a critical baseline for the development of later variants of Polynesian culture throughout the whole Polynesian triangle (Kirch and Green 1987).

Obviously, such an expanded excavation program would also need to be combined with other kinds of research objectives and methods. For example, Weisler's trial application of the non-destructive XRF method of characterizing and sourcing basalt artifacts (see chapter 12) could be followed up with a more intensive study, with much potential to reveal patterns of long-distance exchange at all periods of Manu'an prehistory. Similarly, the variation in ceramics noted at To'aga, such as the distinction between fine thinware and coarse thickware, could be explored along avenues other than just chronological changes in frequency. It may be that these ceramic wares reflect functional, or social, patterns in early Samoan society. These can only be explored through the use of horizontal excavation strategies in which the distribution of ceramics can be closely mapped in comparison to the spatial layout of households.

These suggestions are not meant to be an exhaustive catalog of research problems that might be addressed at the To'aga site but simply some possible research directions that we feel would contribute significantly to current issues in Polynesian archaeology and prehistory. We are pleased that our pioneering phase of research at AS-13-1 has already been able to yield important new insights on Samoan prehistory and look forward to the contributions that future work in the deeply stratified sands of To'aga will doubtless bring.

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