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Edited by
Patrick Vinton Kirch

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Complex anthropomorphic face design on vessel ECA-V-045, from Area B of the Talepakemalai site. Drawing by Margaret Davidson.

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With Contributions by
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Edited by Johanna Baboukis
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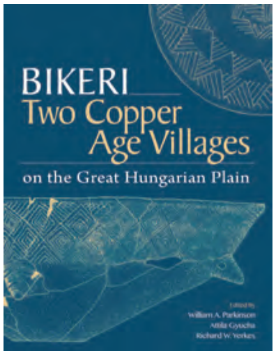

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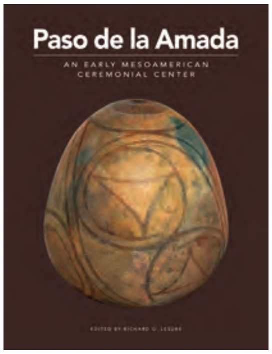

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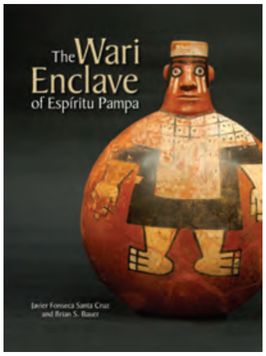

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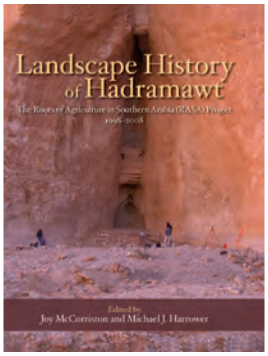

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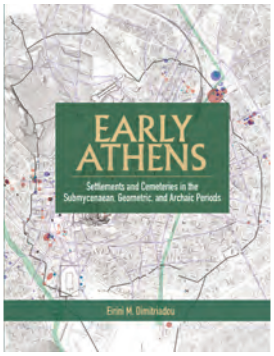

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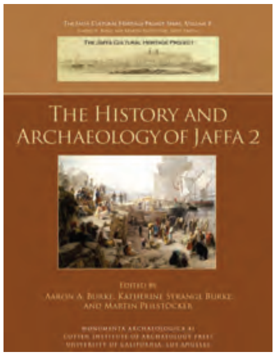

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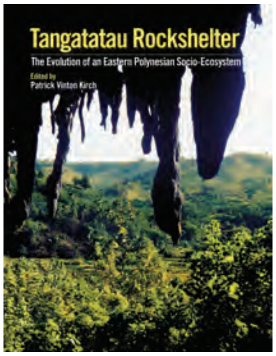

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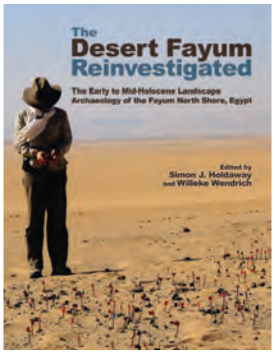

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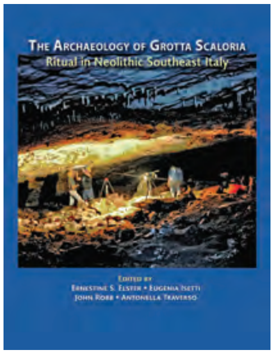

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Preface

The Mussau Project has filled—albeit intermittently—the hours and days of more than three decades of my life. I take this opportunity to share a few of what, for me, were some of the more emotionally charged and remarkable moments, particularly the experiences of fieldwork in the remote, often physically challenging, but always exquisitely beautiful Mussau Islands. Unforgettable is my memory of first sight of Eloaua's uplifted coral limestone cliffs and forested plateau, seen through a gray dawn from the rail of the *Dick Smith Explorer*. I recall the curious mix of emotions and thoughts racing through my mind as the ship's wake agitated the calm waters of the Malle Channel. How would we be greeted—with reserve and hesitation, even suspicion, perhaps, regarding our unusual agenda? Would Eloaua's sites yield the sorts of materials I hoped would answer a host of questions and competing hypotheses about Lapita in the Bismarck Archipelago? Such musings were soon replaced by more immediate issues: How would we get all of our gear safely across the reef? What sort of lodgings might be found? Would our chloroquine supply prove an adequate defense against the infamously virulent malaria of New Ireland Province? Except for the latter (I myself came down with malaria at the end of the 1985 season), in the event it turned out I need not have worried, for we were warmly received from the first hour; subsequent weeks and months of fieldwork based out of Eloaua Village were among some of the most enjoyable I have ever experienced in the Pacific. And, as this volume attests, the archaeological record proved rich beyond expectations.

Then too, it would be hard to ever forget the sequence of events on a baking hot Sunday afternoon—August 11, 1985 to be exact—when the first hint of the unique undisturbed deposits at Talepakemalai began to turn up 65 cm down in test unit 14. Troweling in waterlogged sands that within a few days would yield the first evidence for a Lapita stilt house, sherd after large sherd appeared, most bearing classic dentate-stamped designs. Along with the sherds we found whole *Conus*-shell rings, a pig tusk pendant, and large obsidian flakes. After days of tedious excavating in shallow, disturbed deposits in which the sherds had been highly fragmented and eroded, this turn of events was, as I penned in my field journal, "very exciting to say the least." Later, when unit 14 had been expanded into a 12 m^2 excavation, it was the setting for another dramatic moment as Baua Sagila gently picked up a small piece of porpoise bone which had been lying face-down in the waterlogged sands, turning it over in his hands to reveal an exquisitely carved human representation. A sea deity of the Lapita people? Perhaps. And there are sad memories too, as when we returned to Eloaua the next season, only to hear that Baua had passed away, having choked to death on a fish spine just a few weeks before.

Other scenes that fill my memories of Mussau have nothing to do with archaeology, but are just as precious. They include chasing after a school of tuna fish in the dugout canoe "Two Mile," kilometers off Cape Forster in a running sea, salt spray stinging our eyes as one of the most dramatic sunsets I have ever witnessed gilded the western horizon. Or the wonder of a school of bottle-nosed porpoises chasing up the wake of my tiny Metzler inflatable as we rode across the Malle Channel to Boliu Island, breaking to either side so close that we could reach out and touch their backs as they leaped past the boat. And there was our nocturnal "expedition" to Ekaleu Island to hunt the massive coconut crabs, swarming about under the towering coconut palms of an abandoned German colonial plantation. I think also of watching mesmerized as more than a hundred Great Frigate birds glided low over Eloaua late one afternoon headed for their roost on tiny Enusagila Island.

The people of Eloaua, too, have left their mark with me. Ave, John, Baua, Eric, and other members of the impromptu "Giaman Club" that convened under our makeshift lab tarp in the evenings to drink my tea and tell tales of Mussau in the "time belong ol tumbuna," as well as the remembered upheavals of the German colonial period, and of World War II, enriched my appreciation of their world immensely. Nor will I forget our pre-dawn parting in 1988, shivering on the beach at Eloaua, as Ave, John, Meis, and the others prepared to launch "Two Mile" on a 200 km voyage to Manus, their only navigational aid being John's battered World War II U.S. military compass in which he had utter faith. Invited by the Manus people to come for a time and teach them the Mussau technique of cutting large dugouts from a single log, they saw this as a great adventure, a way of recapturing—I suspected—something of their cultural past handed down in traditions of elaborate exchange networks between Mussau and Manus in the days of their ancestors. They literally stood between two worlds, these Eloaua friends of mine, bent on continuing the voyaging traditions of their ancestors while guided by a surplus military compass! (I have not seen them since, but I had word from Ave that the trip was successful.)

Most of all I remember their eager participation in our project, their openness to my patient explanations in pidgin English of such bizarre concepts as radiocarbon dating, and their amazement that the very ground they knew so intimately—that they had dug and gardened for generations—could yield material witnesses of their own deep past. Their own cultural interpretations of that material record often differed from mine, as when the first preserved wooden house posts were revealed in Area B at Talepakemalai, and Aimalo and Ave pronounced these to be the foundations of a famous "haus matmat" (burial house) that their grandfathers had said once stood on this spot. The event was nonetheless as symbolically charged for them as for me, perhaps more so, as each man knelt to lay his hands on the post and touch a piece of this world that had been brought back from the past. These experiences have shown me that there is always scope for multiple histories, different ways of knowing the past.

Much has been written of the "people without history," which is in reality only a Western intellectual conceit, dependent on the assumption that history requires *written* texts. Colonial education schemes and missionary teachers extended and promulgated this view, as in the Seventh-Day Adventist text I was shown in which the "history" of Mussau begins with the arrival of the first SDA missionaries in 1930! All that came before was presumably not worth knowing (or was presumed to be unknowable), a void of history-less, pagan "savagery." Yet our Mussau friends had never quite accepted this Western view of their past; they still valued the oral-aural "texts" through which generations of their people had constructed and passed down their own histories. I think it was the unexpected excitement at the realization that here was yet another, previously unperceived material "text" of their past—the archaeological record—that so fired the interests of John, Ave, Meis, Baua, Eric, and the others. Without their help, encouragement, interest, and most importantly, their friendship, that world would lie buried still. I hope that this volume, along with the carefully curated collection of artifacts that now resides in their country's National Museum, in some small way helps to repay the debt we owe them, providing a firmer basis for making them a people *with* history.

Acknowledgments

Modern archaeological work is expensive, especially when conducted overseas. The Mussau Project could not have been carried out without the generous financial support provided by the National Geographic Society's Committee for Research and Exploration (both to the 1985 Lapita Homeland Project, and to the Mussau Project specifically through Grant No. 3304-86 in 1986), by the U.S. National Science Foundation (through Grant Nos. BNS-8615147 and BNS-8996182), and by the Wenner-Gren Foundation for Anthropological Research (Grant No. 4687). Additional financial support, as well as critically important equipment and laboratory space, were provided successively by the Burke Museum of the University of Washington (1985–1988) and the Archaeological Research Facility of the University of California at Berkeley (1989–1998).

Prof. Jim Allen, of the Department of Archaeology, La Trobe University, deserves special mention for having organized the Lapita Homeland Project in 1984–1985, and for inviting me to participate, thus launching my foray into Mussau prehistory. Jim and I have at times argued long and hard about our respective interpretations of Lapita (once to the point of sheer hoarseness), but always with mutual respect.

Archaeological research in the Mussau Islands was conducted under Research Permit Nos. 14 and 30, and export of archaeological materials for overseas study under Loan Permit Nos. 74, 87, 101, 129, and 131, issued by the National Museum and Art Gallery of Papua New Guinea. The staff of the National Museum were at all times most helpful with official arrangements, and I would especially like to thank the then Director, Dr. Soroi Eoe, and former Curator of Prehistory, Pamela Swadling. John Saulo, Assistant Curator of Anthropology, and Nick Araho, Assistant Curator of Prehistory, were both able to join us for periods in the field and added materially to the success of the Project.

Other individuals who aided us in Port Moresby include Rex Okona and Jacob Simet of the Institute of Papua New Guinea Studies, who assisted with research visas and immigration matters. At the University of Papua New Guinea, Dr. Les Groube and Dr. Jean Kennedy were both welcoming and gave us useful advice, as well as sharing the results of their own fieldwork in PNG.

In New Ireland Province, Ezekiel Waisale, Minister for Finance, Planning, and Public Service, of the Policy and Planning Department of the New Ireland Provincial Government facilitated our requests for permission to conduct research in the province. Ellison Kalasar, Assistant Secretary for Policy and Planning, and Eli Wanera, Assistant Secretary for Education, were also most helpful with official arrangements. For additional assistance, we also acknowledge Esekia Tomon of the New Ireland Provincial Government, and Herman Sole, the elected Member from Mussau.

Arranging an archaeological expedition to islands as remote as Mussau requires a great deal of forward planning, as Eloaua and Emananus lack trade stores, requiring all equipment and supplies to be furnished externally. Logistical arrangements were greatly facilitated by Roger Dixon, General Manager of Haus Toksave Pty., Ltd. in Kavieng, who acted as our local agent for supplies, aircraft charter, and shipping, and who allowed us to store equipment in his shed between field seasons. Roger's efforts on our behalf went beyond those of normal business, however, entertaining us in his Kavieng home while we were en route to and from Mussau, and sending us small packets of fresh vegetables, cheese, or other delicacies via the irregular small plane to Eloaua.

In the Mussau Islands, official support was provided by the District Manager, William Sibia, who also gave us use of the government Land Rover for a reconnaissance of the east coast of Mussau Island. The local Council member for Eloaua and Emananus, Eric Kop, was at all times supportive and helpful. Aimalo Lavatea of Lomakanauru, the landowner of the ECB site, was likewise generous in his assistance, and shared much traditional information regarding clan history and Mussau culture. Baua Sagila was a valued friend during our 1985 field season, and it was with great sadness that I learned of his passing just before our return in 1986. Saupa of Emananus Island, owner of the EHB site, also gave his permission to excavate and helped with the work. Our excavations at ECA and other sites were carried out by a highly enthusiastic and energetic crew of Eloaua and Emananus islanders, who included at various times: Meis Talogu, Susuvin Matonge, Riller Sagila, Deliah Sagila, Lien Kavigona, Milu Kavigona, Benta Kavigona, Melin Ave, Holson Aite, Kelvin Susuvin, Kevin Susuvin, Bila Ave, Reslin Sagila, Ave Male, John Male, Kavigona Tambu, Mata Sagila, Baua Sagila, Rillinter Hurald, Solly Joshua, Milan Solon, Liah Aite, Naomi Kavi, Bronwyn Meis, Dixy Joshua, Marren Baua, Delwyn Susuvin, Asa Ave, Ellen Ani, Lennae Tamangei, Mobilly Ave, and Rachael Mosoke. I could not have wished for a better archaeological team. I would also like to acknowledge the assistance of those who accompanied and assisted me during the three field seasons in Mussau: Sally Brockwell and Pru Gaffey (1985); Terry Hunt and Marshall Weisler (1986); and Dana Lepofsky and Jason Tyler (1988). John Aini, Carla Catterall, Holly McEldowney, and Mike Ritchie also joined us for periods in the field, and their help was inestimable.

Various colleagues in the United States, Australia, New Zealand, and Papua New Guinea have generously assisted with aspects of data analysis, provided comparative materials or shared unpublished reports and drafts, and in various other ways facilitated our Mussau research. Among them I would particularly like to thank Jim Allen, Melinda Allen, Gwen Bell, Roger Bird, Deborah Cembellin, Scarlett Chiu, Emily Dean, Bill Dickinson, Chris Gosden, Jack Golson, Roger Green, Mark Hall, John Head, Elizabeth Manning, Holly McEldowney, Steve Midgely, Rob Schmitt, John Sinton, Jim Specht, Matthew Spriggs, David Steadman, Glen Summerhayes, Daris Swindler, Christy Turner, Andrew Wright, Douglas Yen, and Alan Ziegler.

The superb line drawings of ceramics and portable artifacts which grace Chapters 11 and 13 are the work of Margaret Davidson, whose patience and accuracy are remarkable. Thérèse Babineau printed all of my black-and-white field photographs from often rather difficult negatives.

A special debt of gratitude goes to Debra and Arlen Prentice, who provided a generous financial subvention that made publication of this volume with its abundant figures and tables possible. In the years immediately following the 1985 Mussau field season, Debra also volunteered in my laboratory to help conserve the thousands of potsherds, truly a labor of love.

I have reserved for last the acknowledgment of my very substantial debt owed to brothers Ave Male and John Male of Eloaua Island, senior members of the clan that holds the Talepakemalai (ECA) site. They not only granted permission to carry out excavations at ECA (despite some early skepticism on John Male's part regarding the nature of our work), but became enthusiastic supporters of the Project as a whole, working closely with us in the excavations, helping in reconnaissance, and in general facilitating our life in their village. Ave Male put his house at our disposal, and in a thousand countless ways made our life there productive and enjoyable. The success of the Mussau Project is in large part due to the support of Ave and John Male, and on behalf of all Project participants, I extend our sincere thanks.

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Abbreviations

AMS	accelerator mass spectrometry
ANU	Australian National University
asl	above sea level
BP	years before present (radiocarbon)
bs	below surface
cal	calibrated
CST	calcareous sand temper
CV	coefficient of variation
ΔR	delta-R, the ocean reservoir factor in radiocarbon calibration
DFA	Discriminant Function Analysis
E	east
EDS	energy dispersive spectroscopy
ED-XRF	energy-dispersive X-Ray fluorescence
ha	hectare
Is.	Island
ITCZ	Inter-Tropical Convergence Zone
km	kilometers
km^2	square kilometers (area)
LHP	Lapita Homeland Project
LPOD	Lapita Pottery Online Database
m	meters
m^2	square meters (area)
mm	millimeters
MN	magnetic north
MNI	minimum number of individuals
N	north
NISP	number of identified specimens
ϕ	phi, unit of the Wentworth grain-size scale
PIXE-PIGME	proton-induced X-ray emission and proton-induced gamma-ray emission
PNG	Papua New Guinea
pXRF	portable X-ray fluorescence
σ	standard deviation
S	south
SEM	scanning electron microscope
SSU	shell sampling units
W	west
XRF	X-Ray fluorescence

CHAPTER 1

Talepakemalai and the Mussau Project in the Context of Lapita Archaeology

Patrick Vinton Kirch

Situated on the small coral island of Eloaua in the Mussau Islands, on the northern arc of the Bismarck Archipelago, Talepakemalai (site ECA in the Papua New Guinea National Museum's site catalog)—extensively excavated over three field seasons from 1985 to 1988—remains one of the largest and earliest known sites of the Lapita cultural complex. Talepakemalai produced one of the most extensive and varied assemblages of ceramics, bone, shell, and stone artifacts, faunal remains, and—due to its waterlogged sediments—anaerobically preserved plant remains from any Lapita site in the southwestern Pacific. I scarcely anticipated, when the third field season was completed, that it would take three decades to complete the work of cataloging, studying, and describing this impressive collection, and of compiling and editing this final monograph. Although various preliminary reports and articles have been published over the years, it has always been my intention to bring a definitive account of Talepakemalai, as well as several smaller Lapita and post-Lapita sites in the Mussau Islands, to completion in monographic format. As Kent Flannery famously quipped: "Archaeology is the only branch of Anthropology where we kill our informants in the process of studying them" (1982:275). Once excavated, the contents of a site are detached from the three-dimensional context that give them meaning. We who have had the privilege of excavating—of literally deconstructing and decontextualizing a site—owe it to future generations to provide as full an account of our fieldwork as possible. This volume aims to achieve that result, fulfilling my obligation as an archaeologist to provide for future generations of students and scholars a detailed record of what we recovered from the waterlogged sands of Talepakemalai and other sites in the Mussau Islands.

Archaeological knowledge and understanding of the Lapita cultural complex has advanced tremendously over the three decades since the Talepakemalai excavations commenced in 1985, as part of the international Lapita Homeland Project (LHP). Yet it is essential to describe the research issues and problems *as these were conceived in the mid-1980s when our work began*, for only in that context can one appreciate the decisions regarding which sites we dug, how we excavated them, and how their contents were analyzed. In this Introduction, I review the core research problems around which the Mussau Project was framed, in the context of what was known about Lapita in the early 1980s. I then review the work of each field season, showing how our research strategies evolved in response to our emerging results, and how we modified both the questions we asked and the methods we applied. In Chapter 18, however, I synthesize the results of the Mussau Project in the context of continuing research on Lapita that has been conducted since we carried out our fieldwork in the 1980s.

The Lapita Cultural Complex: History and Background

The German priest Otto Meyer (1909, 1910) was the first to discover sherds of the ceramic style we now call Lapita, at his mission station on Watom Island, near New Britain (Kirch 1988d, 1997:6–11). In 1920, Bishop Museum archaeologist W. C. McKern (1929) excavated Lapita pottery in Tonga, but unaware of Meyer's finds, McKern mistakenly interpreted his Tongan sherds as a late prehistoric variant of Fijian ceramics. Avias (1950) correctly linked Meyer's Watom sherds with his own finds from New Caledonia. But it was Prof. Edward W. Gifford of Berkeley (along with his graduate student Richard Shutler, Jr.) who, after excavating at the "Lapita" type site (Site 13) on the Foué Peninsula of New Caledonia in 1952, recognized the full significance of this distinctive ceramic horizon that spanned the ethnographic abyss separating Melanesia and Polynesia (Gifford and Shutler 1956; Sand and Kirch 2002). Data accumulated through further fieldwork at Watom, the Île des Pins, Fiji, Tongatapu, and Samoa during the 1950s and 1960s permitted Golson (1971) to distinguish Lapita as a *ceramic series*, the key aspect of an otherwise ill-defined cultural complex. Golson proposed that the great similarities in Lapita designs across this region bespoke a "community of culture" that had once linked the early populations of the southwestern Pacific, again undermining long-held ethnographic conceptions about the separateness of Melanesian and Polynesian prehistory.

Major advances in Lapita archaeology came during the early 1970s, particularly with the Southeast Solomon Islands Culture History Program organized by Roger Green and Douglas Yen (Green and Cresswell, 1976), which reoriented the geographical focus of Pacific archaeology out of Polynesia into Melanesia. Green's fieldwork in the Reef/Santa Cruz Islands applied sophisticated sampling strategies and extensive areal excavation to several Lapita sites (Green 1974a, 1976, 1978). Green's aim was to achieve a broader definition of the Lapita *cultural complex* beyond that of a ceramic series, by including settlement patterns, subsistence economy, and non-ceramic aspects of material culture (Green 1979a). This work spurred debate regarding the nature of Lapita colonization, trade, exchange, dispersal, and other topics (e.g., Groube 1971; Clark and Terrell 1978; Green 1982, 1985; Spriggs 1984).

By the early 1980s, most Pacific archaeologists would have agreed with the following statements regarding Lapita. First, that it was a well-marked ceramic "horizon" with a distinctive design corpus and stylistic "grammar" (see Mead et al. 1975; Green 1978). Less certain were the relationships of some contemporary plainware ceramic assemblages (e.g., that of the early Anutan An-6 site; Kirch and Rosendahl 1976) to the classic dentate-stamped Lapita ceramics. Second, that the geographical range of Lapita (Figure 1.1) was known to extend from Mussau, Watom, and Ambitle in the Bismarck Archipelago, to Vanuatu and New Caledonia, to Fiji, Tonga, and Samoa (with a somewhat enigmatic gap in the main Solomon Islands). Third, that most sites with Lapita pottery dated from the later second millennium BC until about the mid-first millennium BC, although claims had also been made for much later persistence of Lapita pottery in some regions (e.g., Hedrick 1971; Poulsen 1968). Fourth, that Lapita communities preferred to locate their settlements either on small offshore islets or on the coastal terraces of larger islands; combined with evidence for extensive shellfish gathering and fishing, this suggested a strong maritime orientation. Fifth, that communication and exchange of materials between Lapita communities was increasingly evident in the archaeological record (e.g., Ambrose and Green 1972), prompting a model of Lapita people as itinerant "traders" (Clark and Terrell 1978). Sixth, that continuous ceramic sequences in Western Polynesia demonstrated a founding role for Lapita in the origins of the Polynesians. More contentious was the relationship between Lapita and other archaeological complexes which followed Lapita in Melanesia, such as the Mangaasi ceramic complex of Vanuatu (Garanger 1972), which some regarded as developing out of Lapita (e.g., Spriggs 1984). Such was the "state

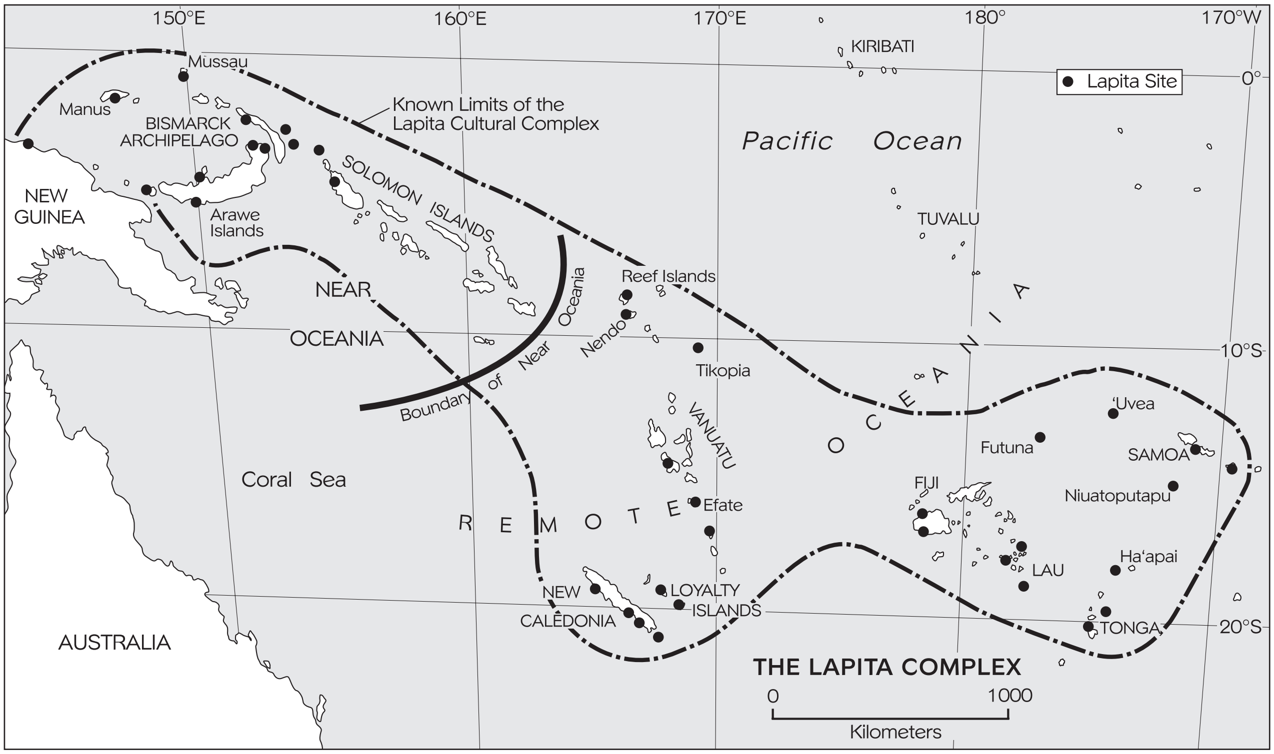


Figure 1.1. The geographical distribution of the Lapita cultural complex, showing the locations of major sites.

of play" among those concerned with Lapita archaeology and its significance for Pacific prehistory, immediately prior to the Lapita Homeland Project in 1984-1985, and to our work at Talepakemalai and other sites in the Mussau Islands.

The Lapita Homeland Project

At the Fifteenth Pacific Science Congress held in Dunedin during February 1983, Jim Allen (then of the Australian National University) approached me, along with several others, with a plan for an international research program to be called the Lapita Homeland Project (LHP). The program would target the Bismarck Archipelago, then thought to be the likely immediate "homeland" of the Lapita cultural complex, but largely *terra incognita* in terms of archaeology and prehistory (Figure 1.2). The Bismarck Archipelago as Lapita homeland was based on Roger Green's idea that "the original Lapita adaptation was to an area with a complex continental environment, which possessed a wide range of resources that related communities could assemble through exchange. This I place in the New Britain-New Ireland area" (Green 1979a:45).

Jim Allen modeled his plan after the successful Southeast Solomon Islands Culture History Program of the 1970s, which had placed several field teams in a circumscribed geographic region, following a loosely coordinated set of research strategies (Green and Cresswell 1976). A similar effort, this time focused farther west on the islands surrounding the Bismarck Sea, could potentially lead to comparable advances in our knowledge and understanding of Melanesian archaeology and prehistory. Having been a participant in the Southeast Solomons Project, as well as having prior involvement with Lapita sites both in the Southeast Solomons and in Western Polynesia (Kirch 1978, 1981), I enthusiastically agreed to participate in the LHP.

During 1984, Allen led a reconnaissance trip to the Bismarcks region of Papua New Guinea (Allen et al. 1984), seeking promising sites and localities for field work by LHP participants, and liaising with PNG government officials at both national and provincial levels. The University of Papua New Guinea and the National Museum and Art Gallery expressed their support for the LHP, while provincial administrators indicated a willingness to grant the required

Figure 1.2. Near Oceania, showing the central position of the Bismarck Archipelago.

permits. Allen (1991) laid out six main research questions that the LHP was intended to address:

1. What was the nature of late Pleistocene/early Holocene human occupation in the Bismarck Archipelago? . . .
2. Was horticulture part of the subsistence strategy throughout the Holocene in the Bismarck Archipelago or was it a later introduction? . . .
3. What was the nature of ceramic development or introduction and its subsequent evolution in the region? . . .
4. To what degree is the distribution of Lapita sites in the region a reflection of cultural preferences, or a reflection of subsequent human and/or natural alterations to the landscape?
5. How far might studies of contemporary trading systems in the region elucidate the nature of past long distance and local exchange patterns?
6. What was the technological range of obsidian exploitation, and what measures of specialization and production can be determined from these data through time? (Allen 1991:3).

By 1985, with funding for the LHP having been secured from the National Geographic Society, Australian National University, and other sources, 19 separate field projects involving 24 archaeologists were scheduled to be undertaken between May and September of that year (Allen 1991:3). The LHP would charter the *Dick Smith Explorer*, a 65-foot steel-hulled yacht, enabling field teams to travel to remote localities independent of the frequently tenuous local means of transport. As comparability of data between field teams was deemed important, LHP participants agreed to use standardized, preprinted field recording forms (a duplicate set of which were to be retained centrally at the Australian National University), and to coordinate radiocarbon dating through the ANU Radiocarbon Laboratory. In addition, each team would submit samples of their obsidian artifacts for centralized analysis at the Australian Atomic High-Energy Commission's Lucas Height's PIXE-PIGME laboratory (Bird et al. 1978; Duerden et al. 1980). A young postdoctoral scholar, Chris Gosden, was hired by the ANU to help coordinate all of the LHP's activities.

Major Themes in Lapita Research Circa 1985

Before describing the 1985 and subsequent field seasons in Mussau, it is important to review the central problems and issues that oriented the Mussau Project. Building upon the initial research questions of the LHP, these Mussau-specific research issues were outlined in two research proposals to the National Science Foundation (Kirch 1986a, 1987b); they were also discussed in the conclusion to an edited review of Lapita archaeology published while the Mussau fieldwork was ongoing (Kirch 1988e). In the following paragraphs I outline each of these issues as we conceived of them during the period of the Mussau fieldwork from 1985 to 1988. In Chapter 18, I return to these issues and review our findings in the lights of more recent and continuing research on Lapita.

Lapita Origins

At the commencement of the LHP in 1985, nothing was more contentious than the issue of Lapita origins. Gifford and Shutler (1956), Golson (1971, 1972), and other early investigators of Lapita, noting the stylistic parallels between Lapita ceramics and certain island Southeast Asian assemblages, had argued that Lapita origins should be traced westward back across Wallace's Line into island Southeast Asia. This model of an island Southeast Asian origin was subsequently given wide exposure by Peter Bellwood (1979, 1980), who combined the archaeological record of early ceramic assemblages extending from Taiwan, through the Philippines, Sulawesi, and Talaud Islands, and on into Melanesia (Lapita), with an emerging historical linguistic interpretation of a rapid expansion and dispersal of Austronesian language-speakers in the third and second millennia BC (e.g., Blust 1985):

> In the Western Pacific . . . Austronesian colonists between 1500 and 1000 BC left an extremely clear-cut trail of pioneer archaeological sites across about 6500 km of ocean and islands (many previously uninhabited), from the Admiralty Islands (north of New Guinea) to as far east as Samoa, in western Polynesia. . . . The resulting Lapita culture, which represents colonisation of virgin territory in most locations where it has been found, is generally well-dated and well-studied in terms of artefacts and economy and suffers from few of the chronological problems which beset the often mixed and undated assemblages from Island South-East Asia [Bellwood 1985:252].

Bellwood's interpretation, however, was not without its detractors. In direct opposition to the views of Bellwood and others (e.g., Spriggs 1984) that the Lapita cultural complex was the archaeological manifestation of a movement of Austronesian-speaking peoples out of island Southeast Asia, Jim Allen, for example, asserted that "the concept of pottery, canoes and horticulture coming simultaneously from the west, as the cultural baggage of Austronesians passing through [Melanesia], is not substantiated in the data" (1984:194). Rather, Allen argued that Lapita could have a local Melanesian origin, arising out of cultural developments that might be traced back into the Pleistocene:

> What is evident in the data from the Bismarcks is that a sufficient time period elapsed to allow for a local cohesive social and economic universe to have developed, one that could receive technologies from outside its immediate region, as well as develop internal technologies; and that could subsequently bring them together in such a way as to lead to both the Lapita expression and the later development of the Bismarck region [Allen 1984:194].

Allen's contention of a local Bismarck Archipelago "homeland" in which Lapita developed out of local antecedents appeared to find support in Anson's (1983, 1986) analysis of the limited Lapita ceramic assemblages then available from this region. Although his sample sizes were limited, Anson argued for the presence of a distinctive "earlier Lapita period in the Bismarck Archipelago which predates the Lapita expansion eastward into the Pacific by some centuries" (1986:164). The sample size issue was not trivial, as pointed out by Kirch et al. (1987), consisting of a mere 16 sherds from the ECA site. Anson placed much weight on a single radiocarbon age determination of 3900 ± 260 BP (GX-5499) obtained by Brian Egloff from the Eloaua ECA site (now known as Talepakemalai). At the time this was the oldest radiocarbon date from any Lapita site, predating Lapita sites in the southeastern Solomons by seven or eight centuries. This seemed to allow the possibility of a considerable time period for local Lapita cultural development in the Bismarcks. However, Anson glossed over the fact that Egloff's ECA excavations had also yielded a much younger date of 3300 ± 180 BP *from the same "coral oven" feature*, raising suspicions about the veracity of the older of the two dates. Clearly, the chronology of the ECA site needed to be resolved, for more than the dating of the ECA deposits themselves depended on it.

By 1985, the Lapita origins debate had become polarized, with the model of Lapita representing an intrusion of Austronesian-speaking peoples out of island Southeast Asia being dubbed the "fast train to Polynesia" model (Diamond 1988), which stood opposed to the "indigenous Melanesian origins" model championed by Allen, and by 1988 even more stridently by Peter White (White et al. 1988:416). Influenced by a holistic anthropological approach that regards historical linguistic and human biological evidence to be as important as that derived from the archaeological record, my view was closely aligned with that of Bellwood; the results of our first two expeditions to Mussau only reinforced my stance, as I stated in my preliminary reports (Kirch 1987a, 1988b). Nonetheless, it was clear that, even if Lapita had resulted from a population intrusion originating from farther west, the Lapita cultural complex in the mid-second millennium BC in the Bismarck Archipelago did involve some element of local cultural borrowing and fusion. This realization led Roger Green to put forward his now well-known "Triple-I" model for Lapita, the I's standing for "intrusion/innovation/integration" (this was first presented at the Fourteenth Congress of the Indo-Pacific Prehistory Association [Green 1991b:298]). Green's Triple-I model was subsequently widely adopted by Lapita researchers, a significant outcome of the LHP (e.g., Spriggs 1997; Kirch 1997:46–47, 2000:93).

Lapita Economy

The nature of the economy that had fueled the remarkable Lapita expansion from the Bismarcks eastward into the previously uninhabited archipelagoes of Remote Oceania—Vanuatu, New Caledonia, Fiji, Tonga, and Samoa—likewise sparked debate in the mid-1980s. If Lapita reflected an Austronesian dispersal—as Bellwood proposed and I was inclined to argue—then its economy should have included a significant array of tropical root, tuber, and tree crops, given that reconstructed words for these plants were known for the Proto-Austronesian language (Pawley and Green 1984; Blust 1985). Bones of domestic pigs, dogs, and chickens had been found in some Lapita sites, usually in limited numbers (Green 1979a), but direct archaeobotanical evidence for plant cultivation was at the time restricted to carbonized remains of coconut shell. Moreover, most Lapita sites consisted of dense shellfish and fishbone dumps, evidence for intensive exploitation of marine resources. An evaluation of Lapita midden deposits in Tongatapu had led Les Groube to hypothesize that the Lapita adaptation had been that of "Oceanic strandloopers" with a "restricted maritime/lagoonal economy" who "expanded ahead of colonization by agriculturalists" (1971:312). In Groube's view, agriculture (including pig husbandry) was introduced later (at least in Tonga), and had not been part of the initial Lapita colonization strategy.

In a landmark synthesis of Lapita archaeology, Green (1979a) had to fall back on indirect evidence to support his contention that the colonization of truly oceanic islands (lacking food plants in general) must have included a horticultural component. Green cited Lapita settlement size and duration of occupation, the presence of subterranean pits probably used for starch paste storage, and a range of material culture typically associated with horticultural societies (cooking ovens, pottery, vegetable scrapers and peelers; see Green 1979a:37). The presence of pig bones (lacking in Groube's earliest Tonga sites) was also critical evidence in Green's favor. In my own work on the Lapita-to-Polynesian transition as evidenced on Niuatoputapu Island in the northern Tongan archipelago, I had likewise argued that the founding adaptation included a dual horticultural-maritime economic base (Kirch 1978).

By the early 1980s, it was also evident that simple *diffusionist* models for the origins of Oceanic horticulture were no longer tenable (Yen 1973, 1982, 1985). Golson's excavations at Kuk in the New Guinea Highlands had raised the possibility of an independent invention of horticulture, involving water control in swampy valley floors, as early as 9000 BP (Golson 1977, 1990). Yen, building on earlier studies by Barrau (1965a, 1965b), drew attention to a wide range of cultivated plants that seemed on botanical grounds to have a Melanesian geographic origin (e.g., such tree crops as *Canarium* and *Inocarpus*, the *Australimusa* section bananas, and the *Cyrtosperma* giant taro). Moreover, there was the nagging problem of rice (*Oryza sativa*), which linguists such as Blust (1995) considered to have been a key part of the Proto-Austronesian economy, but which had never been important in Oceania. If, as Bellwood averred, Lapita marked an early Austronesian intrusion into the New Guinea region, why had such an important crop as rice not been transferred with them? On the other hand, if Allen's (1984) model of Lapita as emerging out of a much older cultural adaptation to the environment of the Bismarck Archipelago was correct, perhaps an indigenous Melanesian form of horticulture had been a part of the Lapita cultural complex from its inception. These were intriguing—even provocative—ideas, but they required a great deal more direct archaeological evidence in order to test hypotheses that were based largely on comparative botanical, ethnobotanical, and linguistic data. One of my hopes in joining the LHP was that Talepakemalai or other sites in Mussau might provide such archaeological materials.

Long-Distance Exchange

Based on his excavation of Lapita sites in the Reef/Santa Cruz Islands of the Southeast Solomons, Green (1974a) realized that he was dealing with the residue of communities that had been involved in quite complex and in some cases geographically extensive networks of trade or exchange. Ambrose and Green (1972) first demonstrated that obsidian from sources in the Bismarck Archipelago had moved southeastward out to the Reef/Santa Cruz sites, a distance of some 2,000 km, part of a suite of imported materials evidenced in these sites (Green 1974a, 1976). Likewise, in Lapita sites of Fiji and Tonga, there was evidence for the inter-island movement of stone adzes, obsidian, and chert (e.g., Kirch 1978, 1988a). These discoveries prompted Clark and Terrell (1978) to propose a "trader" model for Lapita (see Green 1982 for a response). Allen (1984), however, drew attention to the presence of New Britain obsidian in pre-Lapita sites to suggest that long-distance exchange had been present in the Bismarck Archipelago from an early date. In his view, the Lapita networks were simply a later manifestation of a long-standing tradition.

Among the specific questions that I wished to address in the Mussau Project were the following: Was complex exchange present from the beginning of Lapita occupation at Talepakemalai, or did it develop gradually over time? Were there changes in the types of exotic materials imported, as well as in their quantitative rates of flow (as reflected in rates of deposition)? Was there evidence, at any of the Mussau Lapita sites, for specialized production of materials used for exchange? Were exotic materials differentially distributed within the large Talepakemalai site, in such a manner that might shed light on the social mechanisms or correlates of material exchange?

My approach to this problem was to focus on Mussau as a single node or locale within a larger exchange network, whose linkages and interconnections had changed over time, changes which could only be partially tracked from the Mussau perspective. That is, from the archaeological record of Mussau we could potentially trace the changes that occurred at a single node—albeit one that was likely quite central—within the larger Bismarcks sphere. A great deal of our work was directed toward this end, through careful analyses of obsidian, ceramics, chert, and other exotic stone manuports, as well as evidence for specialized shell object production at Talepakemalai. This allowed us to construct a dynamic model of Lapita exchange, as reflected in this single node, utilizing such analytical variables as content, magnitude, diversity, network size, directionality, centralization, specialization, and complexity (see Plog [1977] for discussion of these attributes of exchange systems).

Lapita Society

Whereas origins, economic adaptations, and long-distance exchange are all research questions potentially resolvable from direct material evidence, inferring the nature of prehistoric social formations is far more problematic, often requiring extensive spatial data and complex chains of indirect inference, or argument by ethnographic analogy. Yet to the extent that anthropological archaeologists aspire to be social scientists—or even social historians—understanding the organization and structure of past societies must be a key objective. Certainly for a phenomenon so central to Oceanic prehistory as Lapita, we should like to be able to lay some claim to knowledge of Lapita *societies* as well as their material and economic base.

The very fact that the Lapita cultural complex cuts across the ethnographic distinction drawn for so long between Melanesia and Polynesia by cultural anthropologists (Thomas 1989; Tcherkezoff 2008) makes the use of ethnographic models somewhat problematic. This is because ethnographers have classically pointed to fundamental differences between the social systems of these two regions, Melanesia being the home of "big man" societies while Polynesia is the type locality for "chiefdoms" (Sahlins 1963). How, then, could Lapita represent a "foundation" culture from which such a diversity of social forms simultaneously arose? How, indeed, except perhaps for the possibility that the ethnographers had been misled to overemphasize difference, and to ignore the "devolution" of many island Melanesian social formations in the face of colonial encounters? Reconsideration of the Melanesian ethnographic record suggested that the "big man" model might more properly be restricted to New Guinea itself, where it is associated mostly with Non-Austronesian speaking peoples (Scaglion 1996).

Prior to the LHP, Brian Hayden (1983) put forward a speculative model for Lapita society as consisting of an early form of chiefship. Jonathan Friedman (1981, 1982) also advanced a model of transformation in early Oceanic societies, which, although it did not specifically refer to Lapita, clearly applied to the problem of Lapita social formations in its implications. Friedman proposed that early Oceanic societies were organized as "prestige-good systems" characterized by: "(a) generalized exchange; (b) monopoly over prestige-good imports that are necessary for marriage and other crucial payments, i.e., for the social reproduction of kin groups; (c) bilineal tendency in the kinship structure (asymmetrical); and (d) tendency to asymmetrical political dualism: religious-political chiefs, original people-newcomers, etc." (1982:184). The significance accorded to prestige-good exchange by Friedman opened up one possible *material* line of investigation into Lapita social structures. During the Mussau fieldwork, I attempted to pursue this avenue through investigation of *internal spatial differentiation* in Lapita sites, especially Talepakemalai.

Subsequent to the Mussau fieldwork, another kind of model for Oceanic societies began to energize comparative ethnographic analyses, with considerable promise for archaeology and prehistory. This is the concept of the "house society," deriving from Claude Lévi-Strauss' original proposal of the *société à maison* (1982), subsequently applied by a number of ethnographers to the analysis of Austronesian societies (e.g., Carsten and Hugh-Jones 1995; Fox 1993; Fox and Sather 1996; Kirch 1996; McKinnon 1991; Waterson 1990, 1993, 1995). In such "house societies," the fundamental social unit is typically a group of people who affiliate to a "house" that endures through time, carries a proper name, is associated with an estate of land, has its own prerogatives and rituals, and so forth. As Fox explains,

> Throughout the Austronesian-speaking world, houses are given great prominence . . . . Although a house has a physical referent, the category of "house" may be used abstractly to distinguish, not just households, but social groups of varying sizes. The "house" in this sense is a cultural category of fundamental importance. It defines a social group, which is not necessarily the same as the house's residential group [Fox 1993:1].

Green and Pawley (1998) productively used Proto-Oceanic historical linguistic reconstructions and archaeological data from Lapita sites to argue for important transformations in Lapita houses, with social implications. I have proposed that the Lapita peoples ordered their social world around "houses" in which ancestors played a central role, and that the anthropomorphic representations so commonly displayed on early Lapita pottery were linked to a cult of ancestors (Kirch 1997:132–144, 188–191). Kirch and Green (2001) likewise argue that Ancestral Polynesian Society, which developed out of the eastern branch of Lapita in the Tonga-Samoa region, had a well-developed "house society" system of social organization and residence.

Late Lapita Transformations

A final issue that concerned us in the Mussau Project was in some ways as perplexing as that of origins: what happened to Lapita after about 500 BC, when throughout the southwestern Pacific the distinctive ceramic series seemed to disappear, often quite abruptly? For Western Polynesia (Samoa, Tongatapu, Niuatoputapu, Futuna, and 'Uvea), where continuous ceramic sequences linked Early Eastern Lapita with later Polynesian Plainware (Green 1974b;

Davidson 1979; Kirch 1988a), the implication was that Lapita had been transformed into what we called "Ancestral Polynesian" culture (Kirch 1984; Kirch and Green 2001). Thus Eastern Lapita culture was seen as being directly ancestral to the later ethnographically attested cultures of Polynesia.

In Melanesia, however, continuity between Lapita and post-Lapita phases was less clear-cut, or in some cases ambiguous (Spriggs 1984). In Fiji, the break between Lapita (Sigatoka Phase) and the following Navatu Phase (paddle-impressed) ceramics was seen by some as evidence for cultural intrusion and possibly replacement (Frost 1979); others were inclined to see continuous development. In Vanuatu, Garanger (1972) had excavated sites with distinctive incised, relief, and appliqué decorated ceramics whose relationship—if any—to Lapita was at the time uncertain. Chronological issues regarding Mangaasi were also unclear, so that whether Mangaasi followed Lapita temporally or had overlapped with the latter was unresolved in the mid-1980s (Spriggs 1984; Green 1985). In New Caledonia, the work of Frimigacci (1975), building upon the earlier excavations of Gifford and Shutler (1956), had revealed incised and appliqué ceramics with apparent Mangaasi affinities that likewise followed after Lapita. However, in New Caledonia the issues were further complicated by the possibility that a plainware with paddle-impressing (termed Podtanéan by Green and Mitchell 1983) had been contemporaneous with Lapita, giving rise to the possibility that Podtanéan, and not Lapita, had been the direct antecedent to the later incised wares.

In the Bismarck Archipelago the transition from Lapita to whatever came after was wholly enigmatic. Much of the region appeared to lack pottery during the past two thousand years, although pottery production was ethnographically documented for certain locales, such as Manus (May and Tuckson 1982). Specht (1968, 1972) had defined a 2,000-year ceramic sequence for Buka Island in the nearby northwestern Solomons, but whether this represented a continuity from Lapita was unclear. Likewise, Vanderwal (1978) and others had proposed that the earliest ceramics along the Papuan coast had a probable origin in Lapita, but this putative link was not empirically established. In sum, for most of Near Oceania, it was not possible in 1985 to discriminate among competing hypotheses that later, ethnographically attested cultures had their origins in Lapita (as was the case in Western Polynesia) or, alternatively, that Lapita had been replaced by other cultural groups after about 500 BC. This issue could only be resolved through building local archaeological sequences in many different localities throughout the Bismarcks and adjacent parts of Near Oceania. Stratified and accurately dated assemblages were required to test the possibilities of continuity or of more abrupt change that would imply cultural replacement.

The Mussau Project, 1985–1988

While the five major research themes discussed above oriented our field and laboratory work over several years, the specific objectives and research strategies we applied on site and in the lab evolved substantially over the course of the three field seasons. In the following paragraphs, I review each of our field expeditions along with the specific objectives that we set for ourselves. This account draws upon my grant proposals to the National Science Foundation, National Geographic Society, and Wenner-Gren Foundation for Anthropological Research (Kirch 1985, 1986a, 1987b), from preliminary field reports submitted to these agencies and to PNG government officials, and from my field diaries.

The 1985 Mussau Expedition

Mussau had been an obvious choice for LHP fieldwork because it was one of a few localities within the Bismarck Archipelago already known to have two Lapita sites (sites ECA and ECB, both on Eloaua Is.), based on reconnaissance survey and limited test excavations by Brian Egloff and staff of the PNG National Museum in 1973 and 1978 (Egloff 1975; Bafmatuk et al. 1980). In 1984, Jim Allen and Jim Specht briefly visited Mussau on their Bismarck Archipelago reconnaissance (Allen et al. 1984:8–11). During their seven-day stay, Allen and Specht briefly recorded 16 new archaeological sites, one of which (site EHB on Emananus Is.) yielded sherds with Lapita dentate-stamped decoration. They recognized that the previously tested ECA site (Talepakemalai) on Eloaua Island was much larger than Egloff had indicated, suggesting that "the site offers scope for further testing of areal differentiation" (Allen et al. 1984:9).

The Mussau sub-project of the LHP was scheduled for two months from late July through late September 1985. My objectives were threefold. First, I wanted to delineate the size and extent of the ECA and ECB sites and investigate their stratigraphic sequences and chronologies. It was essential to determine whether the early radiocarbon date of 3900 BP for ECA (Bafmatuk et al. 1980) accurately represented the age of the "early Far Western Lapita" style, as Anson (1983, 1986) had averred. Second, I needed to test the newly discovered EHB site on Emananus Island, to see if this contained ceramics similar to those from ECA and ECB. Third, I wanted to survey the Mussau group more thoroughly, concentrating on the cluster of smaller islands to the southwest of the main island.

On July 22, 1985, I flew from Seattle, Washington to Port Moresby, Papua New Guinea. At the National Museum, I examined Egloff's collections from the ECA and ECB sites, and was told that a final report of Egloff's 1978 excavations was unlikely to ever be completed. The Museum's Assistant Curator of Anthropology, John Saulo (himself a Mussau islander), agreed to join me later during the field season. I then flew to Kavieng, the provincial capital of New Ireland Province, on July 30, where I was able to visit the ongoing excavations at Panakiwuk rockshelter, under the direction of LHP members Jim Allen and Chris Gosden. Joining me in Kavieng were Sally Brockwell and Pru Gaffey, archaeology students from the Australian National University, who had been assigned to accompany me as field assistants in Mussau. On the afternoon of July 31, after assembling additional gear and supplies in Kavieng, the *Dick Smith Explorer* weighed anchor and set course for Mussau.

After a wet and squally passage, the 650 m high peak of Taleanuane on "Big Mussau" rose above the horizon just after dawn. (The main island of Mussau is locally referred to as "Big Mussau," in distinction to the small offshore islet of Emussau, from which the name of the group actually derived.) An hour later the *Dick Smith Explorer* was close off the southeastern coast of Eloaua. The characteristic "stair-step" topography made it clear that the island consisted of several elevated limestone terraces. We dropped anchor in the Malle Channel off of Eloaua Village, where five or six dugout canoes came out to greet us, one bearing Eric Kop, the local Council member for Eloaua and Emananus. I went ashore with Eric, who introduced me to Ave Male, uncle of John Saulo and traditional leader of the Eanaiyu clan, which claimed the ECA site area (Figure 1.3). Ave Male, who had previously hosted Egloff on his field trips, agreed to our proposed work, generously putting one of his two houses at our disposal. Returning to the ship, we offloaded our 14-foot aluminum launch and gear. *Lapita*, as the launch was named, powered by a 25-hp Johnson outboard, gave us the flexibility to reconnoiter the islands of the Mussau group. The *Dick Smith Explorer* hoisted anchor at 11:30 am for a return to Kavieng.

Over the next several days, we reconnoitered Eloaua and Emananus Islands, relocating the ECA, ECB, and EHB sites and arranging with the local landholders to excavate at each of these. Work at ECA commenced on August 6, assisted by nine Eloaua villagers. We began with a series of widely spaced transect excavations in order to define the site's areal extent, a strategy that led us to discover that the area with Lapita-ceramic deposits was not confined to the approximately 2 m high former beach terrace as suggested by Egloff (1975). Instead, we discovered that waterlogged deposits continued into a lower (1 m above sea level) sandy flat to the north of the airfield (see Chapter 3). Over the next few weeks, we opened a 12 m^2 excavation—designated Area B—yielding a stunning array of decorated Lapita pottery (including many partially reconstructable vessels, some with anthropomorphic face designs), shell objects, obsidian flakes, and other small finds (Figure 1.4). Most remarkably, the anaerobically preserved bases of 16 wooden posts or stakes appeared in the waterlogged layer, revealing that this Lapita settlement had originally consisted of stilt houses constructed over a tidal reef flat. This exciting discovery was the first indication of such a settlement pattern for Lapita (although Chris Gosden would soon find similar preserved posts in the Arawe Islands sites off New Britain).

During our 51 days in Mussau we concentrated primarily on Talepakemalai, opening up 41 m^2 of test pits and areal excavations. However, we also surveyed and test excavated the ECB and EHB sites, and made reconnaissance surveys over much of Eloaua and Emananus islands, as well as Emussau, Ebolo, and Boliu islands, and parts of the main Mussau Island. In mid-September we were informed via radio that the *Dick Smith Explorer* was experiencing engine trouble in Manus, and would not be able to transport us

Figure 1.3. Senior leaders of the local Eloaua community lent their support to the Mussau Project from the first field season. From right to left, Ave Male, traditional landholder of the Talepakemalai site; Ororea; Aimalu, traditional landholder of the ECB site; and Bauwa Sagila.

back to Kavieng. We entrusted 17 boxes of pottery and other samples to Ave Male's care until the ship could be repaired and pick them up on her return to New Ireland. After a memorable farewell feast with the Eloaua villagers, Brockwell, Gaffey, and I flew to Kavieng on the Talair six-seater Baron, on September 20.

The 1986 Mussau Expedition

By the close of the 1985 field season, I knew that the archaeological landscape of Mussau encompassed four main kinds of sites: (1) open shell middens containing classic dentate-stamped Lapita pottery, represented by sites ECA, ECB, and EHB; (2) open shell middens with occasional non-Lapita pottery sherds, but more often with pottery wholly absent and marked by the presence of *Terebra*-shell and *Tridacna*-shell adzes; (3) small shell-midden and obsidian scatters, lacking pottery or shell adzes; and (4) rockshelters and caves situated in limestone escarpments. The first two site classes were frequently spatially extensive, with areas ranging from 1,000 up to 72,000 m^2; these sites were invariably found in the immediate coastal

Figure 1.4. Excavations in progress at Area B of the Talepakemalai (ECA) site in 1985. This initial 6 m2 excavation revealed the first anaerobically preserved remains of wooden stilt houses of the Lapita period.

zone, on beach ridges approximately 1–2 m above sea level. The small shell and obsidian scatters, in contrast, usually covered only a few tens of square meters, and were generally situated on the upraised, interior portions of the islands (ca. 10–40 m above sea level), in terrain utilized today for shifting cultivations. (Many of these shell scatters were identified by informants as former locations of temporary garden houses, with ages of no more than a few decades.) The rockshelters were located where the geological conditions provided vertical escarpments in the upraised reef limestone, or where former wave-cut notches or solution caves produced habitable spaces.

Other kinds of archaeological features common on some Pacific islands were notably absent from the Mussau archaeological landscape: there was virtually no stone architecture, such as walls, stone-faced terraces, platforms, pavements, or other constructions that could represent either habitation or agricultural activities. Rather, the cultural remains produced by past generations of islanders in Mussau were largely concentrated in a limited range of coastal shell middens of both Lapita and non-Lapita affiliation, and to a lesser extent in smaller shell-midden scatters and in rockshelters.

In order to fund the 1986 expedition, I submitted a research proposal to the Committee on Research and Exploration of the National Geographic Society (NGS), with the following objectives: (1) expansion of the Area B excavations at ECA, to expose more of the stilt-house structure and its associated materials; (2) further sampling of other portions of ECA, especially those dominated by plainware ceramics; (3) systematic sampling of the ECB and EHB sites, combined with additional survey for Lapita sites; and (4) systematic sampling of one or more of the apparently post-Lapita shell middens that had been discovered during our 1985 reconnaissance forays. The NGS awarded a grant of $22,500 in support of this proposed fieldwork.

I invited two University of Washington anthropology graduate students, both of whom had prior field experience in the Pacific, Terry L. Hunt and Marshall I. Weisler, to assist me in the field in 1986. Knowing that hiring local dugout canoes in Mussau would be problematic and exorbitantly expensive, I purchased a 12-foot Metzler “Maya-S” inflatable dinghy that we airfreighted to PNG, to assure our own inter-islet transport. To deal with the waterlogged deposits at ECA, I also procured three hand-operated marine bilge pumps, along with a large supply of waterproof labels, plastic bags, and a great deal of cotton wool for packing the fragile pottery.

Accompanied by Hunt and Weisler, I arrived in Port Moresby on August 24, 1986, and following visits to the University and National Museum, we flew to Kavieng on August 26. There I arranged with Drew Wright of PNG Fisheries Research, whom I had met in 1985, to send his assistant, John Aini, to Mussau to help us collect fish reference specimens to aid in the identification of Lapita fish remains.

On August 29, we flew to Eloaua on a chartered Talair twin-engine aircraft loaded to maximum capacity of 650 kg with gear and supplies, including our inflatable boat. Brothers Ave and John Male greeted us warmly along with other members of the Eloaua community. We recommenced excavations at ECA (which we now called by its local name of Talepakemalai) on September 1, and continued digging until September 25. We expanded the Area B excavation—with the stilt-house remains—to 24 m^2, obtaining a large sample of decorated ceramics, shell objects, and other materials (Figure 1.5). The marine bilge pumps kept the excavations units free of standing water, also providing a steady flow for wet-screening (Figure 1.6). Additional transect units were dug to clarify the site’s geomorphology and micro-stratigraphy. A large sample of anaerobically preserved plant remains was obtained, including many species of domesticated nuts and seeds, particularly from organically rich deposits just south of the Area B excavations. Holly McEldowney, an ANU doctoral candidate carrying out her own fieldwork in Manus, joined us in Mussau from September 17 until October 3, helping me to collect modern reference specimens of the plant taxa represented in the ECA deposits. John Aini of Fisheries Research joined us from September 5–19, preparing many fish skeletal reference specimens that proved invaluable in the subsequent identification of our archaeological fish fauna by Virginia Butler (see Chapter 7). We closed the ECA excavation on September 25, while artifact and midden processing continued in our field lab. Hunt began transect excavations at the ECB Lapita site on October 6, and later carried out expanded transect tests at EHB on Emananus Island (see Chapter 4).

Figure 1.5. The expanded Area B locus, Talepakemalai (ECA) site, at the completion of excavations in 1986, with the Eloaua Island excavation team. Note the anaerobically preserved wooden post bases.

Figure 1.6. Holson Aite operating one of the marine bilge pumps that we adapted for use in the Talepakemalai excavations. Bronwyn Meis, with shovel, was assisting in cleaning out the back-dirt fill from the 1985 excavation, in preparation for expanding Area B in 1986.

I had been told that a source of clay that might possibly have been used by the Lapita potters could be found inland of the village of Tanaliu, on the northwest coast of the main island of Mussau. On October 2, I organized a reconnaissance trip from Eloaua Island to Tanaliu, 30 km distant by sea (Figure 1.7). This was too far to travel with our Metzler inflatable and its 4-hp motor, so the large dugout canoe "Two Mile" was engaged for the trip. Leaving Eloaua at dawn, we arrived at Tanaliu by 10:30 am. Several Tanaliu villagers guided us to the clay source, two hours' walk inland at an elevation of about 250 m above sea level, where I procured a sample for XRF analysis and comparison to our prehistoric ceramics. We also were shown two large rockshelters, one of which (site EKQ) had calcareous sand-tempered sherds on its surface and looked promising for excavation. Arrangements were negotiated for Weisler to return to Tanaliu to excavate the EKP and EKQ rockshelters.

Figure 1.7. View of the main island of "Big Mussau" as seen from the beach fronting Eloaua Village.

I departed Eloaua on October 10, 1986, leaving Hunt in charge of continued excavations at Lapita sites ECB and EHB, and directed Weisler to test the newly discovered EKP and EKQ rockshelters; they remained in the field until late November. As previously, we were allowed by the PNG National Museum and Art Gallery to export all collections to Seattle for analysis.

Laboratory Interlude, 1986–1987

By the close of the 1986 field season, we had acquired a collection of 60,000 potsherds, nearly 3,000 obsidian flakes, about 800 non-ceramic portable artifacts, 21,726 vertebrate faunal remains, and more than 5,000 anaerobically preserved plant remains, primarily from ECA but also from other sites. Support from the National Science Foundation allowed us to proceed with analysis of this extensive collection, and included funds for three graduate research assistants at the University of Washington and a zooarchaeological consultant, Dr. Alan Ziegler, a specialist in New Guinea fauna at the Bishop Museum. The research design for this laboratory phase was oriented around five objectives, posed as a series of questions specified in the NSF proposal (Kirch 1986a):

1. In morphological (functional) and stylistic terms, what was the sequence of Lapita ceramic change in Mussau? Is a distinct, "formative" Lapita phase indeed recognizable on ceramic criteria? What are the formal relationships between the Mussau Lapita assemblages and those known from other sites in the Bismarcks and from sites farther to the east?
2. What is the extent of heterogeneity in Mussau Lapita ceramic composition? To what extent were Mussau ceramics locally manufactured or imported? What were the changing configurations of ceramic importation over time?
3. What range of exotic lithic materials were imported into the Mussau Lapita communities, and what temporal changes occurred in the diversity and frequency of such imports? To what extent did the importation of exotic lithics change after about 2500 BP with the cessation of classic Lapita?
4. What was the extent of marine exploitation in Mussau Lapita economy? What diversity of resources and biotopes were exploited, what was the intensity of exploitation, what specific strategies were practiced, and how did these change over time? Can the long-term effects of human predation of reef-lagoon resources be detected archaeologically?
5. To what extent were horticultural production and animal husbandry components of the Mussau Lapita economy? Is there evidence for the development or intensification of terrestrial production over time?

I initiated a formal, descriptive analysis of the large sample of excavated ceramics, using procedures and systems developed by Rye (1981), Mead et al. (1975, Donovan (1973), Anson (1983), and others (e.g., Kirch and Yen 1982) for Oceanic ceramic assemblages. An attribute-based approach was chosen, with data coded for entry into a computerized database, initially using the MINARK software system. Before we could undertake this analysis, however, emergency conservation of the thousands of sherds from the waterlogged ECA deposits was urgently required, as these showed signs of exuding salts and in some instances rapid deterioration. After consulting with objects conservator Laura Word of the Bishop Museum, we treated each sherd with an application of B-72 Acryloid, a consolidant, to all surfaces. This task required hundreds of hours of painstaking work under a fume hood because the consolidant and the acetone in which it was suspended are both toxic.

Lapita pottery exchange had emerged as a topic of discussion and debate, in part from Green's work in the Solomon Islands (1976), and from Anson's (1983, 1986) studies of "Far Western" Lapita ceramics. However, with the exception of Anson's pioneering application of X-Ray fluorescence (XRF) compositional analysis, the characterization or sourcing of Lapita ceramics had been limited to petrographic analysis of temper or non-plastic inclusions (Dickinson and Shutler 1979). To address Objective 2, we sampled the Mussau ceramics in a staged fashion, beginning with macroscopic sorting, moving to binocular examination of temper and paste characteristics, and finally to compositional analysis using energy-dispersive X-Ray fluorescence (ED-XRF) by means of a scanning electron microscope (SEM) microprobe. This research became the focus of Terry Hunt's doctoral dissertation (Hunt 1989).

Allen (1984) had drawn attention to the movement of obsidian within the Bismarck Archipelago well before Lapita, a finding that was amplified by excavations in New Ireland rockshelter sites during the LHP in 1985. It was also known that obsidian had been a component of Lapita long-distance exchange as far to the east as the Santa Cruz Islands (Ambrose and Green 1972; Green 1976, 1979a). But the changing configurations of obsidian movement between Lapita communities (as well as of other lithics, such as chert) needed to be worked out in detail. While we took advantage of the LHP program of PIXE-PIGME sourcing of obsidian, it was not possible to use this expensive technique on all of the 3,000 obsidian specimens from Mussau. I decided to apply the method of rapid heavy liquid (sodium metatungstate) density sorting that had been developed by Roger Green (1987), since the main Melanesian sources (Talasea and Lou) could be—at least partially—discriminated on this specific gravity basis. Melinda S. Allen, then a graduate student at the University of Washington, took on this project (see Chapter 14). The ECA and other site excavations had also yielded a collection of about 300 "manuports" (many of which were oven stones), with a diversity of lithologic types. These were characterized using standard petrographic methods by Prof. William Dickinson of the University of Arizona (see Chapter 17).

The large assemblage of vertebrate faunal materials excavated in 1985 and 1986 had been shipped to my University of Washington laboratory, while close to a metric ton of mollusk remains had been processed in the field. In 1986 we had also collected modern fish reference skeletons that, when combined with a reference set I had made on Tikopia in 1977–1978 (deposited in the Bishop Museum, Honolulu), allowed us to identify a significant number of the excavated fishbones. The task of sorting and identifying more than 15,000 fishbones was undertaken by Virginia Butler, then a graduate student pursuing an interdisciplinary Ph.D. in zooarchaeology and ichthyology at the University of Washington (see Chapter 7).

At the time of the Lapita Homeland Project, the question of whether Lapita communities had been "strandloopers" relying exclusively on marine exploitation for their subsistence, or whether they also possessed a horticultural complex, had been hotly debated (Groube 1971; Green 1979a; Kirch 1978, 1979, 1982a). Our discovery of well-preserved plant remains in the waterlogged deposits at ECA, especially of such Oceanic tree crops as *Canarium* almond, *Terminalia* almond, and Tahitian chestnut (*Inocarpus fagiferus*), strengthened the arguments in favor of a horticultural, and more specifically an arboricultural, basis for Lapita economy. Addressing Objective 5, an analysis of the approximately 5,000 plant remains from ECA was completed and submitted for publication in 1988 (Kirch 1989).

A preliminary synthesis of the results from the 1985 and 1986 field seasons was published in the final report of the LHP (Kirch et al. 1991), along with several other papers reporting specific results (Kirch 1988b, 1988c, 1989; Kirch and Hunt 1988b; Kirch et al. 1987; Kirch et al. 1989). Nonetheless, a third field season was essential to fully resolve several research questions that had emerged in the course of our work. I submitted a second proposal to NSF in December 1987, requesting $94,663 to support a third expedition to Mussau, along with an additional phase of laboratory analysis; NSF awarded the grant on June 1, 1988.

The 1988 Mussau Expedition

I laid out five objectives for the Mussau Project's 1988 field season (here again reproduced from the NSF proposal):

1. What is the internal spatial structure of the ECA site, as evidenced architecturally, and by the distribution of cultural materials? To what extent does spatial differentiation indicate functional specialization?
2. What were the technical processes and reduction sequences used to manufacture shell artifacts at ECA? To what extent was the production of shell "ornaments," fishhooks, or other artifacts functionally specialized within the site?
3. What was the extent of marine invertebrate exploitation in Mussau Lapita economy? What diversity of resources and biotopes were exploited, what was the intensity of exploitation, what specific strategies were practiced, and how did these change over time? Can the long-term effects of human predation of reef-lagoon resources be detected archaeologically?
4. What was the extent and role of arboricultural production in the Mussau Lapita economy? Is there evidence for the development or intensification of terrestrial production over time?
5. What was the chronology and nature of the transition from Lapita to post-Lapita phases? How is this transition reflected in ceramics, material culture, subsistence strategy, long-distance exchange, and settlement pattern?

In my NSF proposal, I observed that "Lapita sites are notorious for their lack of meaningful stratigraphy, extensive post-depositional disturbances, and paucity of architectural features" (Kirch 1987b:9). Only Green's RL-2 site in the Reef Islands (Green 1976, 1978), along with two incompletely reported sites in New Caledonia (Frimigacci 1980), had yielded significant architectural or spatial-distribution data on Lapita settlements. In this context, Talepakemalai had particular significance, because: (1) at more than 70,000 m^2 area it is the largest Lapita site on record, with the greatest potential for internal structural differentiation; (2) it was the only Lapita site then known to have well-preserved evidence of wooden architecture; and (3) our prior excavations had demonstrated some spatial differentiation in the distribution of ceramics and other artifact classes.

During the 1986 field season, I had come to realize that Talepakemalai had been a specialized center for the manufacture of shell artifacts, leading to the formulation of Objective 2. Many such shell "ornaments" had been found at other Lapita sites, but little attention had been paid to their manufacture, or to the possibility that rather than being merely objects of bodily adornment, these had functioned as "exchange valuables" in a manner analogous to the shell valuables known ethnographically from many parts of Melanesia. A comparative analysis of data from ten Lapita sites (Kirch 1988c) convinced me that while many sites yielded small quantities of such finished objects, only three sites (including ECA) showed clear evidence for their manufacture. This suggested that certain Lapita communities, including those in Mussau, might have specialized in the production of shell exchange valuables, exporting these in exchange for the importation of ceramics, obsidian, or other exotic materials.

This hypothesis needed to be tested against further data from the ECA site, by paying close attention to manufacture detritus from such mollusk species as *Conus litteratus*, *C. leopardus*, *Trochus niloticus*, *Spondylus* sp., and *Tridacna gigas* and *T. crocea*, from which the putative "valuables" were made. In prior field seasons we had treated such materials (unless they were obviously manufacture stages of shell artifacts) simply as components of the site's shell midden. In 1988, we therefore paid close attention to the quantities of worked or rejected shell material, as well as to the more obviously recognizable stages of artifact reduction, broken specimens, and completed items, reasoning that this would permit an estimate of the quantities of shell being worked at the site, as well as an account of the sequence of production of these artifact classes.

Nagaoka's (1988) review of shell midden analyses from Lapita sites throughout the southwestern Pacific had made it clear that a mere handful of sites had any quantitative data on invertebrate faunal materials. To fully address Objective 3, I decided that we needed to engage a qualified marine biologist to work with the archaeologists, *in the field*, to apply more sophisticated and biologically informed analyses to the problems of Lapita marine exploitation. In particular, I wanted to resolve the question of whether Lapita predation on local reef-lagoon invertebrates had been sufficiently intensive or sustained as to result in measurable effects on the mollusk populations themselves (i.e., resulted in "resource depression"). Elsewhere in the Pacific, Swadling (1976, 1977a, 1977b) and Anderson (1979, 1981) had demonstrated such effects, using metric and morphological measures.

Australian marine biologists Ian Poiner and Carla Catterall had conducted studies of contemporary human predation effects on the ecology and population biology of *Strombus luhuanus*, one of the dominant gastropods in our ECA midden assemblage, and an important food resource in many parts of island Melanesia (Catterall 1986; Catterall and Poiner 1987; Poiner and Catterall 1988). Catterall agreed to join us in the field in 1988, to undertake biological control sampling of the contemporary Mussau mollusk populations, to map the microenvironmental zones on the Eloaua reef and lagoon areas, and to develop a joint protocol for metric and morphological analysis of the archaeological mollusks. Mussau seemed a suitable locality to undertake such work, because the Eloaua islanders have been staunch Seventh-Day Adventists since missionization in 1930. As such (following the dietary restrictions of Deuteronomy), they do not eat shellfish and thus there had been little or no human collection pressures on the Eloaua mollusks for nearly four decades.

With respect to Objective 4, the large collection of anaerobically preserved plant remains obtained in 1985–1986 represented 24 taxa of domesticated or arboriculturally significant species (Kirch 1989). These finds raised questions of whether the characteristic forms of Melanesian arboriculture described by Yen (1974, 1991) had their origins in the Lapita cultural complex.

All of our plant remains from the first two excavations seasons had been recovered by standard sieving procedures; several colleagues had posed the question of whether application of finer sieving (e.g., 1 mm mesh or smaller), combined with flotation, might yielded additional plant taxa. Although I doubted that flotation would significantly increase our sample (given the nature of domesticated taxa known ethnobotanically from Near Oceania, with their large fruits or seeds), this needed to be empirically tested. Thus in our 1988 fieldwork we planned to apply flotation and fine-sieving in the ECA excavations. Also, since the contemporary Eloaua islanders continue to practice intensive arboriculture—cultivating much the same range of species as witnessed in our archaeobotanical samples—there was scope for an ethnoarchaeological study of Mussau tree cropping. The only prior ethnobotanical study of such Melanesian arboriculture had been Yen's pioneering work in the Santa Cruz Islands (Yen 1974). For both the flotation work and the ethnoarchaeological study, I engaged Dana Lepofsky, then a University of Washington graduate student with prior training in paleoethnobotany. She undertook a thorough ethnobotanical study of contemporary arboriculture (Lepofsky 1992), as well as a detailed metrical analysis of the archaeobotanical assemblages (Lepofsky et al. 1998).

Despite our testing of several post-Lapita sites during the 1986 field season (such as EKU and EKS), I was concerned that we had not adequately sampled the non-Lapita archeological record of Mussau, hence the formulation of Objective 5. I wanted to excavate one of the non-Lapita shell middens on either Boliu or Ekaleu islands that we had discovered during reconnaissance, which were characterized by the presence of *Terebra*-shell adzes and *Trochus*-shell armrings. Jason Tyler, a recent graduate of the University of Washington, was enlisted to carry out this task.

Accompanied by Lepofsky and Tyler, I flew to Port Moresby on September 8, 1988, and on to Kavieng on September 16. After securing necessary supplies and provisions, we flew by chartered Talair aircraft to Eloaua on September 20. After acquainting Lepofsky and Tyler with local field conditions and setting up our field laboratory, we re-cleared the ECA site, and recommenced excavations at Talepakemalai on September 22 (Figures 1.8 and 1.9). The main emphasis at ECA in 1988 was on excavating a 130 m long transect along the W250 grid line (with pits spaced

Figure 1.8. Eric Kop and Dana Lepofsky sort anaerobically preserved plant remains from the Talepakemalai (ECA) site in 1988.

Figure 1.9. The 1988 field laboratory was set up adjacent to Ave Male's house in Eloaua Village, which was also our home throughout the Mussau Project. Jason Tyler identifies shell midden samples, assisted by John Male and Meis Talogu, while Dana Lepofsky processes flotation samples for botanical remains.

every 10 m), but we also opened an additional 4 m^2 at Area B (the "Area B extension"), and two units of 4 m^2 each at the north end of the W250 transect, designated as Area C. This work, combined with additional augering, gave us a much clearer understanding of spatial differentiation within this large and complex site (Figures 1.10 and 1.11).

Lepofsky carried out the flotation and fine water-sieving of 1 liter samples from a large number of stratigraphic contexts, dispelling any notion that our sample had been biased to macroscopic remains. We undertook an intensive analysis of the abundant invertebrate faunal materials (primarily mollusk shells) recovered from the W250 transect units. Carla Catterall, accompanied by assistant Mike Ritchie, arrived on Eloaua on September 23; with their aid we not only quantified all mollusk remains by counting and weighing, but also measured metric variables on literally thousands of shellfish remains (Figure 1.12). This task required a huge effort, since after an already exhausting day of digging in the equatorial sun, we then measured shells with calipers by kerosene lantern light, often until midnight. The database that we obtained, however, was essential for testing hypotheses regarding shellfish size changes in the ECA midden deposits (see Chapter 9).

While Lepofsky, Tyler, and I excavated at Talepakemalai, Catterall and Ritchie, using our inflatable boat, undertook an ecological survey of the reefs and lagoons of the Eloaua, Emananus, and Boliu islands, from which they produced a detailed environmental map (see Chapter 2). In addition, they sampled the range of marine and littoral microenvironments for mollusks, and collected control samples essential for interpreting the archaeological assemblages.

On October 6, Catterall and Ritchie departed Mussau, while Nick Araho (Assistant Curator of Prehistory, PNG National Museum) arrived. Araho helped to complete the ECA transect and Area C excavations, which were finished on October 14. The next two weeks were spent in completing the analysis of shellfish samples, flotation analysis, and packing of the ECA collections for air freighting to Seattle. Meanwhile, Lepofsky started on her ethnoarchaeological

Figure 1.10. John Male and Jason Tyler wet-screening along the W250 transect excavations at Talepakemalai (ECA) in 1988.

study of contemporary Mussau arboriculture, while I assisted Tyler in beginning excavations on Boliu Island at the EKE site, which promised to provide a stratified record of the post-Lapita period in Mussau. Tyler excavated at EKE from October 16 through November 24, at times assisted by Nick Araho. With these projects underway, I departed Eloaua on October 29, leaving Lepofsky, Tyler, and Araho to carry out their respective tasks. Tyler and Lepofsky remained in the field throughout November, returning to Seattle in early December. At the close of the 1988 field season, our combined fieldwork in Mussau over three field seasons had resulted in the excavation or testing of 13 sites, with a total excavated area of 159.5 m^2 (Table 1.1).

Figure 1.11. Nick Araho (Papua New Guinea National Museum) records the position of wooden post bases in Area C at Talepakemalai (ECA) in 1988.

Figure 1.12. Carla Catterall plots marine transect data on mollusks on the reefs around Eloaua Island, during the 1988 field season. Our Metzler Maya-8 inflatable boat hangs under the floorboards in the background.

The Mussau Project Three Decades Later

At the end of the 1988 season, I decided to conclude the fieldwork component of the Mussau Project. The temptation to return for yet another field season was tempered by the fact that we had already accumulated a massive collection of materials and data, which now called for intensive analysis and publication. Moreover, during the 1988 season it had become disturbingly evident that Eloaua was an increasingly dangerous locality in which to bring a foreign field team, including graduate students. (Among the changes we noted in the small Eloaua community were the breakdown in the authority of the village elders, and the rise of a youth "gang culture," the latter influenced in part by pornographic and other videos seen by many of the young men on visiting logging ships.)

In January of 1989 I left the University of Washington to take up a professorship at the University of California, Berkeley, which required setting up a new Oceanic Archaeology Laboratory and moving the Mussau collections from Seattle, a time-consuming task. On January 19–21, 1990, I convened a conference of Mussau Project participants at the Archaeological Research Facility, Berkeley, during which research results were presented by Melinda Allen, Gwen Bell, Virginia Butler, Carla Catterall, Terry Hunt, Dana Lepofsky, Jason Tyler, Marshall Weisler, and myself; Prof. Roger Green of the University of Auckland participated as discussant. Problems of stratigraphy and data correlation were ironed out, and plans drawn up for the publication of a final monograph. I initially expected that this might be accomplished within a year or two, but several factors intervened to delay final publication of the Mussau Project, among them a disappointing failure of a few participants to complete their contributions in a timely manner. In 2000, an edited volume compiling the details of site excavations, stratigraphy, and radiocarbon dating was published (Kirch 2000). Subsequent engagement in new research projects in Hawai'i and French Polynesia, however, resulted in putting analysis of the Mussau collections once again "on the back burner."

In his Preface to *Guilá Naquitz*, a monograph on a Mexican cave excavation that took some 20 years to complete, Kent Flannery wrote that he had become converted to "what might be called the 'Paul Masson' approach to archaeology: 'I will publish no site . . . before its time'"

Table 1.1. Summary of Mussau site excavations, 1985–1988

Island	Locality	Site	Site Type	Year Dug	Method	Area Dug m^2	Periods Represented
Eloaua	Talepakemalai	ECA	Open midden	1985, 86, 88	Transect, areal excavation	84	Lapita
Eloaua	Etakosarai	ECB	Open midden	1985, 86	Transect	19	Lapita
Emananus	Etapakengaroasa	EHB	Open midden	1985, 86	Transect	9	Lapita
Eloaua		EHM	Cave	1986	Test pits	3	Lapita
Eloaua		EHN	Rockshelter	1986	Test pit	1	Lapita
Eloaua		EKO	Rockshelter	1986	Test pits	2.5	Lapita
Mussau	Eatulawana	EKP	Rockshelter	1986	Trench	5	Post-Lapita
Mussau	Epakapaka	EKQ	Rockshelter	1986	Test pits	2	Lapita
Emussau		EKS	Open midden	1986	Test pits	4	Post-Lapita
Mussau	Sinakasae	EKU	Open midden	1986	Transect	5	Post-Lapita
Boliu		EKE	Open midden	1988	Transect	19	Lapita to Post-Lapita
Eloaua		EHK	Open midden	1988	Transect	5	Post-Lapita
Enusagila		EKL	Open midden	1988	Test pit	1	Historic
TOTAL						159.5	

(1986:xvii). (The reference is to a marketing ploy once used by the Paul Masson winery—a purveyor of low-cost "jug" wines—which claimed it would "sell no wine . . . before its time.") I, too, have become a convert to this approach, although such was not my intention when I began fieldwork in the Mussau Islands in 1985.

As I began to approach retirement from active teaching at the University of California, Berkeley, in 2014, I laid out my goals for the coming years as an Emeritus Professor. Chief among these was the completion of final publications for several long-delayed projects, among them Mussau. To help assure that this goal would be achieved, I invited my former graduate student Scarlett Chiu, now a researcher at the Academia Sinica in Taiwan, to collaborate on the analysis of the large assemblage of Lapita ceramics from ECA and other Mussau sites. For her Berkeley dissertation, Chiu had studied the pottery from the eponymous site of Lapita (Site 13A) at Koné, New Caledonia (Chiu 2003). Subsequently, at the Academia Sinica Chiu developed the Lapita Pottery On-line Database (LPOD). During several extended trips to the Oceanic Archaeology Laboratory at Berkeley, Chiu and her assistants recorded, photographed, and drew 6,652 sherds of pottery from Mussau, incorporating all of these data into the LPOD. This substantial effort allowed me to complete the analysis of the Mussau ceramics, paving the way for the final publication of the Mussau Project results.

The Mussau Project fieldwork, and the initial series of radiocarbon dates that were run of materials excavated in 1985–1988, took place prior to major advances in radiocarbon dating that came beginning in the 1990s with the development of accelerator mass spectrometry (AMS) dating, and later, with the application of Bayesian modeling and calibration. These advances, along with new series of radiocarbon dates from other Lapita sites elsewhere in the southwestern Pacific, engendered considerable debate on the chronology of Lapita expansion from Near to Remote Oceania (e.g., Specht and Gosden 1997; Denham et al. 2012). I therefore felt it was critical to obtain a series of new, high-precision AMS dates from our Mussau sites, in order to refine the

Mussau chronology as originally published (Kirch 2001b). Between 2016 and 2018, 26 additional samples, mostly of non-carbonized plant materials such as *Canarium* almond nut shells (anaerobically preserved at Talepakemalai) but also including marine mollusks where necessary, were dated at the Keck Carbon Cycle AMS facility at the University of Irvine, California. Combined with the original suite of radiocarbon dates, these new high-precision AMS dates have allowed for a considerable refinement of the Mussau Islands chronology (see Chapter 5).

The original publication plan for the Mussau Project was a series of three volumes. The first of these (Kirch, ed., 2001) dealt with site stratigraphy and dating, and was to be followed by volumes on the botanical and faunal remains, and on the pottery and other artifacts, respectively. Nearly two decades later, necessitated in part by the new radiocarbon dates and refined chronology just mentioned, I decided to abandon this plan and to combine all of the project reports into this single volume. Chapters 1 through 4 of this volume incorporate parts of what was originally published in Kirch (ed., 2001), with considerable revisions. All other chapters are entirely new and have not been previously published.

Three decades have now passed since we closed down the 1988 excavations at Talepakemalai. During this period there have been many advances in Lapita archaeology, both as a result of new fieldwork in various parts of the southwestern Pacific, and through the application of new methods and approaces not available 30 years ago. The results of this research are to be found in dozens of journal articles, and especially in several edited volumes emanating from the international Lapita Conferences that have been held every four years. In preparing the present volume for publication, we have endeavored to reference this body of literature where relevant. However, the reader must keep in mind that we are presenting here the results of work that was carried out in the context of the theories, methods, and assumptions of Pacific archaeology as it was practiced in the mid-1980s. For this I make no apology.

For its time, I believe, the Mussau Project applied a cutting-edge approach and methods that contributed significantly to our knowledge and understanding of Lapita in the Bismarck Archipelago. That some of these methods might now seem slightly dated, or that we did not use techniques that have subsequently been developed, is inevitable. Such are the hazards of archaeological science as an ever-evolving discipline. But the corpus of materials that our teams—ably assisted by our Mussau Island friends and helpers—wrested from the sands of Talepakemalai and other sites in the Mussau Islands remains one of the largest and best documented of the entire Lapita cultural complex. It has taken much longer than anticipated, but with this volume I have the pleasure and satisfaction of knowing that our work in Mussau has now been fully documented, giving the Mussau collections—which will doubtless be the objects of further investigation by future generations of scholars—the critical context that all archaeological materials require in order to be properly interpreted.

CHAPTER 2

The Mussau Islands: Natural and Cultural Environments

Patrick Vinton Kirch

with a contribution by Carla P. Catterall

Lying just south of the equator, amidst some of the greatest biodiversity of the vast Indo-Pacific region, the Mussau Islands provided their indigenous inhabitants with a remarkable range of habitats and resources, both physical and biotic. This chapter summarizes the salient aspects of this environmental canvas from the perspective of human ecology, also paying attention to features of the environment with direct relevance to the archaeological record and its interpretation. The second half of the chapter addresses the ethnographic record for Mussau—as imperfectly as it is known—for insights this may provide to the archaeologist seeking to recover the *longue durée* of human history in these islands.

Geographical Overview

The Mussau Islands, part of the St. Matthias Group which also includes Emira (also known as E Mira or Emirau) to the southeast (and sometimes includes isolated, tiny Tench Is. as well), are situated at 140° 40' E longitude and 1° 25' S latitude. They form the northernmost point along the arc of the Bismarck Archipelago, 150 km northwest of New Hanover Island (Lavongai). The Manus (Admiralty Is.) group lies 200–250 km to the southwest. On unusually clear days it is possible to see the high peak of New Hanover from higher elevations on Mussau, but Mussau and Manus are never intervisible.

The Mussau group proper (Figure 2.1) is dominated by a single large high island, bearing the same name, and by 11 other small islands and inlets that form a cluster to the southwest of the main island (Table 2.1). The largest of these two offshore islands, Eloaua and Emananus (Figure 2.2), together with diminutive Eunakuru and Enusagila, make up an atoll-like formation enclosing a lagoon. They differ from a typical atoll, however, in that they incorporate elevated reefs (*makatea*) as well as unconsolidated sands (*motu*); moreover, the origin of this atoll-like structure appears to be the result of tectonic island-arc uplift, rather than subsidence as in atolls. Eloaua and Emananus have probably been continuously occupied since the early Lapita period, reflected in various aspects of their natural history,

Figure 2.1. Map of the Mussau Islands, based on the Papua New Guinea Topographic Survey 1:100,000 map (Sheet 8894, prepared 1980).

such as the extent of secondary growth and orchard gardens, and the development of anthropogenic soils on the low-lying calcareous flats.

A deep channel (the Malle Channel) lies between the Eloaua-Emananus "atoll" and the other offshore islets, most of which sit amongst a complex of reefs and lagoons, rich in fish and shellfish resources (Figure 2.3). Ekaleu Island, at the northwestern end of the Malle Channel, was the setting for a colonial-era German coconut plantation; the island is still covered in tall coconut palms, with an abandoned

Table 2.1. Geographic characteristics of the Mussau Islands

Island Name	Geological Type	Size (km²)	Maximum Elevation (m)
Mussau	High island, volcanic core with elevated limestone terraces	348	650
Eloaua	Elevated limestone (*makatea*) with peripheral unconsolidated sand beach terraces	7.5	48
Emananus	Elevated limestone (*makatea*) with peripheral unconsolidated sand beach terraces	4	45
Boliu	Elevated limestone (*makatea*) with peripheral unconsolidated sand beach terraces	1	26
Enoanaulu	Elevated limestone (*makatea*)	1	58
Ebolo	Unconsolidated sand cay	0.5	1.5
Emussau	Unconsolidated sand cay, possibly on minimally uplifted limestone core	0.4	2
Ekaleu	Unconsolidated sand cay, possibly on minimally uplifted limestone core	0.3	3
Ebanalu	Elevated limestone (*makatea*)	0.25	17
Tapatu	Unconsolidated sand cay, possibly with minimally uplifted limestone core	0.3	6
Eunakuru	Unconsolidated sand cay	0.3	1.5
Enusagila	Unconsolidated sand cay	0.05	2

Figure 2.2. Aerial photo of the southern part of the Mussau Islands, with Schadel Bay at the top of the photo, and with Eloaua and Emananus Islands at the bottom of the photo. Dumbell-shaped Boliu Island is visible in the middle of the photo. (Photo by the Royal Australian Survey Corps, 1973.)

Figure 2.3. Aerial view of the northwestern part of Emananus Island (in the distance), with Eunakuru Island and adjacent reefs in the middle distance.

Figure 2.4. The view from Eloaua Island across the Malle Channel, with the large island of Mussau in the distance. The stilt posts of a former house protrude from the tidal flats.

wooden frame house that sits atop a large, late prehistoric shell midden. Ebanalu, Enoanaulu, and Boliu islands all have small hamlets and gardens, whereas Emussau, Ebolo, and Tapatu are unoccupied. Emussau, however, has a late prehistoric midden site that we test excavated (site EKS).

The modern population of the Mussau group numbers less than 2,000 persons, concentrated in several villages on Mussau Island proper, as well as on Eloaua and Emananus. The administrative center is at Palakau at the head of Schadel Bay, while the Seventh-Day Adventist mission school is located at Boliu on the opposite side of the bay (Figure 2.4). There is a concrete wharf at Palakau but no airstrip, so that persons flying in or out of the islands must commute between Palakau and Eloaua by canoe or boat. At the time of our fieldwork from 1985 to 1988, rough, unpaved roads connected Palakau to communities at Tavol, Etasitel, Roitano, and Lomakanauru on the east and south coasts, and to the logging mill at Alamul on the southwest. More remote settlements, such as Tanaliu and Etalat in the northern part of Mussau, could be reached only on foot or by canoe. There were no roads at all into the interior. The only airstrip in the group is on Eloaua, an 800 m long packed coral runway constructed by the Seventh-Day Adventist mission in the early 1970s, capable of landing small aircraft (4- or 6-seaters). The Eloaua airstrip is not officially maintained, and has no maintenance staff, radio, or navigational facilities. During our fieldwork there was in theory a once-a-week Talair flight from Kavieng, but on many occasions this was canceled due to bad weather.

Natural Environment and Resources

Unlike the situation in other parts of the Pacific, where there is a long tradition of natural science investigations and a rich scholarly literature, the natural science literature pertaining to Mussau is extremely limited. Prior to our project, only two organized scientific expeditions had ever worked at Mussau, the famous Südsee Expedition of the Hamburgische Wissenschaftliche Stiftung in 1908 (Thilenius 1927), and the Danish *Noona Dan* Expedition in 1962 (Wolff 1966), each for relatively short periods. The Südsee Expedition concentrated largely on ethnography (Nevermann 1933), although they also made geographical and geological observations. The *Noona Dan* Expedition made botanical and zoological collections, but as far as I have been able to determine, these collections were never been fully reported or analyzed. The only other scientific collecting on Mussau was for birds, by A. F. Eichhorn under the auspices of the great amateur ornithologist Lord Rothschild, the specimens being worked up by Hartert (1924). In 2014, a team of the Wildlife Conservation Society conducted a "rapid biodiversity survey" of Mussau, limited to ten days of fieldwork at two localities on Mussau Island (Whitmore 2015). While limited in scope, this biodiversity survey added considerable information regarding plants, birds, herpetofauna, and bats of Mussau.

Given the dearth of geographical and environmental data available prior to our fieldwork, we made many observations of our own during the three field seasons, collecting herbarium voucher specimens of the common secondary forest plants on Eloaua (159 specimens were deposited with the Herbarium Pacificum of the Bernice P. Bishop Museum), obtaining rock samples, and carrying out our own marine ecological survey and mapping (under the direction of Carla Catterall). The notes that follow are made largely from these observations, combined with what can be gleaned from more general surveys of Papua New Guinea and Melanesian natural history, and from the recent biodiversity assessment of Whitmore (2015).

Geology

Structurally, Mussau lies astride the Emirau-Feni Ridge, the northern face of which plunges steeply down into the 6,000+ m deep Manus-Kilinailau Trench (Exon et al. 1986:Figure 2). It is thus on the northern sector of a major geophysical province, sometimes labeled the New Ireland Basin, an "arcuate feature extending 900 km northwestward from the Feni Islands in the east to Manus Island in the west" (Exon et al. 1986:39). The basin's complex stratigraphy and geological history commences with Eocene/early Miocene volcanics, and continues with the deposition of late Miocene/Pliocene carbonates (in some areas with renewed and continuing volcanics). What little information we have on Mussau geology is consistent with this general New Ireland Basin sequence, and some inferences may be drawn from the limited geological data available for New Ireland, New Hanover, and Manus (Brown 1982; Exon et al. 1986; Francis 1988; Hohnen 1978; Jaques 1980; Stewart and Sandy 1986).

The only extant geological map of Mussau is the 1:1,000,000 scale *Geology of Papua New Guinea* published by the Department of Lands, Surveys, and Mines, Port Moresby in 1972. At this greatly reduced scale, only two formations are indicated for the Mussau group. The interior portions of Mussau Island proper are shown as consisting of unspecified volcanics of upper Miocene/Pliocene age, whereas the outer fringe of Mussau and the smaller offshore islets such as Eloaua and Emananus are depicted as limestones, marl, and raised coral reefs of Quaternary age. This highly generalized picture accords with my own observation that, especially on the south, west, and north, Mussau has an extensive "apron" of carbonates that overlie the volcanic core. Along the east coast, a number of streams dissect this volcanic core, from which we collected nine samples of igneous rock, derived from the island's interior (see Chapter 17). These samples fell into two distinct groups: (1) a generically related suite of plutonic (intrusive) diorite-gabbro; and (2) much finer-grained igneous rocks of probable volcanic and hypabyssal origin, with geochemistry of mafic andesite or basalt, and aphanitic textures. The gabbroic plutonic rocks presumably represent the deeply eroded plutonic roots of a local volcanic edifice.

In the south part of Mussau Island (the area inland of Lomakanauru) the massive limestone formation rises in a series of relatively level plateaus, separated by abrupt escarpments (Figure 2.5), indicating that the limestones are of biogenic reefal origin, with the scarps representing different uplift intervals. The main terraces have elevations of approximately 40, 120, and 200 m above sea level.

Figure 2.5. Aerial view of the southern part of Mussau Island, in the vicinity of Lomakunauru Village, where the terrain consists of a series of elevated limestone terraces.

The offshore islands such as Eloaua are entirely devoid of volcanics, an important point for archaeological investigations, since any volcanic stones (worked or natural) found in our excavations had to have been imported, even if only from Mussau Island. (A petrographic analysis of manuports from Talepakemalai is provided in Chapter 17.) Most of these islands, including Eloaua, Emananus, and Boliu, consist of elevated reef limestones and conglomerates. On Eloaua, two major uplift terraces are present, one at an elevation of about 26 m and a higher one (which forms the central, cultivated plateau) at about 46 m above sea level. These have not been dated, but corals in growth position were evident in various exposures; I judged them to be of late Pleistocene age. On other islands, such as Emussau, Ebolo, and Ekaleu, it is uncertain whether the low-lying (ca. 1.5–3 m above sea level) unconsolidated marine sands that make up the islands are anchored to an underlying block of limestone, or whether they have merely formed on an exposed reef platform.

All the offshore islands exhibit geomorphological evidence for a mid-Holocene sea level stand at between +1–1.5 m, in the form of wave-cut, solution notches, and in the deposition of unconsolidated calcareous sand aprons and beach terraces at about 2 m above sea level (current beach terraces, as on Eloaua Is., are only about 1 m above sea level). Eloaua and Boliu islands have narrow “necks” of unconsolidated Holocene sands connecting blocks of elevated limestone, in each case joining what had previously been two separate islets during the former mid-Holocene high-stand.

To summarize, the Mussau Group probably originated during the Tertiary through volcanic island-arc formation, as part of the same regional tectonics that formed New Ireland and Manus. The Miocene/Pliocene volcanics were subsequently capped with extensive submarine deposits of Quaternary limestones, marls, and conglomerates, which were then elevated through tectonic uplift in the late Quaternary. This uplift progression advanced in a series of discrete stages, creating a “stairstep” topography in the southern part of Mussau, and on the offshore islets. These latter were the last to be elevated, presumably during the late Pleistocene. We saw no evidence of Holocene tectonic activity, but geomorphological indicators of a mid-Holocene (6,000–3,000 year BP) higher sea level stand of about +1.5 m are very clear. This is interpreted as a local reflection of the widespread mid-Holocene high-stand thought to have resulted from a combination of eustatic and/or geoidal changes (Dickinson 2014). For the archaeologist, two points are salient: (1) the limited range of volcanic rocks present in the group, and their restriction to the interior of Mussau Island; and (2) the mid-Holocene sea level changes, which had important consequences for shoreline progradation and beach terrace formation in the past 3,000–4,000 years.

Climate

Situated 1°25' S of the equator, Mussau falls within the Inter-Tropical Convergence Zone (ITCZ), probably the most important influence on its climate. The ITCZ is "an organized zone of high cloudiness and rainfall containing deep convective (cumulonimbus) clouds" (McAlpine et al. 1983:15). While there is limited seasonality with a northwest monsoon season from mid-November to the end of March, and a southeast trades season from mid-May until the end of September (Reynolds 1972), seasonality is not nearly so pronounced here as in the more southerly parts of the Bismarck Archipelago. The days are hot and humid, the nights only marginally cooler. Afternoon thunderstorms and heavy cloudbursts are common, as the cumulonimbus clouds rise to frequently spectacular heights at midday.

Mussau falls within the "Lowland Climate 3" zone of McAlpine and others (1983:150–161), which is "lowland humid." Key aspects of this climate are a mean annual rainfall of about 2,700 mm (range 2,000–3,500 mm), mean annual temperature range of 23–30° C, and a net annual water surplus (precipitation/evaporation ratio 1:2). No specific meteorological data are available for Mussau, but the climatic conditions of the group may be inferred from other stations in the region. The two meteorological stations geographically closest to Mussau, both of which fall within the same overall "lowland humid" climatic classification, are Kavieng (New Ireland) and Momote (Manus). Based on data from these stations, we may infer that Mussau has an annual rainfall in excess of 3,000 mm, high positive water balance, mean temperature in the high 20 degrees C, and high relative humidity (roughly 75%). From the perspective of human inhabitants who practice tropical horticulture, these conditions are virtually ideal for the cultivation of a wide range of root, tuber, and tree crops, which indeed thrive in Mussau. The limiting factors for horticulture are not climatic, so much as edaphic and hydrologic. Periodic drought, however, can be a problem. When we arrived in early September of 1988, it was evident that the islands had been suffering from several months of drought. The effects were visible as the plane flew over Eloaua and we saw the parched condition of the secondary forest on the limestone plateau. In the gardens, the greatest impact was on the dryland taro, while the sweet potatoes and manioc suffered much less.

Soils and Other Landform Features

Human habitation and land use in Mussau (primarily for gardening) is confined to the coastal areas and elevated limestone plateaus, with the underlying parent material for soil development consisting of limestones, marl, and carbonate conglomerates of varying ages and degrees of weathering. We observed that soils are relatively shallow, parent limestone often lying only 50 cm or even less beneath the surface, with frequent limestone outcrops. The dominant soils appear to be *rendolls*, a widespread type of mollisol that forms on limestone in a wet, humid climate with low to moderate seasonality (Bleeker 1983:112–114). Such soils have "moderate to high fertility levels" with relatively moderate to high amounts of available nitrogen and phosphorus, although potassium may be more limited (1983:113). On Eloaua, these soils appear to produce good yields, but the frequent occurrence of limestone outcrops is a limiting factor.

A second category of soils is restricted to the unconsolidated calcareous sand terraces fringing the offshore islands and parts of Mussau Island. These anthropogenic soils consist of Lapita and post-Lapita age midden deposits rich in organic materials such as charcoal, shellfish, bone, and other detritus of human occupation, with a calcareous sand matrix. These soils are essentially identical to those described from the larger islets of Micronesian atolls, under the rubric "Arno loamy sand" (Wiens 1962:345–346), in which there is a highly organic layer, black to very dark gray when wet, which derives its coloration in large part from anthropogenic input of charcoal and ash. Well drained and organically enriched, they are prime soils for the cultivation of such root crops as *Colocasia* and *Alocasia* aroids, and for introduced manioc (*Manihot esculenta*). Areas with these soils have been extensively gardened, and the mechanical action of digging sticks used to make planting holes and to harvest tubers has thoroughly churned the upper 30–40 cm of these soils, with negative consequences for the archaeological record.

The geomorphology of the Mussau Islands is strongly controlled by the basal geological structure. A radial drainage pattern dissects the volcanic interior of the main island. Some of the larger streams penetrate the surrounding limestones to reach the sea, as at the head of Schadel Bay and along the east coast. In other areas such as the southeastern tip of Mussau, and on all of the offshore islands, there is no surface drainage at all, the limestone karst absorbing rainfall like a sponge. In these areas, water for drinking, cooking, and bathing must be obtained either by rain catchment, or by digging shallow wells near the shoreline to tap the Ghyben-Herzberg aquifer of slightly brackish water (see Wiens 1962:317–326 on such aquifers).

Flora

The flora of New Guinea and the Bismarck Archipelago is an extension of the East Malesian floristic zone (van Steenis 1950; van Balgooy 1971), a region exceedingly rich in biodiversity. New Guinea has been estimated to have on the order of 1,465 plant genera (Paijmans 1976), although not all of these are present throughout the Bismarcks, or on Mussau. Certainly, however, for islands of their size the Mussau group are floristically rich, immediately evident to someone who has had prior experience collecting plants in the tropical central Pacific. Compared with Niuatoputapu or Futuna in Western Polynesia, where I had made botanical collections as part of my ethnoecological fieldwork, the diversity of plant taxa in Mussau was initially overwhelming. There is no guide to the flora of Mussau, and indeed for the entire Bismarck Archipelago the best source remains Peekel's *Flora of the Bismarck Archipelago for Naturalists* (*Illustrierte Flora des Bismarck-Archipels für Naturfreunde*), authored between 1895 and 1945 by this German priest, and published posthumously (Peekel 1984). Peekel worked primarily on New Ireland, but most of the taxa he records are present in Mussau; his *Flora* was an invaluable asset during our 1986 and 1988 expeditions. My prior familiarity with the widespread coastal flora common to the Solomon Islands and Western Polynesia, assisted by Peekel's *Flora*, and where necessary by collecting and pressing voucher specimens, allowed us to discern the main vegetation associations present on the offshore islands such as Eloaua and Emananus, which are described below. The "rapid biodiversity survey" conducted by the Wildlife Conservation Society in 2014, and which was limited to two lowland localities on the main island of Mussau, identified 243 plant species, including six new to science (Whitmore 2015:viii).

Vegetation Patterns of the Offshore Islands

The vegetation patterns of Eloaua and Boliu islands were mapped in 1988 by Dana Lepofsky (Figures 2.6 and 2.7), and are representative of the spatial distribution of the vegetation associations discussed below.

Strand Vegetation and Littoral Forest. The strand vegetation of Mussau consists largely of widespread halophytic taxa, primarily pioneering species with floating seeds that are readily dispersed by ocean currents. The beach morning-glory (*Ipomoea pes-caprae*) spreads over beach sand while the beach ridges immediately above the high-water mark are stabilized by shrubs including *Pandanus tectorius*, *Scaevola frutescens*, and *Messerschmidia argentea*, as well as various grasses. On low-lying sand cays such as Eunakuru and Enusagila, there are thickets of the salt-tolerant *Pemphis acidula*.

In many areas, the littoral forest literally overhangs the ocean, the limbs of great *Calophyllum inophyllum* trees—often festooned with *Dendrobium* orchids and other epiphytes—shading the water's edge. Along with *Calophyllum* (whose wood is important for carving canoes, bowls, and other implements), other common littoral trees include *Barringtonia asiatica* (used for fish poison), *Terminalia catappa*, *T. samoensis*, *Pandanus tectorius*, *P. obtusifolia*, *Hernandia ovigera*, *Erythrina variegata*, *Thespesia populnea*, *Cerbera manghas*, *Ficus* sp., *Guettarda speciosa*, and *Cordia subcordata*. *Hibiscus tiliaceous* also grows densely in some areas just behind the strand. Ironwood trees (*Casuarina equisetifolia*) are common in some places, where they form monospecific stands (noted as "ironwood forest" on the maps). Coconut palms (*Cocos nucifera*) are frequent along and inland of the strand, in some places as planted groves.

Mangrove Swamps. Saline mangrove swamps occur at places around the coast of Eloaua, Emananus, Boliu, and Ebolo islands, and completely cover Tapatu Island. They are also extensive around the perimeter of Schadel Bay on Mussau Island, in some places nearly 1 km wide. Both *Rhizophora apiculata* and *Bruguiera gymnorhiza* are present, as are *Xylocarpus moluccensis* and *Cenops tagal*. Thickets of *Acrostichum* fern occur on the inland margins of these swamps where *Guettarda* trees are found; *Nipa* palms are also common. These swamps are the habitat for several genera of mollusks (e.g., *Telescopium*, *Cerithidea*) and for certain

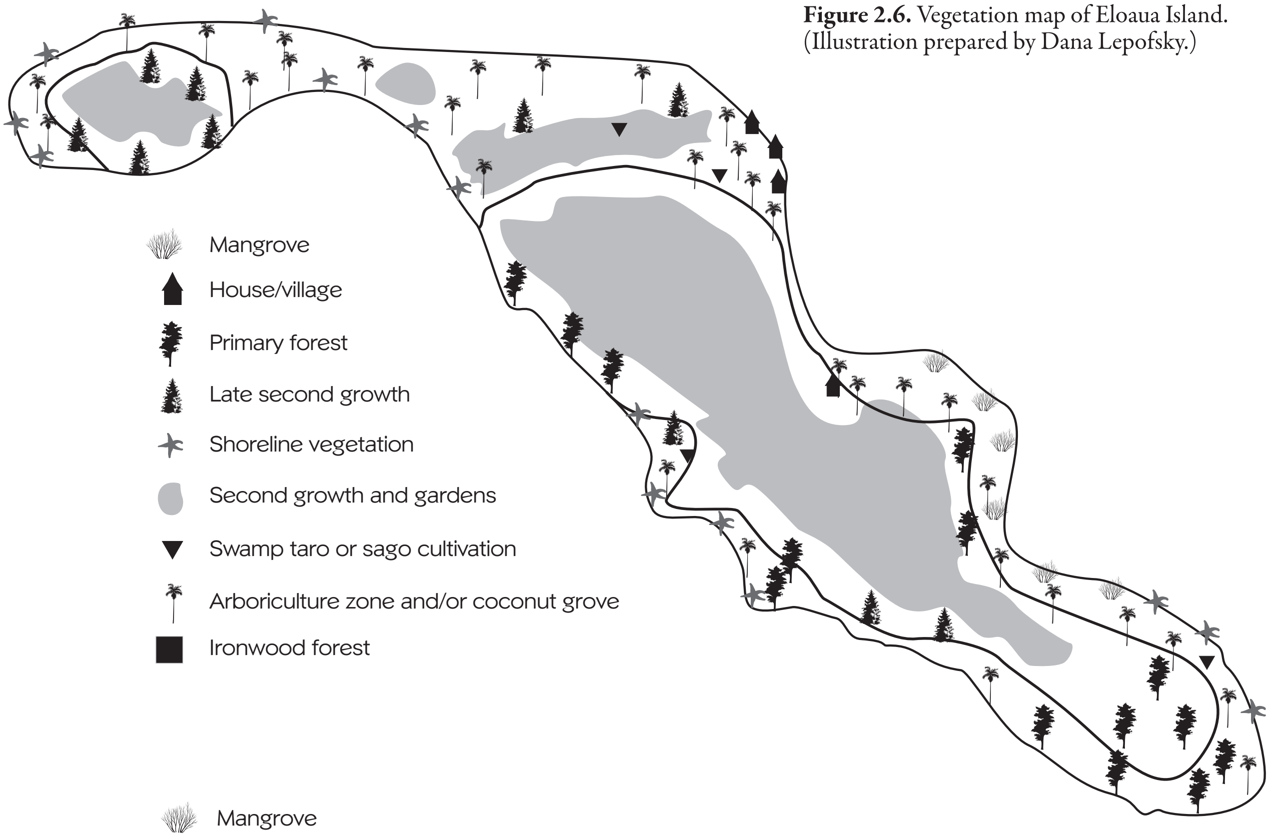


Figure 2.6. Vegetation map of Eloaua Island. (Illustration prepared by Dana Lepofsky.)

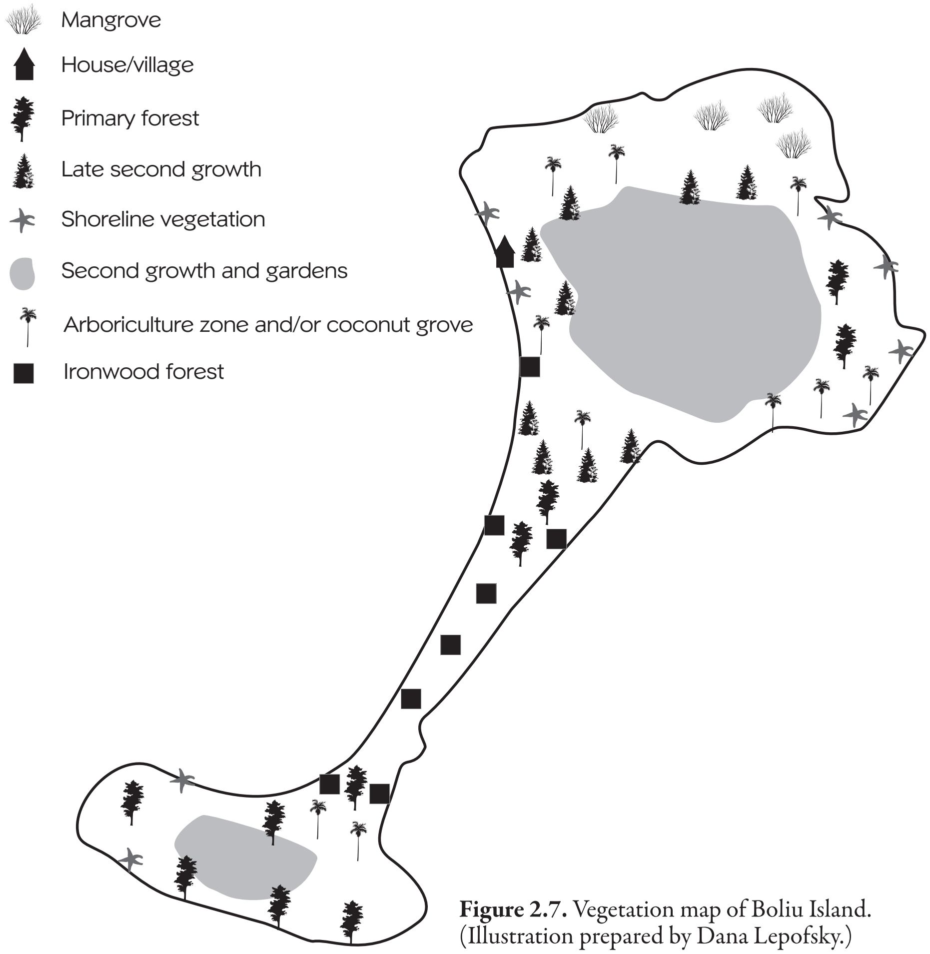


Figure 2.7. Vegetation map of Boliu Island. (Illustration prepared by Dana Lepofsky.)

Figure 2.8. Aerial view of the northwest coast of Emananus Island, showing habitations dispersed among coconut palms and other economic trees of the arboricultural zone.

crustacea. The area in mangroves is probably now more extensive than it was at the time of the mid-Holocene higher sea-level stand. The Lapita site of EHB on Emananus, and the later prehistoric midden site of Elunguai (EHN) on Eloaua, both have mangrove swamps separating them from the sea, but were formerly situated on open beaches.

Remnant Primary Forest. Little primary forest remains on the offshore islands, due to several millennia of intensive land use. On Eloaua and Boliu, small areas cling to the steep limestone escarpments or in areas where there is no soil (as at the southeastern tip of Eloaua). *Calophyllum* sp., *Syzigium* sp., and *Intsia bijuga* are dominants, but some *Pometia*, *Terminalia*, and *Pandanus dubius* were also noted.

Late Second Growth. These small areas consist of mature trees estimated at 40–60 years old. Among the taxa noted here are *Calophyllum* sp., *Intsia bijuga*, *Syzigium* sp., *Pometia pinnata*, *Ficus* spp., *Pandanus dubius*, and others for which we were only able to obtain native Mussau names.

Arboricultural Zones. Substantial tracts on the low-lying calcareous beach terraces have been planted to a range of tree crops, forming an anthropogenic "arboricultural zone." Among the dominant trees are breadfruit (*Artocarpus altilis*), coconut (*Cocos nucifera*), the tropical almond (*Canarium indicum*), Tahitian chestnut (*Inocarpus fagiferus*), Vi-apple (*Spondias dulcis*), several species of *Pandanus*, and the Malay-apple (*Syzigium* sp.) (Lepofsky 1992). House sites are frequently dispersed within this zone as well (Figure 2.8).

Swamp Taro and Sago Cultivations. In a few low-lying, naturally swampy areas on Eloaua Island, plantings of giant swamp taro (*Cyrtosperma chamissonis*) and/or sago palm (*Metroxylon* sp.) are found.

Swidden Cultivations and Second Growth. On both Eloaua and Boliu, the elevated limestone plateaus are extensively used for shifting cultivations (Figure 2.9). New gardens are cleared annually; individual family plots are delineated by logs laid out in a rectangular grid. The primary crops are dryland taro (*Colocasia esculenta*) and manioc (*Manihot esculenta*), but prior to the historic-period introduction of manioc (of South American origin), yams (*Dioscorea* spp.) were the other important crop. Indeed, a few *Dioscorea alata* plants are still grown, and feral yam species *D. bulbifera* and *D. nummularia* are common throughout the second growth. A minor crop is sugarcane (*Saccharum officinarum*). Also common throughout this zone is *Cordyline fruticosa*, the leaves of which are used for parceling food for cooking in the earth oven, and the starchy roots of which are occasionally cooked. *Morinda citrifolia* plants are also frequent although they do not seem to be purposively cultivated. The young second growth includes *Macaranga* sp. and much *Pandanus tectorius*, along with other unidentified species.

Terrestrial Faunal Resources

Without doubt, birds were the most important terrestrial faunal resources in Mussau. Hartert (1924) enumerated 39 species based on the collections obtained by A. F. Eichhorn for Lord Rothschild. Our archaeological faunal assemblages added four species to Hartert's list (Steadman and Kirch 1998). The "rapid biodiversity survey" by Whitmore and colleagues in 2014 recorded 45 species (33 of these being landbirds) at two localities on the main island (Whitmore 2015:38). Among the birds known to have been taken by


Figure 2.9. Young taro (*Colocasia esculenta*) plants growing in a swidden garden on the elevated limestone plateau of Eloaua Island.

the prehistoric inhabitants of the offshore islands (for food, feathers, bone, or other uses) are petrels (*Pterodroma* sp.), the brown booby (*Sula leucogaster*), osprey (*Pandion haliaetus*), golden plover (*Pluvialis dominica*), several species of larids (*Sterna fuscata*, *S. hirundo*, *Anous stolidus*, *A. minutus*), fruit doves and pigeons (*Ptilinopus* spp., *Ducula* sp., *Caloenas nicobarica*), a cockatoo (*Cacatus* sp.), barn owl (*Tyto* sp.), and the glossy starling (*Aplonis metallica*). The domestic chicken (*Gallus gallus*) is also represented in our archaeofaunal collections. A full account of the bird bones recovered from the Mussau sites is provided in Steadman and Kirch (1998).

Other than birds, terrestrial animals which would have been of food value are more restricted than in New Guinea or the larger islands of the Bismarcks. There are several species of fruit bat or "flying fox" (*Pteropus* spp.) that provide a sweet meat, as well as fur that is sometimes used for ornamentation. Other taxa of true bats are also present (e.g., the genera *Hipposideros*, *Dobsonia*, *Nyctimene*), but their value as food resources is doubtful. The only marsupial present is the spotted cuscus (*Spilocuscus maculatus*, formerly known as *Phalanger maculatus*), which attains a length of about 1 m, including its long tail. Based on evidence from New Ireland cave excavations, this was probably introduced prehistorically by humans into the Bismarcks (Flannery and White 1991). The rat fauna of Mussau is entirely unknown, although some larger species of *Rattus* are certainly present, along with the commensal Pacific rat (*R. exulans*). The herpetofauna is not adequately recorded, although we observed that various lizards are common (including varanids [Varanidae], geckos [Gekkonidae], skinks [Scincidae], and scale-footed lizards [Pygopodidae]), as are snakes (families represented in Mussau include Boidae, Colubridae, Pythonidae, and Typhlopidae [Whitmore 2015:34]). Frog families known to be present include Ceratobatrachidae, Hylidae, and Ranidae (Whitmore 2015:33).

Crustaceans are common in the littoral forests. The hermit crab (*Coenobita* cf. *olliveri*) inhabits dead gastropod shells, with larger individuals especially fond of making their homes in *Turbo* shells; these hermit crabs are good bait for hook-and-line fishing. Large numbers of *Cardisoma* land crabs, which grow to have claw-to-claw spans of 20 cm or more, patrol the undergrowth when not hiding in their subterranean burrows. We were told that these were eaten prior to the conversion of the Mussau people to Seventh-Day Adventism, but their main relevance to archaeology is as bioturbators (Specht 1985). The *Cardisoma* burrows are as much as 10 cm in diameter, and penetrate as deep as 80–100 cm below the surface, although they do not go below the water table. When prospecting for buried midden deposits in the coastal beach terraces, one is well advised to examine the burrow tips of these crabs, which frequently contain potsherds, obsidian flakes, or other artifacts.

Most notable of the terrestrial crustacea is the noble *Birgus latro*, or coconut robber crab. This nocturnal creature with massive claws and a leg-to-leg span of up to 50 cm feeds on coconut meat, which it obtains by husking and breaking open the coconut shells. Prized for its succulent flesh, it is rare or endangered in many parts of the Pacific. Owing to the religious dietary restrictions of the Mussau people, the populations of *B. latro* have not been subject to human predation in recent years; the abandoned coconut plantation island of Ekaleu is overrun with them. That the Lapita people formerly enjoyed them as well is indicated by carapace fragments recovered from ECA and other sites.

Marine Littoral Environment and Resources

The offshore islands, and parts of Mussau Island, are surrounded by extensive reefs and lagoons that are prime habitats for a diversity of fish and shellfish; the open seas and channels can be trolled for game fish. Mussau sits within the zone of highest marine biodiversity within the vast Indo-Pacific faunal province (Stoddart 1992). There are several thousand species of edible fish, rays, eels, sharks, mollusks, and crustacea in the Mussau waters. Both the green sea turtle (*Chelonia mydas*) and the hawksbill turtle (*Eretmochelys imbricata*) are present, and there are several genera of porpoises (including *Grampus*, *Tursiops*, and *Delphinus*). One of my fondest memories of fieldwork in Mussau is of a large pod of bottle-nosed porpoises playing in the wake of my Metzler inflatable boat, some coming so close that I was able to reach out and touch them.

The dense mangrove swamps rimming Schadel Bay are the prime habitat of *Crocodylus porosus*, the estuarine crocodile, labeled by one expert in herpetology as a "man-eating monster" (Loveridge 1946:45). Ranging in length from 5 up to 10 m, they can overpower "the average man or woman when taken unawares" (1946:46). My Eloaua friends told me of several crocodile attacks. Curiously, although these crocodiles are substantial "meat packages" whose flesh is quite palatable, only a single crocodile bone was recovered among the thousands of excavated vertebrate remains in our sites (this bone was from Area C at site ECA, see Chapter 6). This suggests that the fear and respect accorded these ferocious animals have always outweighed any interest in hunting them for food.

In addition to animal foods, the marine environments of Mussau are rich in edible seaweeds, which are regularly harvested by the Mussau women. At least five different species are collected; we were told that baskets of dried seaweed used to be traded to communities on the main island.

As part of our study of prehistoric mollusk exploitation carried out in 1988, an environmental survey of the reefs and lagoons surrounding Eloaua, Emananus, Boliu, and Emussau islands was made by Carla Catterall and Mike Ritchie. Catterall has contributed the following section summarizing the results of this survey.

Shallow-Water Marine Habitats of the Offshore Islands

by Carla P. Catterall

There are extensive shallow-water marine areas within the Mussau environmental system, consisting mainly of living coral reefs and associated habitats (Figure 2.10), which occur in two major subsystems. The first of these is adjacent to the southern part of Mussau Island, and is henceforth referred to as the *Southern Mussau* system. The second occurs in association with Eloaua and Emananus islands, and forms an elevated coral atoll-like system to the south, together with several smaller islets and cays. This system is referred to henceforth as the *Eloaua Atoll* system. The latter is separated from the reefs associated with Mussau Island by a deep channel about 1 km wide (the Malle Channel).

Methods Used for Habitat Assessment

A qualitative assessment, description, and map of these shallow-water marine habitats was made during a 15-day period in September 1988. The first stage of mapping consisted of delineation of foreshores and of the edges of both shallow-water and deep-water features, based on a detailed map produced by the Royal Australian Survey Corps (Edition 1-AAS, Series T601, Sheet 8894), at 1:100,000 scale (from 1973 aerial photography, supplemented by patrol reports and hydrographic charts). This map was then transferred to a smaller-scale version on waterproof paper, which was extensively annotated during three days spent systematically inspecting shallow-water areas from a Metzler inflatable boat, with frequent pauses to assess the underwater habitat, either by looking over the side with a face mask, or by snorkeling around less easily resolved areas. During this time, records were made of: water depth; topography; substrate (relative percentages of sand, rubble [coral detritus], rock, and live coral); type and dominant genera of coral formations present; approximate cover and dominant genera of algae or seagrass (low 5–30%,

Figure 2.10. Aerial view of part of Boliu Island, with its extensive reef flats. The main high island of Mussau looms in the far distance.

moderate 30–65%, dense 65–100%); and various other features of biological significance.

A detailed map showing the spatial distribution of a large number of habitat categories was then drawn in the field. These categories were then cross-checked, pooled, and rationalized into a simpler and ecologically meaningful set of generalized habitat types, which were in turn cross-checked against an enlarged aerial photograph of the area. Following map compilation, limited quantitative surveys of shellfish density and species composition were also made within selected habitat types.

Map and Description of Shallow-Water Habitat Types

The variety and spatial arrangement of major shallow-water marine habitat types now present in the Eloaua atoll system are shown in Figure 2.11. Figure 2.12 shows an idealized cross section through part of an atoll system to indicate the typical topographic and depth characteristics of each habitat type. Figure 2.13 presents quantitative data on the areal extent of the main habitat types. Such a pattern is typical of tropical Pacific coral reef areas, such as those found in the Pacific atolls and on the outer Great Barrier Reef of Australia. Comparable descriptions of such systems can be found in Wiens (1962). These reefs characteristically contain a high diversity of habitat types and of species, arranged in a complex spatial pattern, and have developed in a context of clear water and low nutrient availability.

Where terrestrial runoff from continental areas (or other factors) leads to sedimentation and nutrient enrichment, there are typically a variety of associated changes within the adjacent coral reef ecosystem. These include a differentiation between inshore areas (where mangrove swamps and seagrass beds are more likely to develop) and offshore areas. Within the Mussau environmental system these processes have led to a pattern which in the southern Mussau system includes considerable areas of mangrove swamp (mainly north of the mapped area, adjacent to the large, mountainous island of Mussau), and a higher proportion of seagrass beds than the Eloaua atoll system, where few mangroves occur and the small land areas consist of uplifted coral platforms which provide little nutrient or sediment runoff.

The following are descriptions of each of the habitats distinguished in Figure 2.11. The tidal range in the Mussau area is usually less than 1 m.

Sand or Rubble Flat (S): Areas 0.5 to 1 m deep at low tide, these habitats are composed of shallow sand or rubble with variable algal cover and little else. Three subcategories can be distinguished. S1 (shallow sand bank) consists of drifts of relatively coarse 100% unvegetated sand. S2 (rubble plain) consists of areas with some sand together with rubble (40–95%); there may also be an algal cover of *Caulerpa* spp., and/or sparse seagrasses. S3 (sand plain) consists of areas of 100% (or almost) sand cover, sometimes of a fine and silty nature, which may have a sparse to dense algal cover of *Caulerpa* spp. (including *C. racemosa* and *C.*

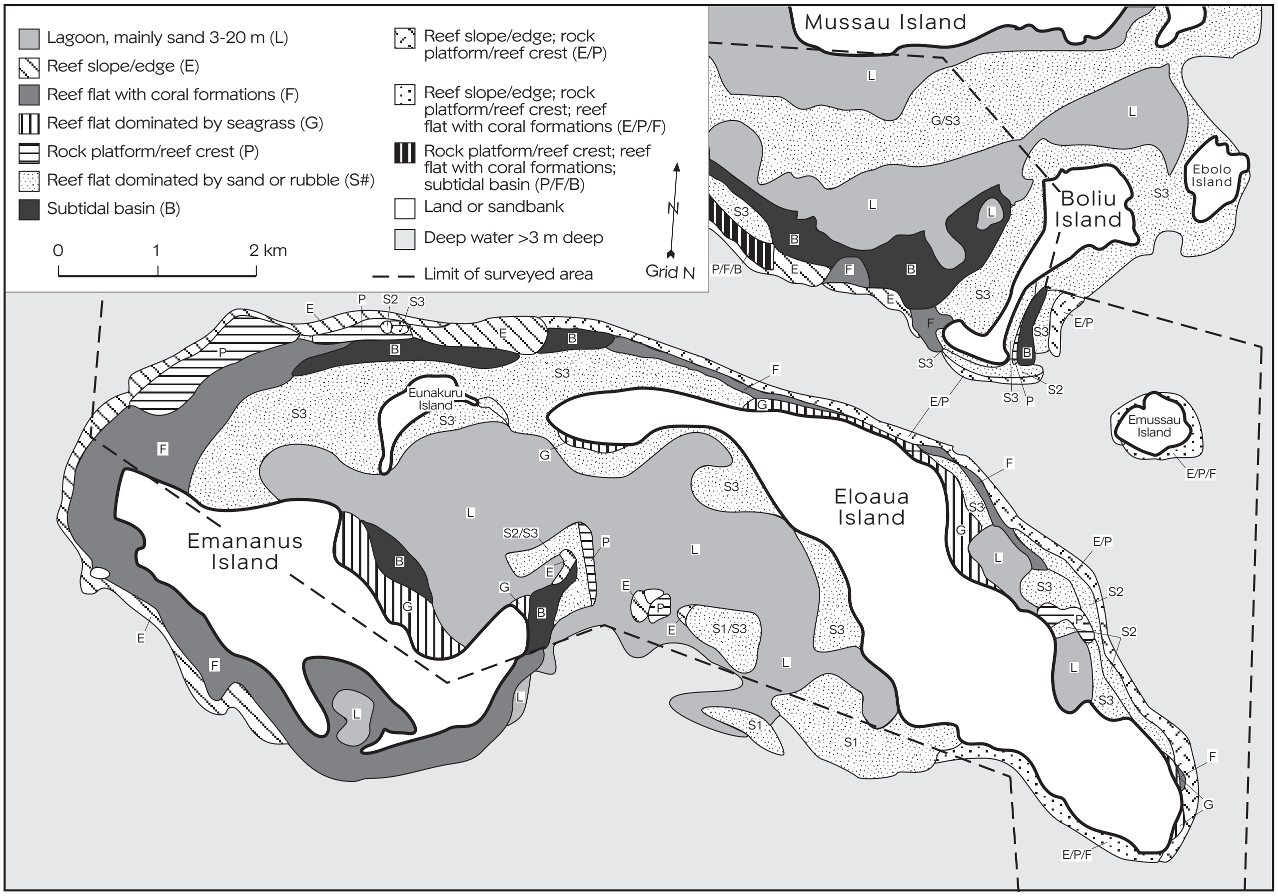


Figure 2.11. Distribution of the types of shallow-water marine habitats mapped for the southern Mussau Island and the Eloaua atoll systems. See text for description of the mapped zones. (Map prepared by C. Catterall.)

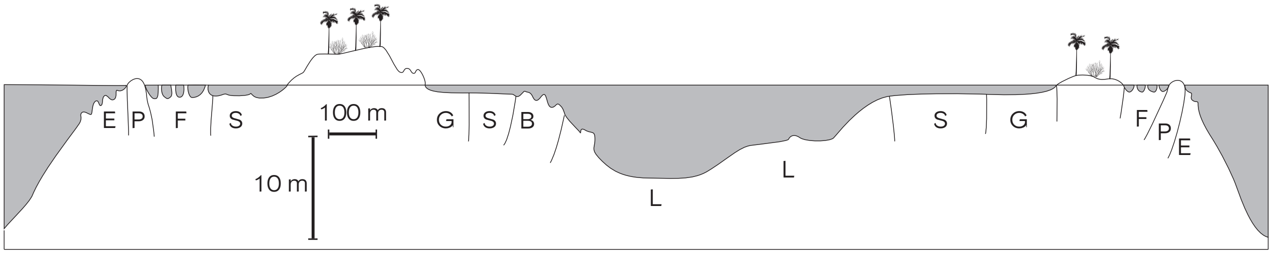


Figure 2.12. An idealized cross section through part of an atoll system to indicate the typical topographic and depth characteristics of each habitat type.

cupressoides), and/or a cover of filamentous algae which can vary from a surface film to a thick covering of aggregated algal strands and mats.

Seagrass Flat (G): Areas mainly 0.5–1 m deep at low tide, these habitats have a substrate of sand and/or rubble in varying proportions, which supports a moderate to high cover of seagrass. The seagrass community in different places is dominated by varying mixtures of *Cymodocea* (mainly *C. rotundata*, but may include *C. serrulata*), *Thalassia hemprichii*, and the large *Enhalus acoroides*. Species of the alga *Caulerpa* (especially *C. racemosa*) and/or *Halimeda* may also occur in a sparse to dense mixture

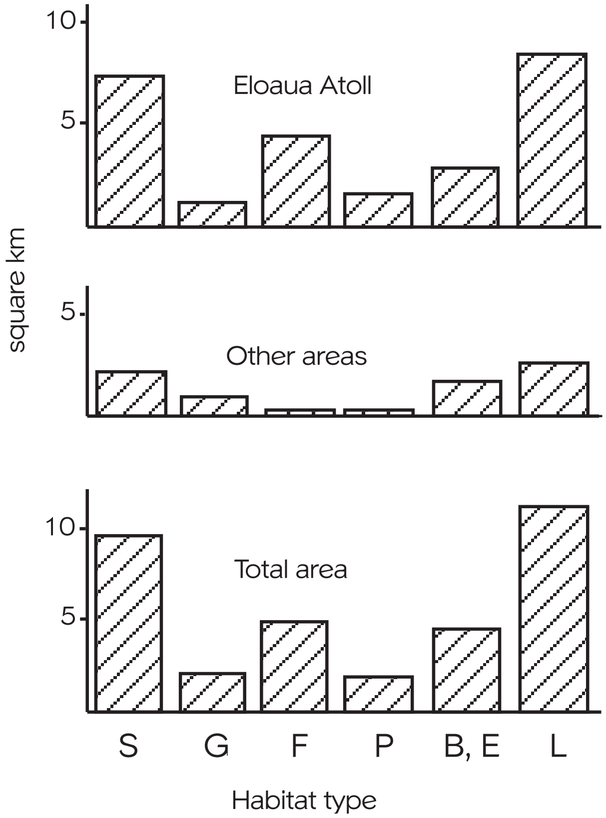


Figure 2.13. Areas covered by habitat types within the Eloaua atoll system, part of the southern Mussau system, and the entire mapped area (as shown in Figure 2.11).

with the seagrass in *Thalassia* and *Enhalus* beds. Among the edible mollusk species typically occurring in seagrass flats are *Anadara*, *Acrosterigma*, and *Gafrarium*.

Coral Mosaic Flat (F): Typical "reef flat" areas are 0.5–1 m deep at low tide and are composed of a spatial mosaic of live (sometimes partly dead) coral patches (1–2 m diameter) interspersed with areas of sand and rubble. The cover of coral clumps may vary in different areas, from some areas which consist of sand and rubble with as little as 10% live coral cover to areas consisting of sand with a 60–90% cover of coral clumps (microatolls). There may be a sparse to moderate cover of seagrass (mainly *Thalassia* and *Cymodocea*) or algae (mainly *Caulerpa*) on the sand and rubble sections of the coral flat. Important molluskan taxa found in this habitat include the large bivalves *Hippopus hippopus* and *Tridacna* spp., and gastropods of the family Strombidae (*Lambis*, *Strombus*).

Rock Platform/Reef Crest (P): This is the shallowest habitat type, being mainly about 0.5 m deep at low tide. The substrate consists mainly of coralline rock, formed from dead coral slabs and boulders, which may form a relatively smooth plain as a result of either wave action or the cementing effect of coralline algae. In other areas, the rock platform may be topographically complex, and include large boulders thrown up during storm surges, or deeper sections that contain actively growing coral colonies (often *Acropora* spp.). Sections of some rock platforms may have a thin cover of sand and algae (especially *Caulerpa*). Seagrass may be present at sparse to moderate densities. Rock platforms are usually present on the outer exposed edges of reefs, and are often better developed in less sheltered situations. This is a prime habitat for the *Tridacna* clams, as well as many other smaller bivalves and gastropods, including *Conus* spp.

Subtidal Basin (B): This category includes basins and slopes of sand interspersed with large coral formations ("bommies"), at depths of 1.5–2 m at low tide. Coral cover varies in different places, from scattered microatolls (usually *Acropora* or *Porites* spp.) comprising as little as 5% of total cover, to more densely arranged coral formations constituting up to 50% cover, in a spatial mosaic interspersed with sand patches. The latter resembles a deeper version of some types of coral flat. The sand may be fine and silty, and may have a surface film of filamentous algae, especially in places where the coral cover is low. The subtidal basins are habitat for such mollusks as *Chama*, *Spondylus*, and *Hyotissa*.

Reef Slope/Edge (E): The outer slopes and drop-offs of coral reefs, which often lie on the seaward side of the reef crest, make up this habitat type. This is a transitional zone, which slopes from 1 m at low tide to 10–20 m with increasing distance from the reef. The zone is topographically very diverse, and is typically biologically very rich. A variety of coral species and formation occur, including many *Acropora* colonies of varying sizes, and massive *Porites* coral that which may reach 2–4 m in diameter and height, reaching almost to the surface from deeper areas. The considerable variation in the nature of the reef slope is associated with the degree of exposure to prevailing winds. The slope itself may be rapid or gradual, live coral cover may vary from about 10% up to about 90%, and the remaining substrate may consist of either sand, rock, or both. High rock cover usually occurs in exposed situations, and high sand cover in more sheltered situations such as lagoonal slopes.

Lagoon (L): Large areas of deep sand (3–5 m) are enclosed within coral reefs in this habitat type. There may be sparsely scattered (5% cover or less) live or dead coral "bommies," which may support a sparse to dense cover of algae (mainly *Caulerpa*). The sand cover is often 100%, especially in deeper lagoons, and the sand may be very silty, and may have a surface film of filamentous algae.

The different habitat types described above each support different assemblages of plant and animal species, a fact recognized by the contemporary Eloaua people. For example, they stated that the gastropods *Anadara* and *Acrosterigma* occur mainly in seagrass beds, and this was consistent with the results of our quantitative faunal survey. The distribution and relative areas of the different habitats are thus a major determinant of the numbers and kinds of shellfish present in the Mussau environmental system. For example, in the present-day Eloaua atoll system, the lack of mangroves means that the gastropod *Telescopium* should be virtually absent from the area, and is only expected to be common near Mussau Island, where there are substantial mangrove stands.

Variation in faunal assemblages within and between archaeological sites may result from: (1) underlying differences in the availability of different faunal taxa, as a consequence of changes in the area covered by different habitats; (2) differences in human exploitation techniques, or cultural selectivity; and (3) direct or indirect effects of exploitation on the population density and age structure of various species of the shallow-water marine fauna. A knowledge of the habitat distribution, and of whether it may have changed over time, permits some prediction of the organisms available to prehistoric collectors, and may also be used in the interpretation of changes in the midden assemblages. It follows that baseline information useful in the interpretation of midden assemblages includes the answers to the following questions: (1) What habitats are present, and where? (2) What is the relationship between habitat type and density of various faunal taxa? and (3) How are contemporary habitats likely to differ from those present at the time of archaeological site formation? These are matters that are taken up more fully in Chapter 9.

Coastal Geomorphology and Holocene Sea-Level Change

In his early synthesis of Lapita archaeology, Green (1979a:32) asserted that Lapita sites tended to be situated "on raised coral platforms, marine terraces, and marine sand beaches from which the sea had fairly recently retreated." My experiences in Tikopia (Kirch and Yen 1982) and Niuatoputapu (Kirch 1988a) confirmed this observation, for on these islands the earliest Lapita settlements had been established on beach terraces now both inland of the modern shoreline, elevated between 2–5 m above the modern tidal range. These geomorphological settings suggested that the Lapita sites had been formed during a period of higher relative sea level, followed by a retreat in sea level (and corresponding coastal progradation) during the post-Lapita period (i.e., the last 3,000 years). These experiences predisposed me to pay careful attention to geomorphological indications of sea level changes during my Mussau fieldwork.

During the 1980s, geomorphological studies on various Pacific islands yielded abundant evidence for a mid-Holocene higher sea-level stand over much of the region (e.g., Ash 1987; Bloom 1980, 1983; Chappell 1982, 1987; Isla 1989; McLean 1980; Miyata et al. 1990; Montaggioni and Pirazzoli 1984; Pirazzoli and Montaggioni 1986, 1988; Yonekura et al. 1988). Such evidence includes cemented coral platforms and degraded microatolls (paleo-low-tide indicators), incised shoreline notches (paleo-high-tide indicators), and paleobeach ridges and terraces (paleotidal range indicators), many of which were dated by radiocarbon or other techniques. Continued study of such features, both by geomorphologists and by archaeologists, has now produced a substantial body of evidence confirming such a mid-Holocene high-stand (e.g., Allen 1998; Dickinson 1998a, 1999, 2001, 2014; Dickinson and Green 1998; Dickinson et al. 1994, 1998; Fujimoto et al. 1996; Hallmann et al. 2018; Kirch 1993). The vertical magnitude of this high-stand has been estimated for different islands and subregions of the Pacific, from as low as +0.8 m in French Polynesia, to perhaps +3.0 m in parts of the western Pacific. The timing of this peak high-stand is also a matter of debate, but a broad consensus has emerged that this occurred between an envelope of 6,000 to 4,000 years BP. Given the association of numerous Lapita age sites with paleobeach terraces, this high-stand must have persisted until at least 3,000 years BP. Based on rapid progradation of beach sands that commenced at the To'aga (Samoa) site around 2,000 years BP, as well as similar evidence from Tikopia and Niutoputapu (Kirch 1993), sea-level retreat to the modern level was certainly in train by this time.

Geoarchaeological evidence for a dynamic coastal environment of Eloaua Island during the period that the Talepakemalai (ECA) as well as the ECB, and EHB Lapita sites were formed includes evidence of older shorelines and paleobeach terraces (see Chapter 3). This evidence is corroborated by three kinds of geomorphological observations made during our Mussau fieldwork. (1) The first is the presence of low-lying aprons of unconsolidated calcareous beach sands that form the modern coasts of much of Eloaua, Emananus, and other offshore islands in the Mussau group today. The berms of these beach terraces are typically about 1 m above the modern mean tide level. These unconsolidated sand aprons are typically the setting for modern Mussau villages and hamlets, but show no evidence of archaeological deposits older than about 1,000 years BP. (2) In a number of islet localities, these low-lying sandy aprons abut, on their inland perimeters, with paleobeach terraces that are typically about 1 m higher than the seaward aprons, and thus about 2 m higher than modern mean sea level. It is on such paleobeach terraces—especially that in the central part of Eloaua Island (Figure 2.14)—that archaeological deposits of Lapita age are found, such as the ECA and EHB sites. These slightly elevated paleobeach terraces must have formed as a result of the mid-Holocene high-stand, while the seaward, low-lying sandy aprons developed during the subsequent phase of sea-level retreat. (3) The third indicator of a higher sea-level stand consists of incised shoreline notches found along the cliffed limestone coasts where the sandy terraces and aprons are absent. As has been documented for other limestone coasts (e.g., Yonekura et al. 1988), such notches form through a combination of corrosion and bioerosion, from wave action at high tide and from solution. Such an incised shoreline notch is shown in Figure 2.15.

I measured profiles of three such incised shoreline notches, one at Esapinoaka Island (a small islet north of Boliu Is.), and two on Boliu Island (the first at Talinganitavao Point on the northwest side of Boliu, the second at Etangatumanusa directly across the Malle Channel from Eloaua Is.). In all cases, the maximum extent of incision lies about 1–1.5 m higher than modern mean high water (Figure 2.16). In two cases, a "double notch" is present, with the lower notch being actively incised today while the upper notch is partially coated with stalactites and flow stone, indicating no active incision. Thus, these upper incisions indicate a period of higher relative sea level. Given the absence of evidence for local tectonic uplift, the most plausible interpretation is that they formed as

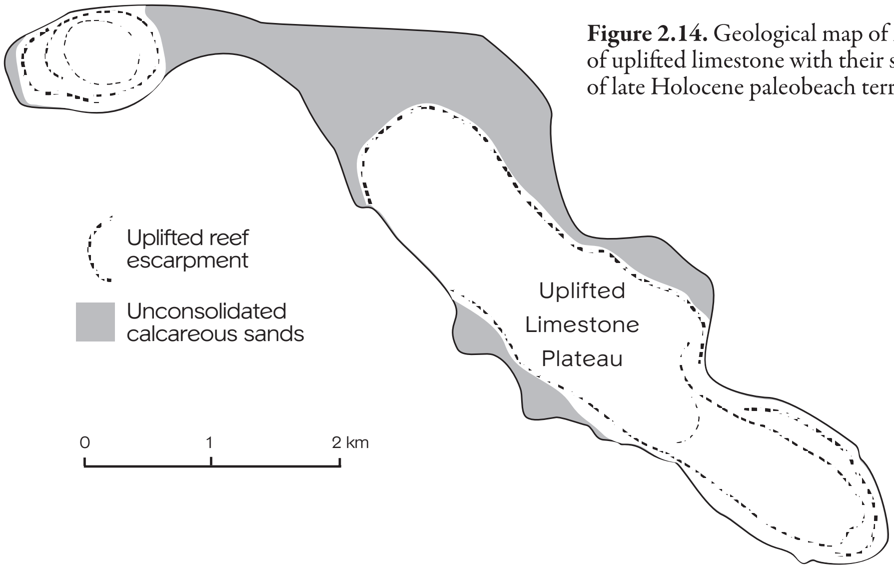


Figure 2.14. Geological map of Eloaua Island, showing the central areas of uplifted limestone with their sharp escarpments, and the distribution of late Holocene paleobeach terraces of unconsolidated marine sands.

Figure 2.15. A typical incised shoreline notch along the coast of Boliu Island. Dana Lepofsky stands with the stadia rod on the currently eroding solution platform.

a consequence of the mid-Holocene high-stand, which therefore must have been around +1 m.

This evidence for local coastal dynamism has implications both for the archaeological record of Mussau, and for interpretations of marine ecology and human subsistence patterns during the past few thousand years. Archaeologically, understanding the temporal pattern of changing sea levels—from a mid-Holocene high-stand followed by a fall in relative sea level and rapid coastal progradation—is critical to the interpretation of formation processes at Lapita sites such as Talepakemalai. But these coastal processes have also affected the extent and character of the marine microhabitats of the Mussau offshore islands, with major implications for the distribution and extent of human-exploited resources, including mollusks, crustaceans, seaweeds, and inshore fishes.

The Ethnographic Record

The Mussau ethnographic record is almost as impoverished as that for the islands' natural history. The primary source is Nevermann's 250-page volume (1933) in the monumental *Ergebnisse der Südsee-Expedition* series, at first glance a seemingly comprehensive ethnographic account. However, the expedition visited the Mussau group for less than two months, from August 9 to September 16, 1908; ethnographic inquiries were made using an interpreter who spoke Pidgin English, a far from satisfactory method. Not surprisingly, a large part of Nevermann's volume deals with material culture, while sections on social organization or religion are superficial and of questionable accuracy. Nonetheless, the expedition achieved a remarkable amount in such a short stay, providing a record impossible to replicate. Other early German sources include Parkinson (1901, 1905, 1907), who made brief visits to Mussau in 1900, Danneil (1901), and Meyer (1900). In 1925, E. W. Pearson Chinnery, Government Anthropologist to the Territory of New Guinea, spent slightly more than two months in the St. Matthias Group, publishing a set of ethnographic "notes" only slightly less extensive than those of Nevermann (Chinnery 1925). Although the majority of his text deals with Emirau rather than Mussau, Chinnery does provide additional useful information.

The Mussau Language and Its Affinities

The Mussau language has never been comprehensively studied, although Chinnery (1925) collected a short vocabulary and Nevermann's (1933) monograph contains many words. Blust (1984) worked with several Mussau speakers residing in Manus, obtaining a 570-word list, allowing him to make some assessment of synchronic and diachronic phonology. Blust established that Mussau is an Austronesian language, part of the Oceanic subgroup. Blust (1978) felt that there

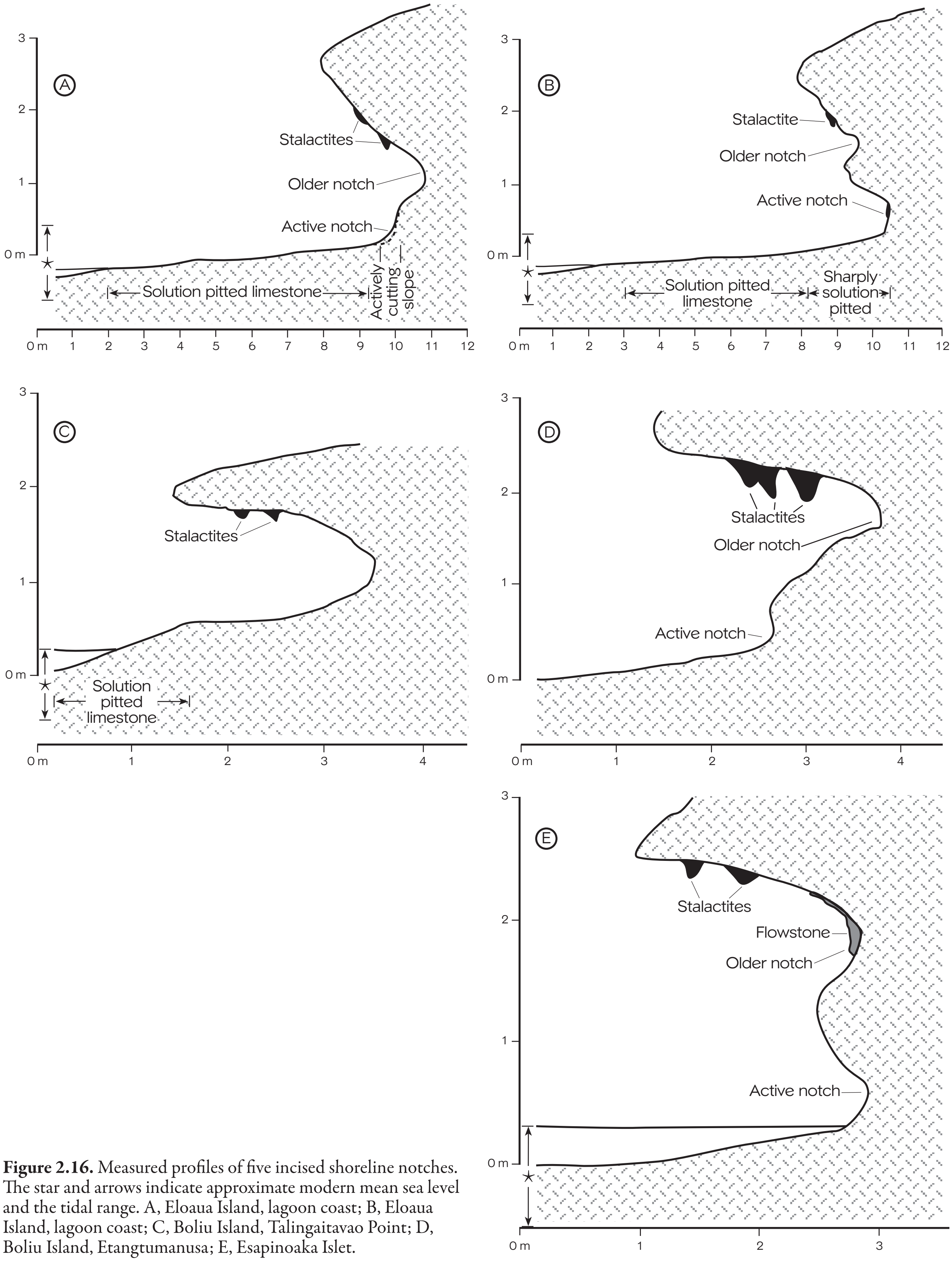


Figure 2.16. Measured profiles of five incised shoreline notches. The star and arrows indicate approximate modern mean sea level and the tidal range. A, Eloaua Island, lagoon coast; B, Eloaua Island, lagoon coast; C, Boliu Island, Talingaitavao Point; D, Boliu Island, Etangtumanusa; E, Esapinoaka Islet.

was little basis for subgrouping Mussau with the languages of the Admiralty group (Manus), nor does it seem to fit well with any of the other first-order subgroups that Ross (1988) defined for the Near Oceanic region. Mussau is not a part of the New Ireland group of languages. Ross (1988, 1989) was uncertain about whether Mussau comprised a separate subgroup or should be linked with the Admiralty cluster, although he suggests that Mussau may represent, like the Admiralty group, a separate first-order subgroup within the Oceanic cluster (this is questioned by Blust 2013:729). In an overview of Austronesian subgrouping, Ross wrote:

> the Admiralties family and the St Matthias group, are each clearly defined by a set of innovations, and Proto-Admiralty has been reconstructed . . . The St Matthias group may yet prove to be specifically associated with the Admiralties family; it is not closely relat[ed] to its southern neighbors on New Ireland [Ross 1995:89].

Ross (personal communication, 1988) also "noted that the very features that link the Admiralties and Mussau also link both with Micronesia." However, the evidence is not sufficient to say whether these features are retentions or shared innovations (or mutual borrowings).

If Mussau does prove to be a first-order (or even relatively high-order) subgroup of Oceanic, this has significant implications for culture history, given the putative linkage between the earliest Lapita phase in Near Oceania and the emplacement of the Proto-Oceanic dialect linkage. Alternatively, if it proves to be related to the Admiralty cluster, this could imply that there was originally a dialect linkage between Manus and Mussau, which would be entirely consistent with the archaeological evidence for material exchange between these island groups.

Social Organization

According to Chinnery (1925:205–206), Mussau society was divided into two exogamous groups, E Veli (with the *valusu* pigeon as its totem), and Saitalai (with the *sava* eagle as its totem). I was given this same information by Ave Male in 1985. Chinnery provides a lengthy list of subgroups under each of these main exogamous divisions. Chinnery says that inheritance was matrilineal (1925:129). He uses the term "chief" to describe the political leaders (the Mussau term is *vau* or *vaum*), but does not say whether these positions were hereditary.

Mussau never seems to have been densely settled, with the population concentrated in small pockets here and there. Parkinson (1907) thought the total population to be not more than 1,000, while Nevermann (1933:38), based on his partial census of several villages, doubled that estimate. Still, a population of only 2,000 in a group of islands with a total land of area of 363 km^2 gives an approximate density of only about 5.5 persons/km^2. In this regard, Mussau reflects a widespread Near Oceanic pattern of low population density, which contrasts strikingly with the situation in Remote Oceania. As argued at greater length elsewhere (Kirch 2000), these differences likely reflect the effects of endemic malaria and other infectious and debilitating disease in Near Oceania, which suppress population growth.

Settlement Patterns, Land Use, and Subsistence

The settlement pattern observed in the early German colonial period was one of dispersed hamlets or small villages composed of clusters of dwellings, situated near the shore, and generally set among groves of fruit and nut trees, not unlike today. Chinnery (1925:205) gives the term *masiliki* for these hamlets. Referring to Emira, he adds that "formerly, it was said, large chief's houses, with carved posts, occurred" (1925:147). Nevermann's photos of a hamlet and house in Enai on Mussau Island are reproduced here as Figure 2.17 and contrast with the contemporary settlement pattern and house types, shown in Figure 2.18.

Parkinson (1907) described the Mussau huts (called *ale*) as "very primitive," with *Pandanus*-leaf thatched roofs just high enough to allow one to stand upright. There was no special sleeping place, but in each "there was a hearth and beside it a little heap of stones the size of a fist which are probably made hot for the purpose of preparing food."

Taro (*asi*), bananas (*uri*), and breadfruit (*ulu*) were the main starch staples, according to Parkinson (1907), the first two crops grown in "extensive gardens" near the villages. He notes that coconuts were sparse, especially on the offshore islands, but that there were more coconut palms on the southeast side of Mussau Island. He saw neither dogs nor fowls; pigs were present but not numerous on the small

Figure 2.17. View of a traditional hamlet at Palakau and house at Enai, taken during the Südsee Expedition of 1908 (from Nevermann 1933:Plate 10). Note that the Palakau hamlet is set among large economic trees of the arboricultural zone, with small house gardens adjacent.

Figure 2.18. A contemporary village setting on Eloaua Island, showing a mix of sago-leaf thatched houses, and houses with rough-cut planking. Like its predecessor shown in Figure 2.17, this hamlet is situated in the arboricultural zone.

islands, but raised "in great numbers" on the larger island. Nevermann (1933:83–107) confirms taro and banana as main staples, but also lists a significant number of the tree crops by native name, including *tauno* (*Pometia pinnata*), ï (*Inocarpus fagiferus*), *aitabagi* (*Terminalia whitmorei*), *natu* (*Burckella obovata*), *malai* (*Spondias dulcis*), *ta* (probably *Dracontomelon dao*), *alinaca* (*Barringtonia magnifica*), and *ieri* (*Pandanus kaernbachii*). One aspect of arboriculture evident in 1908, but now completely absent due to the impact of missionization, is the cultivation of betel nut (*Areca catechu*). Nevermann says that clearing the swidden gardens was men's work, while the planting, weeding, and harvesting were done by women.

According to Nevermann (1933) the main animal food was fish, including sharks and bonito, but other flesh foods included cuscus, dolphins, birds, wood maggots, grasshoppers, mussels, snails, and octopus. Pigs were raised on both Mussau and Emira, and wild boar hunted as well; pigs are said to have been eaten primarily at festivals, when many were consumed.

Material Culture

Nevermann (1933) extensively describes and illustrates the material culture of Mussau; there is no need to repeat here a long list of objects. I will, however, comment on some items that are reflected in the archaeological record; Figure 2.19 reproduces some of Nevermann's illustrations of these specimens.

Of household equipment, Parkinson (1907) noted wooden bowls and coconut shell water containers. Coconut scrapers consisted of a wooden stool-like arrangement with a *Cardium* shell lashed to it; Nevermann (1933:103–104) illustrates several variant examples. Of some interest, because we recovered archaeological examples from the Talepakemalai site, is a taro peeling knife ("Taroschabemuschel") made from pearlshell with a ground cutting edge (1933:106, Figure 52); these implements are still used on Eloaua today. Parkinson (1907) also mentions a kind of short pestle made of *Tridacna* shell.

Parkinson (1907) saw several kinds of fishing nets (he gives the terms *uben* and *kea* for these), but says no fishhooks were noticed. Nevermann (1933:Figure 31), however, illustrates a few crude one-piece hooks of tortoise shell. Nevermann also illustrates several kinds of fish nets, poles, and spears, and some rather crude angling hooks made of tortoise shell.

According to Parkinson (1907), all of the "axes" (adzes, called *iama*) were made of *Terebra* shell, and he notes that no adzes of stone or *Tridacna* were seen. Nevermann (1933:117–120) concurs with this statement, noting that *Tridacna* adzes were, however, observed on Tench Island. The apparent absence of *Tridacna* adzes in Mussau is notable, because they do appear in the archaeological record, although in late-period sites *Terebra* adzes are more common.

Parkinson (1907) reported that the Mussau men wore no clothing, but that some of them covered the glans penis with a *Cypraea* shell, "in exactly the same way as they do in Manus." He gives the Mussau name for this shell as *bule*. Nevermann (1933:Figure 22) illustrated a number of these shells, which had incised or carved designs. Parkinson also mentions "rather crudely ground armrings" (*mare*) of *Trochus* shell, worn by both men and women, along with "small tortoise shell rings, in the nostrils." The armrings are again illustrated by Nevermann (1933:Figure 15), and we recovered examples of these from post-Lapita period sites in Mussau. Of particular interest is the use of a backstrap loom on Emira (but evidently not in Mussau), a technology most likely introduced from Micronesia. (The loom is well illustrated by Nevermann [1933:Plate 9].) These looms were used to weave narrow belts worn for dancing, a kind of loin covering worn by women, and large mats for wrapping the dead (Chinnery 1925:196).

Given the archaeological record of obsidian importing and use in Mussau, Nevermann's comments (1933:116) on obsidian "knives" ("Obsidianmesser") are of some interest. He observed that obsidian was used for shaving and for skinning animals, and gives a Mussau word, *palane*, for these flakes. He says that the Mussau people obtained these flakes by searching in the bush or at the edge of the bush, particularly along the east coast of Mussau Island (at Enai, Etasitel, and Etalat), and that not all locations where obsidian could be found were known to everyone. Since we know that obsidian does not occur geologically in Mussau, this suggests that the Mussau people in Nevermann's time scoured the sites of old villages or hamlets to find obsidian flakes. This in turn raises the possibility that obsidian found in some archaeological contexts (especially in the post-Lapita period) could well have been recycled from earlier occupation sites, and need not imply direct importation from an external source.

Trade and Exchange

Given the extensive archaeological record for long-distance exchange, especially in the Lapita period, the ethnographic record of exchange or trade is of some interest. Parkinson (1907) remarked that canoes he saw on the offshore islands were small, and not adapted to open water voyaging; he estimates that the largest might hold eight or ten people. But in a later (1905) visit to the east coast of Mussau, he saw "big, well made canoes which I had not observed on my previous visit. These magnificent barks, some of them up to twenty-four meters in length, are carefully and not inartistically carved and painted at both ends" (1907). These he estimates could hold 30 to 40 people. Despite the presence of these canoes, however, Parkinson says that the islanders are "not seafarers, and probably never leave their coasts." However, Parkinson goes on to note that on Emussau he was shown a spear from Manus, "a sign that

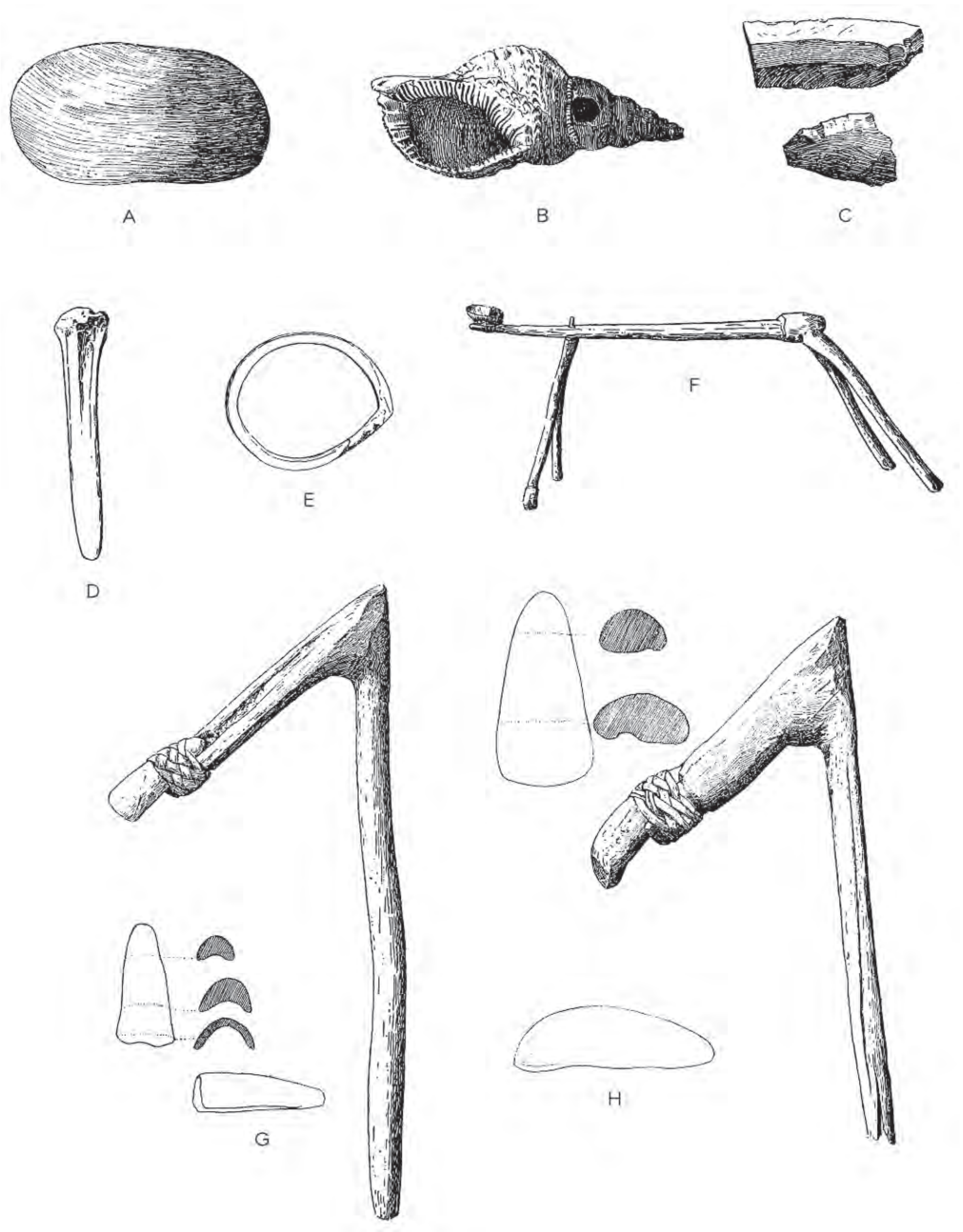


Figure 2.19. Mussau artifacts collected by the Sudsee Expedition of 1908: *a*, taro-peeling knife of pearl shell; *b*, *Triton*-shell trumpet; *c*, obsidian knives; *d*, bone spatula; *e*, Trochus-shell armband; *f*, coconut grater; *g*, *h*, hafted adzes with shell blades. Note: objects are not all depicted at the same scale.

there is occasional communication with these Western neighbors" (1907). Apparently the Emussau people told him of five such visits from Manus people, noting that they did not like to receive these visitors because they were "warlike and quarrelsome." Parkinson also relates a vague account of immigration "from the north," and—noting the presence of a Micronesian-type loom in Emira—speculated on contacts from the Micronesian region.

Nevermann (1933:163–178) treats "trade and commerce" in somewhat greater detail, although much of his account deals with canoe technology. He concludes that their canoes were not suitable for long sea trips (although this may simply reflect his European bias), and concludes that this is the reason that regular trade was never established with New Hanover, despite intervisibility of these island groups. Nevermann goes on to discuss local trade within the Mussau group, as well as between Mussau and Emira (1933:174–177). He notes that on the main island most communication between villages was along the beach or by canoe, as the paths were rough and limited. A main article of trade between the southern part of Mussau, where reefs are extensive, and the northeast coastal villages was dried seaweed, which the women from the southern villages would pack in baskets. Similarly, the Malakat people in the north traded calabashes and strings of wooden beads to those in the south (Enai). Other trade goods mentioned are pigs, pig tusks, and *Dasyurus* teeth for necklaces, red dye obtained from root (turmeric?), taro corms, bananas, and fish. The Emira people traded their loom-woven fiber belts, skirts, and mats to Mussau, as well as carved spears. Chinnery reports that "in the old days of trade with St. Matthias [Mussau], the people of E Mira distributed large numbers of *pais* [belts] and *kalio* [loin coverings] in the way of exchange for the taro, pig, and betel nut brought by the St. Matthias traders" (1925:201). Nevermann implies that there were formal exchange relationships between four villages of the east coast of Mussau and counterpart villages in Emira.

Regarding longer-distance relationships with other island groups, Nevermann (1933:175–176) repeats some of Parkinson's account regarding stories of a Manus chief (Po Sin) who spent time in Mussau before returning to Manus by way of New Hanover. He also recounts another story of a voyage by some people of Eboliu Island, who around 1883 sailed to Manus to present a festival. Since Nevermann had convinced himself that the obsidian flakes found on Mussau were of local origin, he discounted the possibility that they had been derived through external trade, although he notes that this was Hellwig's theory.

To sum up the limited data on trade and exchange available from the early German colonial period, there was extensive and regularized trade among the various villages and hamlets of the Mussau group itself, and between certain communities in Mussau and Emira. There are sufficient hints at connections with Manus to make it clear that the Manus group was well known to the Mussau people, and that either Manus people came to Mussau on occasion or vice versa (or both). However, such contacts seem to have been more irregular and infrequent. Curiously, despite the fact that New Hanover is visible from Mussau in clear weather, there seems to have been no contact between these groups.

CHAPTER 3

Excavations at Talepakemalai (Site ECA)

Patrick Vinton Kirch

The site known to Eloaua islanders as Talepakemalai, and designated ECA in the site numbering system of the Papua New Guinea National Museum (Figure 3.1), is the earliest and largest of any Lapita sites known in Near Oceania, and hence of critical importance in our understanding of the Lapita cultural complex and its role in Oceanic prehistory. This chapter presents the results of excavations conducted at Talepakemalai from 1985 to 1988, with an emphasis on stratigraphy, depositional sequence, and spatial and stratigraphic distributions of material culture. The radiocarbon chronology for Talepakemalai and analyses of faunal and floral remains, ceramics, and other artifacts are presented in subsequent chapters.

Talepakemalai has a distinctive history in the annals of Lapita archaeology. When the Lapita Homeland Project was conceived in 1983–1984, ECA was the earliest and the most westerly Lapita site known, making it of obvious importance to the Project's objectives. The discovery—early during the 1985 field season—of extensive waterlogged deposits with preserved stilt-structure posts was the first indication that Lapita settlements had included pole dwellings situated over reef flats, raising critical issues of survey design and sampling. Our 1985 excavations yielded an unprecedented array of ceramics and non-ceramic objects, while the 1986 season added numerous well-preserved macrobotanical remains indicative of extensive arboriculture (Kirch 1989). Talepakemalai, with an area in excess of 82 ha, remains the largest Lapita site on record (Kirch 1997:167), and its deposits span a time range from the late second millennium until the early first millennium BC. Over this time span Lapita pottery changed radically, so that the early assemblages, rich in finely executed dentate-stamped, might hardly be seen as a part of the same tradition as the later pottery, characterized by large, globular jars with incised decorations and notched rims. Yet the ceramic progression is particularly well documented at Talepakemalai, making this site a key to the interpretation of the Lapita ceramic sequence in the Bismarck Archipelago.

Figure 3.1. Map of the Mussau Islands, showing the locations of excavated and tested sites, including site ECA.

The Setting

Talepakemalai straddles a coastal terrace of unconsolidated calcareous sands forming an isthmus between the northern and southern upraised limestone blocks of Eloaua Island (Figure 3.2). This sandy terrain lies between 1 and 2.36 m above sea level, with the higher ground situated away from the present shoreline and closer to the edge of the southern upraised limestone block. An aerial view of this part of Eloaua Island is shown in Figure 3.3.

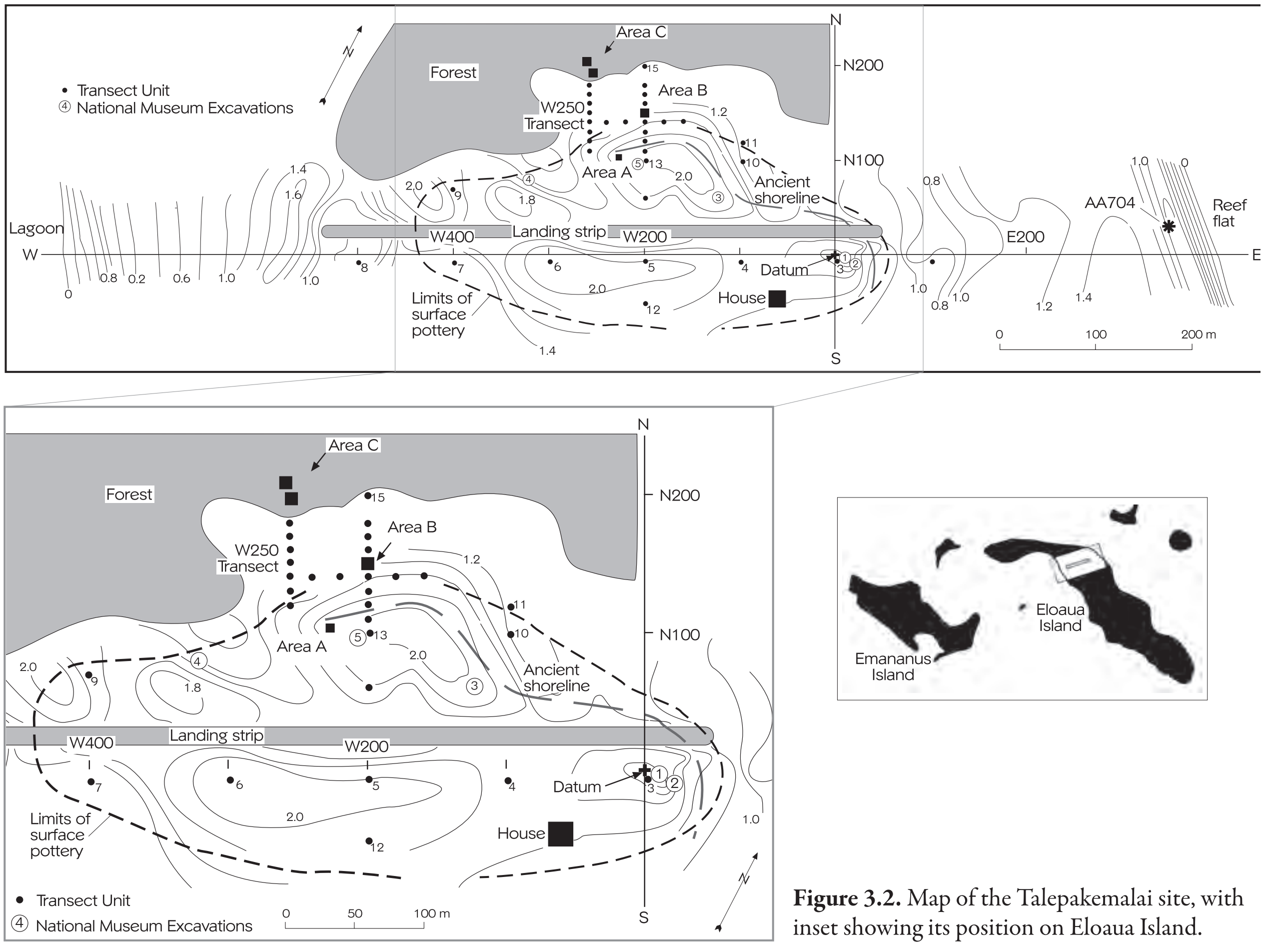


Figure 3.2. Map of the Talepakemalai site, with inset showing its position on Eloaua Island.

The geomorphology of Talepakemalai offers clues to the depositional history and formation of the site. The airstrip running across this part of Eloaua Island provided an ideal transect from lagoon shore to seaward shore, as shown in Figure 3.2. Walking this transect in 1985, I soon realized that a series of alternating depressions and ridges along both shorelines were probable indicators of former shorelines, evidence for coastal progradation. It also became apparent that the the central part of this transect, on which the aircraft landing strip had been situated, was higher than the modern beach terraces. In order to obtain precise elevation data on these topographic features, I surveyed several transects across the coastal plain using a Lietz telescopic level and stadia rod; selected transect profiles are shown in Figure 3.4. As can be seen in the diagram, the modern beach ridges on the seaward and lagoon shores stand at approximately 1 m above sea level. (For the transect surveys, "mean sea level" was taken to be high tide as measured on September 9, 1988 at 2:30 pm. The difference between this high water and the reef platform exposed at the foot of the seaward beach during low water is 0.52 m.) Inland of the modern beach terrace, one rises up onto a slightly higher terrace, which stands between 1.8 and 2.35 m above sea level.

I realized early on during the 1985 season that this higher terrace represented a paleobeach ridge that had formed in relation to a higher sea level than at present (see Dickinson 2001, 2014). I reasoned that unless there had been a major change in local reef topography and/or coastal wave energy regimes, the approximately 1 m differential between high water and beach ridge should have pertained in the past as well as at the present. Thus the 2 m terrace was likely to have formed at a time when the local sea level was about +1 m higher than at present. This hypothesis fit well with what we knew about a +1–1.5 m higher sea level in the mid-Holocene, as described in Chapter 2. Moreover, as I plotted the distribution of surface pottery sherds over

Figure 3.3. Aerial view of part of Eloaua Island, showing the small plane runway that runs through the ECA site, and that was responsible for its initial discovery in 1973. Boliu and Eumussau Islands are also visible, along with the southern part of Mussau Island.

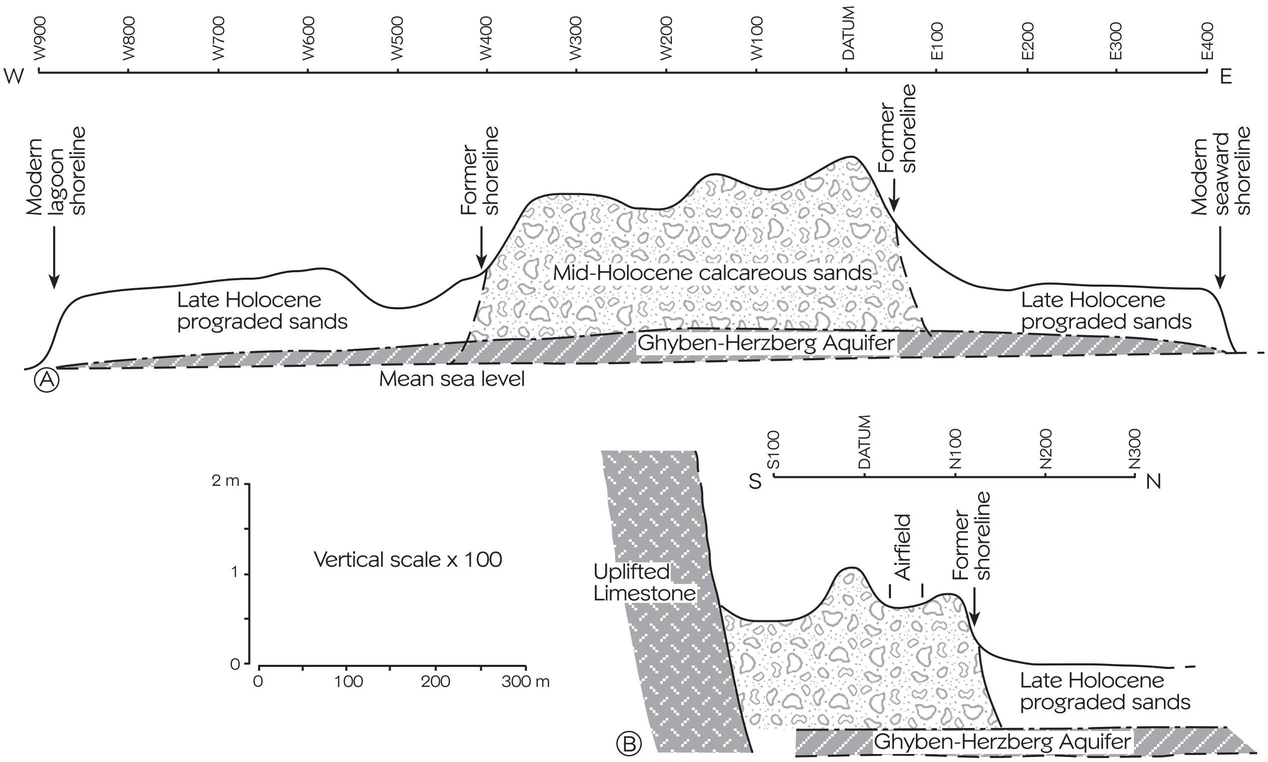


Figure 3.4. Elevation profiles across the ECA site, showing geomorphic features associated with the mid-Holocene higher sea level: *a*, E–W profile across Eloaua Island; *b*, N–S profile through the central part of the ECA site.

the cleared transect of the airstrip, I discovered that these archaeological remains were found almost exclusively on the higher, paleobeach ridge and terrace.

This slightly higher, central part of the Talepakemalai site, across which the airplane landing strip was cut, and which corresponds to the area of surface pottery and shell midden distribution, is covered with a degraded, second-growth vegetation dominated by *Pandanus tectorius*, *Morinda citrifolia*, and *Macaranga* sp., along with low shrubs, ferns, and grasses. This degraded scrub contrasts markedly with the dense climax forest bordering the site on the north and covering part of the waterlogged zone (e.g., the north end of the W250 transect). World War II aerial photos of Eloaua (in the archives of the Bishop Museum, Honolulu) show this distinctly degraded *Pandanus* scrub vegetation occupying the same area as today. This second-growth vegetation is the result of short-fallow cultivation of *Dioscorea* yam and sweet potato, along with some taro. The Eloaua villagers regard the dark loamy soil found in this area as especially fertile, prized for gardening. In fact, the dark loam is an anthropogenic soil, consisting of an extensively reworked Lapita midden deposit, heavily enriched with finely dispersed charcoal, bone, shell, and other organic matter (see Chapter 2). For how long the ECA site has been gardened in this manner cannot be determined, although thorough churning of the cultural deposit over the higher portions of the site, and the small, fragmented and worn potsherds suggest that such gardening has a long antiquity. Utilization of anthropogenic midden soils for root-crop cultivation is not unique to Eloaua, and is a regular occurrence throughout the southwestern Pacific. The ECA situation is paralleled, for example, by the Lapita occupation zone on Niuatoputapu Island in Tonga (Kirch 1988a:38–41), where an identical anthropogenic midden soil is regarded by the island's inhabitants as the best edaphic environment for the cultivation of *Dioscorea esculenta* yams.

Being prime agricultural land, the ECA site area is subdivided into a number of discrete, named land sections, held by different clans. Five land section names were given to me by Ave Male: Talevungateo (Tok Pisin translation, "*place em i gat wada*" or "place with water"), Etanamakapa ("*olgeta kaikai pinis*" or "everyone finished eating"), Talepongakosa ("*liklik hill long graun*" or "small hill above the ground"), Taleliubua (no translation obtained), and Talepakemalai ("*ol e stap unda dis pela diwai nam belong em malai*," or "they dwelt under the malai tree"; the *malai* tree is the Vi apple, *Spondias dulcis*). The Talepakemalai tract, belonging to Male's clan, includes that part of the ECA site where we focused our excavations (Areas A, B, and C). We have therefore appropriated this garden toponym as the name for the entire site, although strictly speaking it applies only to the north-central portion of the ECA site.

Site Discovery and Prior Excavations

The initial discovery of ECA resulted from a succession of serendipitous incidents. In 1973, the Seventh-Day Adventist mission commenced clearing of a small aircraft-landing strip on Eloaua Island to allow access to Mussau by the mission's single-engine plane. A small tractor equipped with a rear-mounted grader blade was shipped to the island to assist the islanders in leveling the ground for the airstrip. After clearing the scrub brush along a 30–40 m wide strip across the island, and following minor grading and leveling with the tractor, a layer of crushed coral limestone obtained from a small quarry at the foot of the first uplifted terrace escarpment was laid down. During these clearing and leveling operations, "broken pots and some bones were uncovered and noticed by villagers working on the project" (Egloff 1975:15).

At the same time that the airstrip was under construction, Brian Egloff of the PNG National Museum and Art Gallery made a trip to Mussau "as an ethnographer to collect weaving, but on the first day [site] ECA was located and I tried to define the site before the medical boat arrived to pick me up" (Egloff, personal communication, 1985). According to the published report Deku Malua, a teacher at the Malakut Primary School, brought Egloff a large potsherd decorated in fine dentate stamping of classic Lapita style, tipping him off to the presence of the site (the sherd is illustrated in Egloff 1975:Figure 14a, and also in Bafmatuk et al. 1980:80). Recognizing the significance of a primary Lapita site in the Bismarck Archipelago, at a time when only the Watom and Ambitle sites were yet known, Egloff conducted several trial excavations in three areas adjacent to the airstrip (see Egloff 1975:Map 4 for excavation locations). These tests yielded pottery (much of it with Lapita-style decoration), some obsidian flakes, and a small sample of vertebrate faunal material. These finds were reported in a short monograph (Egloff 1975) in which the ECA site was summarized as follows:

> Site ECA proved to be an extensive midden with considerable potential. Six one by two metre units were excavated with cultural debris being generally encountered no deeper than circa 30 cm below the surface of the ground. However, one specific area of the site, that being where units AA, AB, and B are located is particularly rich in cultural debris and appears to have undisturbed midden lying in a shallow depression in the surface of the coral sand subsoil [Egloff 1975:15].

Among the ceramics, Egloff noted the presence of "pedestalled vessels," remarking that similar pedestaled pottery had recently been recovered from archaeological sites at Collingwood Bay in eastern Papua (1975:29–30). Unfortunately, "material suitable for radiocarbon dating was not recovered," and no direct assessment of the site's age was made.

In 1978, Egloff organized a second trip to Eloaua accompanied by Francis Bafmatuk and Resonga Kaiku of the PNG National Museum and Art Gallery. Kaiku was enrolled in an undergraduate degree program in archaeology at the University of PNG, and "the second trip was basically designed to provide Resonga with sufficient data upon which to construct a thesis" (Egloff, personal communication, 1985; the proposed thesis was never completed). The team "conducted a test excavation" of unspecified dimensions on the north side of the landing strip in a garden belonging to Ave Male (reexamination of this area in 1986 revealed that the 1978 excavation was approximately 9 x 2 m in extent). The only published report of this National Museum excavation is a popular article by Bafmatuk and others (1980), reporting the first two radiocarbon dates for the ECA site, both run on samples from a single "coral oven": 3030 ± 180 BP (GX-5498) and 3900 ± 260 BP (GX-5499). The great discrepancy between these two dates did not go unremarked by the excavators, who opined that the uppermost sample could have been contaminated by charcoal from recent gardening (Bafmatuk et al. 1980:80). They believed that the lower, and older, sample had produced a correct age determination: "The lowest sample, dated at close to four thousand years ago, is considerably older than the dates obtained from Lapita sites in Eastern Melanesia and certainly ranks as one of the oldest Lapita-associated dates in Melanesia" (Batmatauk et al. 1980:80). The early GX-5499 date was cited for the next several years (e.g., Allen 1984:188; Anson 1986:162) as evidence for initial Lapita occupation in the Bismarck Archipelago around 4000 BP. Anson (1986) emphasized the older ECA date of 3900 BP in his argument for a distinctive "Far Western" Lapita style antedating the earliest Lapita to the east which was "present in the Bismarck Archipelago for several centuries before moving eastward" (1986:162).

In sum, at the commencement of our 1985 field season, two prior test excavations had shown that the ECA midden deposits were extensive, lying on both sides of the landing strip. However, the boundaries of the cultural deposits and the areal extent of the site remained to be determined. The range of ceramic variation could be partly ascertained from Egloff's 1975 monograph, but the faunal sample (especially invertebrate remains) was inadequate to interpret the site's economic prehistory, while non-ceramic artifacts were extremely limited. The age of the site was also in question, given two radiocarbon dates deriving from the same putative "coral oven" with ages 870 years apart. Four problems thus defined the initial research objectives for our 1985 season at ECA: (1) to determine the areal limits of the site; (2) to refine the stratigraphic interpretation; (3) to ascertain the chronology of occupation; and (4) to obtain and analyze an expanded sample of ceramics, material culture, and faunal-floral materials.

Excavation Methods

At the commencement of the 1985 field season, horizontal metric grid control was established and the site was initially mapped with the aid of a Lietz telescopic level and stadia rod. A datum was established about 20 m south of the landing strip near its eastern end (see Figure 3.2), on the highest part of the paleobeach terrace. A grid system was staked out running out from this datum in four cardinal directions. This main site datum has an elevation of 2.36 m above sea level. All 1-m^2 excavation units are designated by the intersection of their east–west and north–south grid numbers (e.g., a unit designated W250N150 would be situated 250 m W and 150 m N of the site datum). Elevation profiles were taken along key transects, correlated to sea level through the use of elevation readings with the aid of a tide chart. For this I used the NOAA tide chart (NOAA 1987), with our tidal information based on Truk Island (Dublon Harbor), applying the necessary temporal and height correction factors stipulated for Emirau (station 3089; NOAA 1987:331).

Excavation proceeded by "natural" stratigraphy, that is, by sedimentary units of deposition. However, when a natural stratum proved to be fairly thick (e.g., more than about 10 cm) it was usually subdivided into two or more levels. The *level* is thus the minimal unit of vertical control in our excavations. A single level may or may not correspond to a stratigraphic *layer*, depending upon whether the latter was subdivided into more than one level. However, levels never cross stratigraphic boundaries.

The main excavation tool was the Marshalltown trowel, aided by whisk brooms and paintbrushes for fine work. Excavated sediment was transferred to buckets using plastic dustpans, and the bucket contents then sieved (see Recovery Techniques, below). Artifacts found in situ were three-dimensionally plotted; all other materials were provenienced by unit and level, with each lot or item numbered sequentially within each level. Thus the field code ECA/W250N150/6/42 would refer to the forty-second *item* recovered from *level* 6 of *Unit* W250N150 in *site* ECA. Vertical control was maintained either by recording the depth below surface, bs (from the southwest corner of the unit), or by measuring depth with telescopic level and stadia rod and converting this to depth below site datum. During and after excavation, a photographic record was made using both black-and-white and color 35-mm film. At least one stratigraphic profile of each unit was drawn at 1:10 scale. Layers were described according to a standard set of criteria, including grain size, lithology, color (Munsell system), structure, nature of stratigraphic boundaries, and so forth. Sediment samples were taken from selected stratigraphic profiles for laboratory analyses of grain size and other characteristics. Sediment sampling followed the procedures outlined by Stein (1985, 1987).

Certain terms widely used in archaeological parlance nonetheless vary considerably in their definitions, and therefore we wish to be explicit regarding their meaning in this monograph:

Grid Unit (or simply *unit*): the horizontal unit of control, a 1 x 1 m block. Units may be further specified as *test* units or *transect* units.

Level: the vertical unit of control within a unit. Levels never cross natural stratigraphic boundaries, although they may be of artificially defined thickness within natural strata, when it was necessary to subdivide a thick deposit for purposes of vertical control. Levels are numbered with Arabic numerals from top to bottom. (Because our 1985 excavations were undertaken as a part of the Australian-organized Lapita Homeland Project, we fell into the habit of referring to levels as "spits," using the Old World term common among Australian archaeologists. Our field forms likewise use the term "spit." In this monograph, however, we exclusively use the American term "level.")

Layer: a natural sedimentary and depositional stratum, defined in terms of lithology, structure, grain size, color, boundary contacts, and similar criteria. One *layer* may correspond to one or more *levels*. Layers are numbered with Roman numerals from top to bottom; facies distinctions within layers are sometimes designated with letters (e.g., Layer IA).

Analytic Zone (or simply *zone*): an aggregate of levels across two or more units, combined for purposes of analysis and reporting of cultural content. Levels combined into an analytic zone are regarded as being chronologically and stratigraphically equivalent. Analytic zones are designated with capital letters, from top to bottom; subzones are numbered with numeric subscripts.

Recovery Techniques and Sampling Biases

As the Mussau Project progressed, we became increasingly engaged with issues of recovery and sample bias, especially after Butler (1988) and Nagaoka (1988) undertook systematic reviews of the Lapita faunal evidence (and of the different screening methods used to recover these) prior to the 1988 expedition. In 1985, we had little choice in recovery methodology, because the screening equipment was provided in advance by the organizers of the LHP, consisting of several sieves of 7 mm and 5 mm mesh, and a single sieve of 3 mm mesh. (The single 3 mm sieve, in poor condition, broke before the end of the field season.) We used the 5 mm mesh as much as possible, taking control samples with the 3 mm mesh to determine whether there was significant size bias in the assemblages retained by the 5 mm sieves. These tests indicated that the 5 mm mesh sieves were retaining most of the small faunal remains, as well as all potsherds and obsidian flakes. In 1986 we therefore equipped ourselves with a number of new 5 mm mesh sieves, as well as additional 3 mm sieves. (In North America, mesh sizes of 1/4" and 1/8" are routinely used, with most zooarchaeologists insisting that the 1/8" mesh is essential to avoid bias toward larger elements in faunal assemblages. The 5 mm sieves we used in Mussau are approximately 3/16", while the 3 mm sieves are slightly finer than 1/8".) In 1986, we also initiated the regular use of wet-sieving at the ECA site.

We remained concerned about possible bias in the dominant use of 5 mm mesh in our excavations, and at the urging of Virginia Butler conducted additional comparative sieve tests in 1988. Butler's analysis of faunal suites recovered through the 5 and 3 mm meshes revealed no statistically significant differences between the fish remains recovered; I am thus satisfied that our screening methodology did not introduce significant bias into our assemblages. For persons working with the Mussau Project collections in the future, a database has been compiled indicating mesh size, and use of wet or dry sieving, for all units and levels of all sites. Thus sampling decisions regarding the Mussau collections can be made explicitly on the basis of recovery technique.

During the 1988 season, we devoted substantial effort to the systematic subsampling of every unit and level excavated at the ECA site with 1 liter bulk sediment samples, which were both floated and fine-sieved through 0.125 inch mesh to recover minute floral and faunal materials. This labor-intensive work yielded only marginal improvements in recovery rates, but again reassured us that our main sieving techniques were not biased.

Recovery is affected not only by excavation and screening methods, but by what is retained for analysis and further study. I determined early on that we would save for analysis 100% of all cultural materials retained in whatever sieve size was being utilized, for every excavated unit. This procedure reflects the view that excavation itself is already an act of sampling a universe (the site) of unknown—but almost certainly not random—distribution, and that a priori subsampling for faunal remains or other particular classes of material would only lessen our ability to understand site structure. We thus concur with Leach and Leach (1979) in their stated justification for collecting "massive residues" from excavations at Palliser Bay, New Zealand: "this approach was adopted in the belief that the analysis of cultural samples will only reveal information about the samples and not the population from which they derive. Cultural evidence is not distributed randomly; therefore, random sampling will not reveal cultural distributions" (1979:5). The wisdom of saving all cultural materials retained by the sieving operations was questioned by team members more than once as—already exhausted by a long day of digging in the tropical heat and humidity—we worked long into the night sorting, weighing, and counting staggering quantities of shell midden. Indeed, the processing of invertebrate midden materials consumed a large amount of time and labor; at the ECA site alone, we processed 1.43 metric tons of shell midden during the three seasons.

Although 100% of all excavated and sieved cultural materials were returned to the field laboratory, budget restrictions dictated that only some materials could be shipped to the United States for study and eventual curation. Thus, sampling decisions again had to be made to analyze under field conditions certain classes of cultural materials which would then be discarded. The following classes of materials were retained for permanent curation: (1) non-ceramic artifacts; (2) diagnostic sherds (include rims, carinations, bases, and any sherd bearing decoration), as well as large representative samples of plain body sherds; (3) vertebrate faunal remains; and (4) paleobotanical remains except for unmodified wood and coconut endocarp, which were sampled. Minimally, shell midden from each level was bulk weighed prior to discarding. For a large number of units, shell midden was first sorted to taxonomic class, each class being weighed individually. During the 1988 field season, this procedure was extended by also counting shell MNI for individual taxa, and by taking extensive series of individual shell measurements (see Chapters 8 and 9).

Recording Systems and Databases

The field and laboratory recording systems and databases used by archaeologists in the complex process of converting an in situ depositional context of cultural materials—a *site*—to a curated "archaeological record" are not trivial matters, for such systems of recording, indexing, and retrieving data impose a certain structure by their very existence. The importance of standardized recording procedures was recognized by the organizers of the 1985 Lapita Homeland Project, who provided all field teams with preprinted excavation recording forms, in self-carbon duplicate sets. The intent was that each field team would retain the top copy, submitting the duplicate to the Australian National University, where data would be coded and entered into a Lapita Homeland Project-wide database using the MINARK software program. Regrettably, this well-planned scheme did not materialize, as some team directors failed to use the preprinted forms, and because funds were not available for data coding and computer entry after the conclusion of fieldwork.

For the 1986 and 1988 expeditions, I modified the field recording forms, with improvements based on our 1985 experience. This "level form," an example of which is shown in Figure 3.5, provides the primary record for each excavated level. The sheet records provenience data, sieve size and wet/dry recovery data, whether depth was recorded below datum or below surface, start and end depths for the level, diagrams of all features at the start and end of excavation, descriptions of sediment, recovered finds, etc., and a list of all objects provenienced by *x, y*, and *z* (depth) coordinates. In addition, I maintained a daily log, and recorded stratigraphic profiles of excavated units in standardized bound field notebooks. Three additional preprinted forms were used to assist in processing and recording of excavated materials in the field laboratory: (1) The first was a "small finds form" on which the washed and sorted pottery sherds from each level were enumerated according to sherd type (rims, body sherds, etc.) and decorative technique. Also recorded on the small finds sheet were data on coral oven stones, and on worked shell debris (chipped *Trochus* and *Conus* shell detritus from the manufacture of shell artifacts) determined during the processing of shell midden. (2) The second form recorded weight and NISP/MNI counts of mollusks. (3) The third form (used in 1988 only) recorded standard measurements on individual midden shells. Examples of these field laboratory forms are illustrated in Figure 3.5.

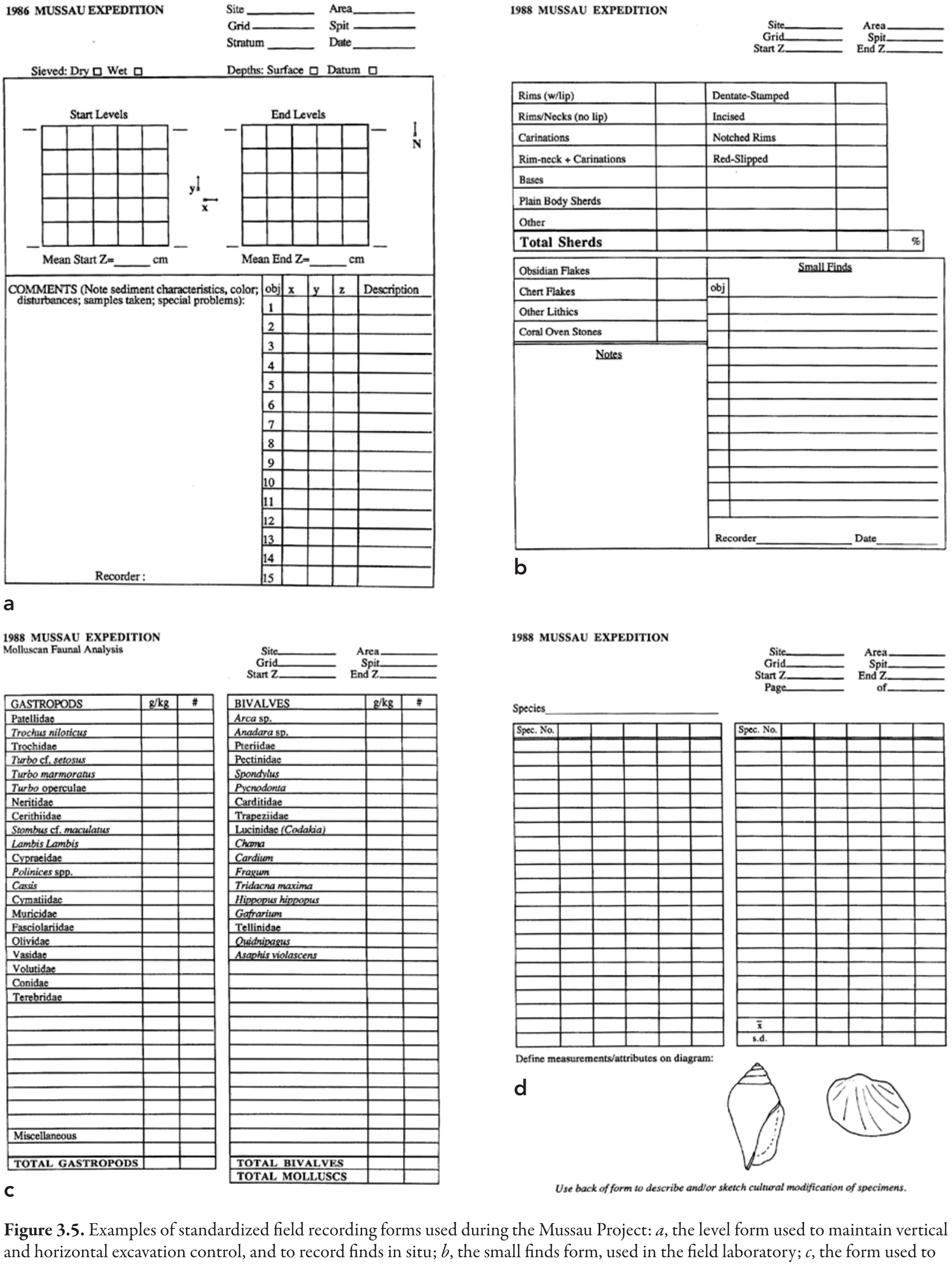
Upon our return from the field, finds were unpacked and checked against the level and small finds forms, catalog numbers written on all objects with indelible ink, and the following standard data set was coded for entry into the computer database: (1) item code, or catalog number, based on the site/unit/level provenience; (2) item type, whether artifact, faunal or floral sample, or other material; (3) raw material; (4) class (e.g., rim sherd, flake, adze, or specific taxon in the case of floral and faunal materials); (5) count (1 in the case of individual artifacts); (6) weight (in grams); and (7) a free-form comments field. These data fields were coded not only for all excavated artifacts, but for all floral and faunal materials (including those discarded in the field), and other kinds of samples.

The software and hardware utilized for this Mussau Project Database have changed several times over the 35-year life of the project, reflecting the rapid advances in computer technology from the mid-1980s to the present. A prototype of the database with over 14,000 entries was first developed at U. C. Berkeley using the UNIX platform on two networked SUN 3/50 workstations in the Oceanic Archaeology Laboratory; the database software used was Sybase SQL. In 1991, we transferred the database (which now exceeded 16,000 records) to a stand-alone PC, using Borlan's PARADOX for DOS. This software proved much easier to use, while continuing to allow relational queries. Data could be transported to Borlan's QUATTRO-PRO spreadsheet program, which provided a variety of statistical routines and graphical displays. For more complex statistical analyses, we used the SPSS and SAS software packages. Eventually, PARADOX ceased to be supported, and the database files were once again transferred, to Microsoft Access and Excel formats, in which they currently reside.

The Mussau Project database includes a total of 22,727 records representing 231,874 individual artifacts, faunal and floral remains, radiocarbon samples, and other materials. In addition to the main Mussau database, several specialized databases were developed, including those for ceramics, fishbones, and obsidian. More recently, the entire corpus of diagnostic Lapita pottery from sites ECA, ECB, and EHB has been recorded digitally on the Lapita Pottery Online Database (LPOD) maintained at the Institute of History and Philology, Academia Sinica, Taiwan (http://lapita.rchss.sinica.edu.tw/web/). Additionally, datasets associated with this book are available at www.dig.ucla.edu/talepakemalai.

Excavation Objectives and Strategy

As the work at Talepakemalai proceeded over three field seasons, our research objectives evolved considerably, requiring changes in excavation strategy and procedures. In 1985, we had no idea that the site would prove to be so extensive, or that we would encounter a waterlogged component with abundant organic materials necessitating special excavation and recovery techniques. During the 1986 and 1988 seasons efforts were made to address these conditions, and new research questions were also outlined (see Chapter 1). The



1986 MUSSAU EXPEDITION

Site ________ Area ________
Grid ________ Spit ________
Stratum ________ Date ________

Sieved: Dry ☐ Wet ☐ Depths: Surface ☐ Datum ☐

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

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

obj	x	y	z	Description
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Recorder :

a

1988 MUSSAU EXPEDITION

Site ________ Area ________
Grid ________ Spit ________
Start Z ________ End Z ________

Rims (w/lip)		Dentate-Stamped	
Rims/Necks (no lip)		Incised	
Carinations		Notched Rims	
Rim-neck + Carinations		Red-Slipped	
Bases			
Plain Body Sherds			
Other			
Total Sherds			%

Obsidian Flakes	
Chert Flakes	
Other Lithics	
Coral Oven Stones	

Notes

Small Finds

obj	

Recorder ________ Date ________

b

1988 MUSSAU EXPEDITION
Molluscan Faunal Analysis

Site ________ Area ________
Grid ________ Spit ________
Start Z ________ End Z ________

GASTROPODS	g/kg	#
Patellidae		
Trochus niloticus		
Trochidae		
Turbo cf. *setosus*		
Turbo marmoratus		
Turbo operculae		
Neritidae		
Cerithiidae		
Stombus cf. *maculatus*		
Lambis Lambis		
Cypraeidae		
Polinices spp.		
Cassis		
Cymatiidae		
Muricidae		
Fasciolariidae		
Olividae		
Vasidae		
Volutidae		
Conidae		
Terebridae		
Miscellaneous		
TOTAL GASTROPODS		

BIVALVES	g/kg	#
Arca sp.		
Anadara sp.		
Pteriidae		
Pectinidae		
Spondylus		
Pycnodonta		
Carditidae		
Trapeziidae		
Lucinidae *(Codakia)*		
Chama		
Cardium		
Fragum		
Tridacna maxima		
Hippopus hippopus		
Gafrarium		
Tellinidae		
Quidnipagus		
Asaphis violascens		
TOTAL BIVALVES		
TOTAL MOLLUSCS		

c

1988 MUSSAU EXPEDITION

Site ________ Area ________
Grid ________ Spit ________
Start Z ________ End Z ________
Page ________ of ________

Species ________________

Spec. No.					

Spec. No.					
$\bar{x}$					
s.d.					

Define measurements/attributes on diagram:

Use back of form to describe and/or sketch cultural modification of specimens.

d

Figure 3.5. Examples of standardized field recording forms used during the Mussau Project: *a*, the level form used to maintain vertical and horizontal excavation control, and to record finds in situ; *b*, the small finds form, used in the field laboratory; *c*, the form used to record shell midden analyzed in the field laboratory and discarded; *d*, the form used in the 1988 season to record detailed metric data on individual midden shells.

following paragraphs provide an overview of the changing research objectives and excavation strategies applied during the three seasons of fieldwork at Talepakemalai.

The 1985 Season

Arriving on Eloaua in early August 1985, and after reconnoitering the ECA site with Ave Male as my guide, I decided that the highest priority was to define the site's boundaries and to construct an accurate site map. For this purpose, a series of intersecting *systematic transects* with test units positioned at regular intervals appeared to be the most appropriate strategy. I had previously applied such a transect approach in defining large open midden sites in both Tikopia and Niuatoputapu (Kirch and Yen 1982; Kirch 1989). I expected the systematic transect units to yield a representative sample of ceramics and other cultural remains, thus meeting our objectives of defining the site's cultural content.

After establishing the site datum and coordinate grid system, a primary east–west transect was laid out along the N0 line, with test excavation units positioned every 100 m parallel to the landing strip, beginning at E100N0 and extending to W500N0. (The first set of transect units excavated in 1985 was initially numbered TP-1 to 15, and are so referenced in field notes and earlier reports, rather than by their coordinate grid locations.) Excavation of these units quickly showed that the cultural deposits through this central part of the site were uniformly shallow, typically consisting of 15–25 cm of dark loam containing highly fragmented and worn potsherds along with some bone and shell midden. These deposits had been extensively reworked through intensive gardening; only in one unit (W100N0) did two pits or possible postmolds extend below the reworked garden soil into the basal calcareous sands. The N0 transect units also allowed us to define the east and west boundaries of the site, demonstrating that these coincided with low, swampy depressions marking former shorelines.

The second phase of transect testing commenced along three perpendicular north–south transect lines, at W100, W200, and W400. At the same time, systematic surface walking and recording the presence of sherds, shell midden, fire-cracked rock, and other cultural debris helped to define the areal extent of the site. Rather than several concentrations of midden as depicted in Egloff's map (1975:Map 4), we determined that cultural materials were distributed more or less continuously over an area of at least 72,500 m^2 (the area within the dashed line labeled "limits of surface pottery" on Figure 3.2). It was also evident that this area of surface distribution of cultural materials corresponded to a former beach terrace, 0.8–1 m higher than those portions of the coastal flat bounding the site on the east, north, and west.

Our initial impression that the ECA cultural deposits might prove to be uniformly thin and heavily disturbed by gardening activities was contradicted when we opened Unit W200N100 (originally designated TP-13). Because this unit was positioned just 7 m east of the trench excavated in 1978 by Bafmatuk and others (1980), I fully expected our new excavation to reveal the same shallow, single-component stratigraphy reported by them. When we dug below the dark loamy garden soil, however, we were surprised to discover pottery, obsidian, bone, and shell midden extending well into the white, calcareous beach sands down to 100 cm, at which depth the deposit became strongly cemented, prohibiting further excavation with trowels. The large sherds in the lower white sand layer of Unit W200N100 lacked the broken and worn sherd edges typical of those from the upper garden soil. These finds contradicted the simple stratigraphic interpretation of the site suggested by Egloff (1975), and by Bafmatuk and others (1980), at least for this portion of the site, making further testing essential.

Another transect unit was opened up 50 m farther north along the W200 line (W200N150, originally designated test unit 14), at a location beyond the putative former shoreline, where there were few if any cultural materials on the surface. Indeed, based on our surface survey and my initial interpretation of the site's geomorphology, the W200N150 location was thought to lie beyond the site's periphery, and was opened up merely to confirm this hypothesis. While the upper 65–70 cm of this unit yielded only minimal cultural material, at approximately 70 cm bs we encountered a concentrated deposit of large, unweathered sherds, nearly half of them carrying classic dentate-stamped Lapita decoration. At this depth the sandy deposit became waterlogged; it was clear that we were at the tidally fluctuating contact with the brackish-water

Ghyben-Herzberg aquifer. Directly associated with the thick deposit of sherds were abundant large obsidian flakes, two whole *Conus*-shell rings, a small *Conus*-shell bead, and a perforated pig-tusk pendant. Our field notes for this day reveal the dual sense of exhilaration and confusion created by the emerging finds in the W200N150 pit. Testing what we thought would be the northern periphery of the site, we had unexpectedly encountered an extremely rich, undisturbed Lapita deposit, inundated by the island's freshwater lens.

I decided at this juncture to temporarily halt the systematic transect excavation strategy, switching to two locations for expanded areal excavations. *Area A* consisted of a 2 x 3 m block defined by Units W228-229/N100-102, about 20 m west of the 1978 PNG National Museum excavation (and 28 m west of our TP-13). Situated on the higher beach terrace (ca. 1.90 m asl) just above what I interpreted as the former shoreline (represented by a north-dropping slope of ca. 0.8 m), Area A was chosen to reveal the stratigraphy of this elevated terrace, and to confirm whether cultural materials extended appreciably below the disturbed dark loamy garden soil (Figure 3.6). The lower white sands did indeed yield considerable plain pottery, dominated by large jars with restricted orifices and flaring rims. However, a mere three sherds had dentate-stamped designs.

A second 6 m^2 areal block was laid out to incorporate the W200N150 (test unit 14) pit which had produced the striking Lapita finds in waterlogged deposits below 70 cm depth. This block—designated *Area B*—was defined by Units W200-201 and N149-151. (With the commencement of the Area B excavation, a permanent datum was established [at 1.91 m above sea level], and we began taking all depth measurements with the use of a surveyor's level and stadia rod. This datum was maintained throughout all three excavation seasons.) Stripping off the dry upper deposits (the dark garden soil, followed by a gray sandy deposit) we found that cultural materials were infrequent, especially in the gray sandy deposit as one approached the water table between 60–70 cm below surface. Just as the deposit turned white and became increasingly damp and sodden, a thick concentration of Lapita sherds appeared along with obsidian, bone, and shell midden. Unequipped for a proper "wet site" excavation, we faced several technical problems. Lacking pumps to remove the brackish water that seeped continually into the pits, we always kept one unit lower than the others, and used buckets to bail out this sump. As we proceeded deeper, the Area B excavation would flood completely overnight, requiring an hour or more of bailing each morning. Knowing that the water table fluctuated tidally, I used a tide table to plan work around predictable periods

Figure 3.6. The completed Area A excavation, during the 1985 field season.

of low tides with a corresponding lower water table in the excavation. Gradually, we were able to extend the Area B excavation well into the waterlogged deposit.

A second problem was that the thoroughly saturated sherds were soft and fragile when first exposed, although they became relatively hard after drying. Experiments with different drying conditions revealed that rapid sun-drying was detrimental, sometimes resulting in severe shrinkage, warping, and cracking. Therefore, as sherds were removed from the waterlogged sands, they had to be carefully laid out on trays (we used damaged sieving screens for this purpose) and kept in cool, shady conditions to dry out slowly over several days. The floor of our field house became an obstacle course of hundreds of sherds drying in the most protected situation we could afford them. The water saturation of the ECA sherds proved to be a continuing problem beyond the drying stage, as the salts left within the sherds began to migrate toward the surface, causing exfoliation and cracking. This necessitated intensive laboratory conservation, as described in Chapter 1.

We were now excavating in an undisturbed deposit, for not only were the sherds, artifacts, and faunal materials in an excellent state of preservation, but we encountered matching sherds making up large portions of vessels lying intact just as they had been discarded and broken (Figure 3.7). Taking advantage of several days of unusually low tides, we approached the base of the thick concentration of Lapita materials, exposing a deposit of coral reef rubble representing the precultural surface.

When we first broached the waterlogged deposit in the W200N150 (TP-14) test, the highly decomposed top of a vertical wooden shaft or post appeared. At first I thought this might be the base of a rotted tree root, but as more of this object was exposed as we proceeded into the waterlogged zone, the wood became increasingly well preserved. On August 28, taking advantage of a particularly low tide and hence low aquifer, we brought the Area B excavation to the bottom of this object and removed what proved to be the worked base of a wooden post that had been set upright into the coral reef rubble. Adze marks were visible on the tapered point of the post, which was 65 cm long. There was little doubt that this post was directly associated with the Lapita materials (as radiocarbon dating would subsequently confirm). The realization that we had a site with intact Lapita wooden architecture occasioned excitement among both the archaeologists and our team of Eloaua workers. (While the archaeologists were excited by the prospects of recovering—for the first time—perishable architecture of Lapita age, the Eloaua people saw the discovery of the preserved post as confirmation of an oral tradition that a

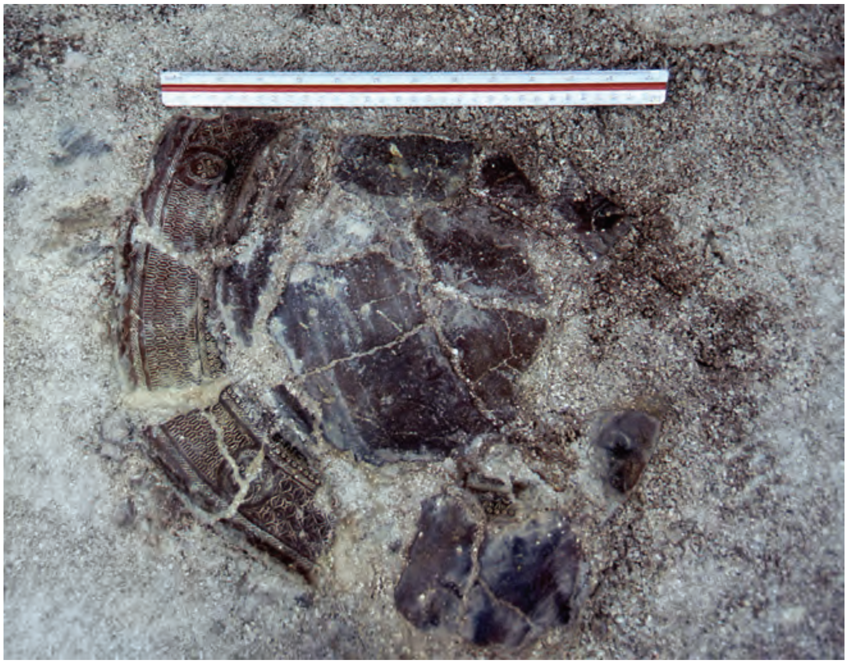


Figure 3.7. A finely decorated, flat-bottom Lapita dish as exposed in situ in the 1985 Area B excavation.

special "haus matmat" [burial house] had formerly stood in the area known to them as Talepakemalai.) Several other smaller wooden stakes appeared in Units W200N151 and W201N151 as we cleared the deposits down to the coral rubble layer.

At this juncture—despite the exciting nature of the Area B finds—it was essential to temporarily halt the ECA site work, in order to test two other Lapita sites: ECB on Eloaua and EHB on Emananus Island. Neither of these sites proved to contain a waterlogged component as at ECA. After sufficient transect tests were completed at ECB and EHB, I decided to conclude the 1985 season by expanding the Area B excavation at ECA. We gridded out another 6 m^2 area adjacent to the existing block, comprising Units W198-199/N149-151. This excavation clarified our understanding of the Area B stratigraphy, yielding additional well-preserved wooden posts forming the corner of a structure. Since we had determined that the Lapita materials had been deposited subtidally and had not been subsequently disturbed, I reasoned that the posts were the supports for a stilt- or pole-house that had been elevated above the reef flat at a time when the island's shoreline was situated approximately 30–40 m south of Area B. After completing this 6 m^2 expansion to Area B, the base of the excavation—with wooden posts left in situ—was protected by laying down a sheet of thick plastic, followed by backfilling.

The 1986 Season

On September 1, 1986 we recommenced the Talepakemalai site excavations. My first priority was to expand the Area B excavation by at least double to expose more of the stilt-house architecture and to increase the sample of associated cultural materials. I also wanted to refine our model of the site's geomorphology and depositional history, in regard to former shorelines and to the progradation of the coastal flat that buried and preserved the Area B wooden architecture. A systematic transect approach was again appropriate, this time utilizing close-spaced transect units extending outward from the Area B block in order to fit Area B into a micro-stratigraphic and geomorphological context.

Having learned from the challenging experience of excavating the waterlogged Area B deposits without adequate equipment in 1985, we arrived on Eloaua in 1986 armed with tools to allow us to tackle the site's unique conditions. I had purchased in the United States two sizes of manually operated diaphragm-type pumps intended for use as bilge pumps on small boats. These not only allowed us to continually remove water from the pits, but the outflow could be used to wet-sieve the excavated sediment. Without wet-sieving, the water-saturated sand passed through 5 mm mesh only with great difficulty; the use of the water outflow from the pumps allowed us to screen materials through 3 mm mesh, and so to recover fine bone and floral materials without significant breakage. I had also prepared new field recording forms, and had brought along better surveying and photographic gear and—very importantly—an abundant supply of waterproof labels, plastic bags, and cotton wool for packing and protecting the fragile waterlogged pottery.

With Terry Hunt and Marshall Weisler as excavation supervisors, I engaged 13 to 15 Eloaua islanders to assist in the excavations. The backfilled 12 m^2 Area B block from 1985 was reopened and the plastic sheeting that had protected the floor of the excavation was removed. A new block of six squares adjoining the 1985 excavation on the east side was gridded out (Figure 3.8), comprising Units W195-197N150-151. This was matched several days later by a south expansion (Figure 3.9), comprising Units W198-200N147-148. In total, we exposed 24 m^2 at Area B, within which we defined two alignments of anaerobically preserved house posts meeting at a reinforced corner. Initially, I had hoped to trace these alignments to additional corners, and thus expose an entire stilt-house outline. This goal was thwarted by the sheer volume of cultural materials recovered, and by the massive amounts of time and labor necessary to wet sieve, recover, and process them. I decided that it was a higher priority to conscientiously recover all vertebrate and invertebrate faunal materials retained in the 5 and 3 mm mesh sieves, as well as 100% of the ceramic assemblage, than to merely *sample* the cultural materials in the interests of exposing more wooden architecture. An additional consideration was that as the excavation grew in area, the volume of water to be pumped increased proportionally. As the full 24 m^2 reached the sub-water table level, the task of pumping out the excavation each morning (the pits would fill with water during the night) became more time-consuming, to a point where the entire 15-member team was engaged in pumping and bailing for as much as two to three hours before excavation could commence (Figure 3.10).

Figure 3.8. View of the Area B excavation during the 1986 field season, with the east expansion being excavated through Zone B. Note the use of pumps to keep the water table low, and to provide water for wet sieving.

Simultaneously with the expanded Area B excavations, we laid out a series of transect test units along the W200 grid line, which had been tested by the W200N100 (TP-13) and W200N150 (TP-14) pits in 1985. Units were laid out at 10 m intervals along the W200 line, beginning at W200N110 and ending at W200N200 (see Figure 3.2). A second series of four units was laid out along a perpendicular axis following the N140 grid line, at 20 m intervals. These two transects were positioned to reveal a detailed picture of the stratigraphic context surrounding Area B over a distance of 100 m north–south and 80 m east–west. The north–south transect along the W200 line furthermore extended across a major geomorphological transition: a drop of 0.8 m in elevation (from 2.01 above sea level at W200N100 to 1.20 in the vicinity of Area B), which I interpreted as the approximate location of the former shoreline of Eloaua Island.

These transect excavations verified that the W200 transect indeed crossed a former shoreline feature, so that at the time of the mid-Holocene higher sea-level stand the Area B stilt house had stood on a reef flat over open water. Moreover, the W200 transect pits lying between Area B and Unit W200N100 exposed a deeply buried zone of fine, silty-textured calcareous sediment that contained a high

Figure 3.9. Excavating in Zone C of the south expansion of Area B during the 1986 field season. Two wooden posts can be seen emerging from the Zone C sediments.

Figure 3.10. View of Area B during the 1986 excavation, with the east expansion down into Zone C, and the south expansion partly excavated through Zone B. Note the standing water in the previously excavated (1985) area, due to the Ghyben-Herzberg aquifer, which continually flooded the deeper portion of the excavation, and which had to be pumped dry every morning.

quantity of anaerobically preserved organic materials, especially wood fragments, coconut husk and endocarp, and remarkably, a variety of seeds, nut shells, and other floral remains. We came to refer to this fine-textured deposit as the "muck zone." As with the foreshore reef-flat environment fronting Eloaua Village today, there was in Lapita times a low-energy tidal flat lying between the stilt house and the former beach slope, which had trapped organic refuse discarded by the site's inhabitants. Here was another unanticipated payoff of the waterlogged condition of this Lapita site, for the abundant plant remains consisted of a wide range of economic taxa (see Chapter 10). For the first time, a Lapita site had yielded an abundance of direct, macrofloral materials of ethnobotanical significance. We closed the 1986 excavations at ECA on September 25, although two more weeks of intensive work were required to complete the processing of shell midden and prepare all other materials for shipment to Seattle.

The 1988 Season

The third season at Talepakemalai began on September 22, 1988, with Dana Lepofsky and Jason Tyler assisting as site supervisors, and a crew of 10 to 15 Eloaua men and women. After recutting the now overgrown W200 transect line and relocating our Area B datum, we cleared a transect running north–south along the W250 line, 50 m west of our 1986 transect and parallel to it. This new W250 transect started on top of the former beach ridge and cut across the former shoreline feature, extending out over the buried reef flat. As with the 1986 transect, test units were laid out at 10 m intervals, commencing at N70 and running continuously to N200, a total of 14 units. (Later in the season, one additional transect unit, W225N150, lying halfway between the W200 and W250 transects, was excavated under the supervision of Nick Araho of the PNG National Museum.) I expected this transect to provide a second stratigraphic and geomorphological sequence to assist in the interpretation of the site's depositional history, to reveal the extent of stilt-house structures west and north of Area B, to further sample the buried foreshore zone of anaerobically preserved plant remains (the "muck zone"), and to provide samples of shellfish remains for our shell technology and invertebrate exploitation studies. In all these respects, the W250 transect served admirably. As in 1986, hand-operated bilge pumps were used to keep the pits (often reaching depths of 1.8 m) from flooding, as well as to provide water for wet-screening.

A further innovation in 1988 was the use of volumetrically controlled samples for fine-screening and flotation, to test whether our samples were biased toward larger-sized items. While all excavated sediment was routinely wet-screened through 5 mm mesh, we took 1 liter bulk samples of sediment from every level, processing these in our field laboratory by flotation with wet-sieving of the non-floating fraction through 0.125 inch mesh. Flotation involved pouring the bulk sample into a bucket which had the bottom removed and was covered with a fine mesh. The floating fraction was skimmed off and air-dried; this material was subsequently examined by Lepofsky for small plant remains. This time-consuming flotation yielded little in the way of plant remains, because most of the preserved seeds and nut cases were large enough to be captured by the 5 mm mesh screens. Nonetheless, the effort was worthwhile in eliminating any doubt concerning potential size bias in our paleoethnobotanical collections. The non-floating residue was wet-sieved through 0.125 inch mesh and air-dried. The small vertebrate remains recovered from fine-sieving were subsequently examined by Virginia Butler to check for size and recovery bias in her analysis of the ECA fish remains.

As the W250 transect excavations proceeded, I realized that stilt or pole structures had formerly been erected over the reef flat throughout the zone sampled by the transect, evidenced by one or more preserved wooden posts or stakes in upright position in many of the test units to the north of the former shoreline (situated at about N105). Thus the stilt structure exposed in Area B was just one of a complex of pole-supported structures that extended over a zone some 100 m from the original shoreline.

As our transect excavations progressed from south to north, I could also see that the pottery assemblages exhibited changes in the frequency of particular vessel forms as well as in decorative techniques and motifs. Having completed a preliminary analysis of the Area B ceramic assemblages from the 1985–1986 seasons, I knew that these differences along the W250 transect reflected chronological changes in the Lapita pottery complex. As we approached the north end of the W250 transect, dentate-stamped pottery was largely replaced by incised pottery. In short, there was an age progression along the W250 transect. Evidently, the shoreline had rapidly prograded while the Talepakemalai site was being occupied, so that as the shoreline migrated northward, the zone of pole houses gradually shifted to the north as well.

When Unit W250N190 came down upon two especially large wooden posts—associated exclusively with incised pottery (which I knew to be dominant at the terminal end of the Mussau Lapita ceramic sequence)—I decided to expand the excavations in this vicinity. Because the sandy deposits here were completely unconsolidated and susceptible to collapse (especially as one penetrated below the water table), we were not able to open up an extensive area. However, two blocks of 4 m^2 each, offset 1 m north–south and east–west, were gridded out and designated *Area C* (Figure 3.11). These exposed an array of 20 posts and stakes, along with an assemblage of incised pottery, obsidian, and other cultural materials, providing an excellent sample of the late end of the occupation sequence at Talepakemalai.

We also expanded excavations at the Area B locality, with a new 4 m^2 block defined by Units W200-201N144-145, separated by a 1 m baulk from the south edge of the 1986 Area B excavation. Our aim here was primarily to obtain a closely controlled sample of molluskan midden for analysis by our marine biologist colleague Carla Catterall (see Chapter 9). However, this also permitted us to obtain an additional sample of ceramics and other materials which, because we were able to impose particularly good stratigraphic control (having previous knowledge of the stratigraphic sequence from previous seasons), we were subsequently able to use for detailed temporal analysis of the ceramic sequence in Area B. This block is referred to as the Area B Extension.

Finally, we carried out a series of corings using a 10 cm diameter bucket auger west along the N140 grid line 50

Figure 3.11. Excavation in progress in the two 4 m^2 excavation units of Area C, during the 1988 field season.

m to W300, in order to track the subsurface extent of the organic zone containing preserved plant remains. These cores, combined with the transect operations, revealed that the waterlogged part of the Talepakemalai site extends over an area of at least 10,000 m^2 lying north of the old shoreline. All of this area is also north of the zone of surface sherd distribution, with the combined total area for cultural deposits at ECA something in excess of 82,000 m^2. This makes ECA the largest Lapita site yet recorded in either Near or Remote Oceania. While I am reasonably confident that the W250 transect reached the northern extent of subsurface cultural deposits in the vicinity of Unit W250N200, the full extent of these waterlogged deposits to the east and west remains undetermined. Excavation of additional transects would have been required to achieve this objective, beyond the resources of our 1988 expedition. Suffice it to say that more work remains for a future generation of archaeologists at Talepakemalai.

The 1988 season at ECA ended on October 12, when all units were backfilled. Over three field seasons, we excavated a total of 84 m^2 at the site, reflecting a volume of about 95 m^3 of sediment, 100% of which was sieved (Table 3.1). Given a total site area in excess of 82,000 m^2, our excavations represent a mere 0.1% sample of this immense site. Yet the acquisition of that sample was no small feat, requiring the expenditure of 849 person-days of fieldwork, accompanied by an even greater amount of labor in laboratory processing, cataloging, and analysis, all supported by a small fortune in grant funds. While a 0.1% sample is two orders of magnitude smaller than the "mystical" 10% figure often cited as minimal by devotees of random sampling, the quantity of cultural materials produced is daunting: 44,089 ceramic sherds, 94,749 vertebrate faunal remains, 7,905 plant remains, 1.43 metric tons of mollusk shells (all of which were weighed and processed), and hundreds of other artifacts and manuports. In retrospect, I regret that we were unable to expose at least one complete stilt-house structure. However, when I remind myself of the effort expended simply to achieve what we did, I am brought back to the reality that an excavation of sufficient magnitude to expose a full structure—minimally 150 contiguous m^2 or more—would have consumed financial resources, time, labor, and equipment far beyond those available.

Table 3.1. Summary of the Talepakemalai site excavations

Field Season	Location	Units (m^2)	Volume (m^3)
1985	Airfield Transects	15	12.0
	Area A	6	6.0
	Area B	12	13.2
1986	Transects (W200)	13	16.65
	Area B	12	13.2
1988	Transects (W250)	14	18.7
	Area B (extension)	4	4.4
	Area C	8	10.4
TOTALS		84	94.55

The ECA Site Excavations

I turn now to the results of our excavations, beginning with the 1985 transects and progressing to the later areal excavations and transects focused on the northern, waterlogged portion of the site. The emphasis here is on the stratigraphy, features, and spatial patterning of the various excavation units, with only brief summaries of the cultural materials recovered, as these latter are the subject of subsequent chapters.

The Airfield Transects (1985)

The "airfield transects" were the first set of test units excavated in 1985, along the main N0 grid line parallel to the landing strip, and along the perpendicular W100, W200, and W400 grid lines. At the time of their excavation, these were designated TP-2 through -12, and are identified as such on the site plan (Figure 3.2). (TP-1 was intended to be excavated at the E200N0 grid locality. When TP-2 at E100N0 proved to be sterile, however, a simple shovel test was put down at TP-1, also confirming a complete absence of cultural material.) Along the N0 line, TP-2 (E100N0) and -8 (W500N0) both proved to be culturally sterile, thereby defining the east and west boundaries of the Lapita deposit. TP-3 through -7 all contained cultural materials, but the deposits were uniformly shallow and heavily reworked by gardening. The stratigraphic section recorded at TP-6 (W300N0) is fairly typical:

Layer I: 0–25/27 cm bs. Color: dark brown (7.5 YR 3-4/2). Sandy loam with a dense root mat in the upper 5 cm. Thoroughly reworked and featureless. This deposit contains small, worn, and highly weathered potsherds along with some bone, and marine shell that is "chalky" textured due to chemical decomposition (resulting from humid acids). The contact with Layer II is gradational over a 3–4 cm zone.

Layer II: 25/27–35+ cm bs. Color: pinkish white (7.5 YR 8/2). Medium-sand sized calcareous sediment consisting of sand grains mixed with reef detritus (water-rolled shells, branch coral fingers, foraminifera tests, etc.). This deposit is culturally sterile.

The Layer I deposit in all of these test units yielded pottery, some with Lapita decorations, but in virtually all cases the sherds were small, highly worn, and weathered. The poor condition of the sherds undoubtedly derives from repeated reworking of this deposit for root-crop gardening, which also destroyed any features that might once have been present. The only exception was in Unit 4 (W100N0), where two circular pit or postmold features were found to extend from the base of the cultural deposit down into the underlying Layer II sand.

The limits of surface sherd and shell midden distribution, as recorded by intensive surface walking, did not extend farther south than the S80 line, as shown by the dashed line on Figure 3.2. TP-12, at W200S50, was excavated to test this southern periphery of the site, and as with the units described above, yielded only a small quantity of worn sherds in a thin Layer I deposit.

On the northern side of the airfield, TP-10 and -11 were excavated at W100N100 and W100N110 respectively. Neither of these units revealed any features, with only low densities of small potsherds and some shell and bone midden being present.

TP-9 was excavated at W400N72, also on the northern side of the landing strip, just south of a steep slope leading down to a low-lying swampy depression that represents the position of the Lapita-period reef flat prior to coastal progradation. The unit was excavated into the top of the mid-Holocene paleobeach terrace. Because this unit yielded a particularly early radiocarbon age determination (see Chapter 5), its stratigraphy and other details are potentially significant. The stratigraphy of TP-9 was as follows:

Layer IA: 0–12/15 cm bs. Color: very dark gray (10 YR 3/1). This consisted of an organically enriched loam, the modern soil used for gardening by the Eloaua villagers, and was heavily penetrated by rootlets. The contact with Layer IB was gradational.

Layer IB: 12/15–30/35 cm bs. Color: grayish brown (10 YR 5/2). A fine-grained sand, stained grayish in color from the downward percolation of organic materials from Layer IA. Both Layers IA and IB were midden deposits with substantial quantities of pottery and shell midden.

Layer II: 30/35–110 cm bs. Color: white (10 YR 8/1-2). Medium to fine-grained calcareous sand, representing the paleobeach deposit. The water table was reached at 110 cm bs, and excavation was terminated.

Virtually all cultural materials were confined to Layers IA–IB, although 9 sherds were found dispersed through the upper part of Layer II. Layer IA yielded 210 sherds and 44 pieces of obsidian, and Layer IB yielded 205 sherds and 16 pieces of obsidian. Layers IA–IB also contained a high density of shell midden, with more than 20 kg of mollusks recovered.

From the upper part of Layer II, in association with the nine dispersed sherds mentioned above, we obtained a sample of wood charcoal which yielded a conventional radiocarbon age of 3260 ± 90 BP, which calibrates to 3702–3252 BP (2σ, 95.4%). However, the wood charcoal was not identified to taxon, and there is a likelihood that some amount of "in-built age" is inherent in this date (see Chapter 5 for further discussion).

In all of the airfield transect units, some dispersed charcoal was present in the Layer I garden-soil deposit. However, as the dark loam had been repeatedly turned over and thus incorporated charcoal from burning the second growth during gardening, it seemed likely that most of this charcoal derived from post-occupation activities, and would be inappropriate for assessing the age of the Lapita occupation. Only in TP-9, with its deeper cultural deposit, were we able to obtain a charcoal sample directly associated with Lapita pottery and midden.

Area A Excavations (1985)

Area A was excavated to obtain an expanded sample of the cultural deposits on the paleobeach terrace (at an elevation of 1.9 m asl) located just south of the Lapita-period shoreline. This was the same area tested by Bafmatuk and others (1980) in 1978, and by us at TP-13 in 1985, the latter revealing ceramics extending down for some depth into the basal calcareous sands. Area A consists of six contiguous units defined by Units W228-229/N100-102 (Figure 3.12).

Area A Stratigraphy. Lithologically, the stratigraphy of Area A did not differ appreciably from that evidenced in the airfield transect test pits, with the upper reworked garden soil overlying a basal deposit of calcareous sand and reef detritus. However, while cultural materials in the airfield tests were confined to the upper Layer I deposit, in Area A (as in TP-13) they extended down into the Layer II beach sands to a depth of 1 m bs. The stratigraphic section of the south face of Area A was as follows:

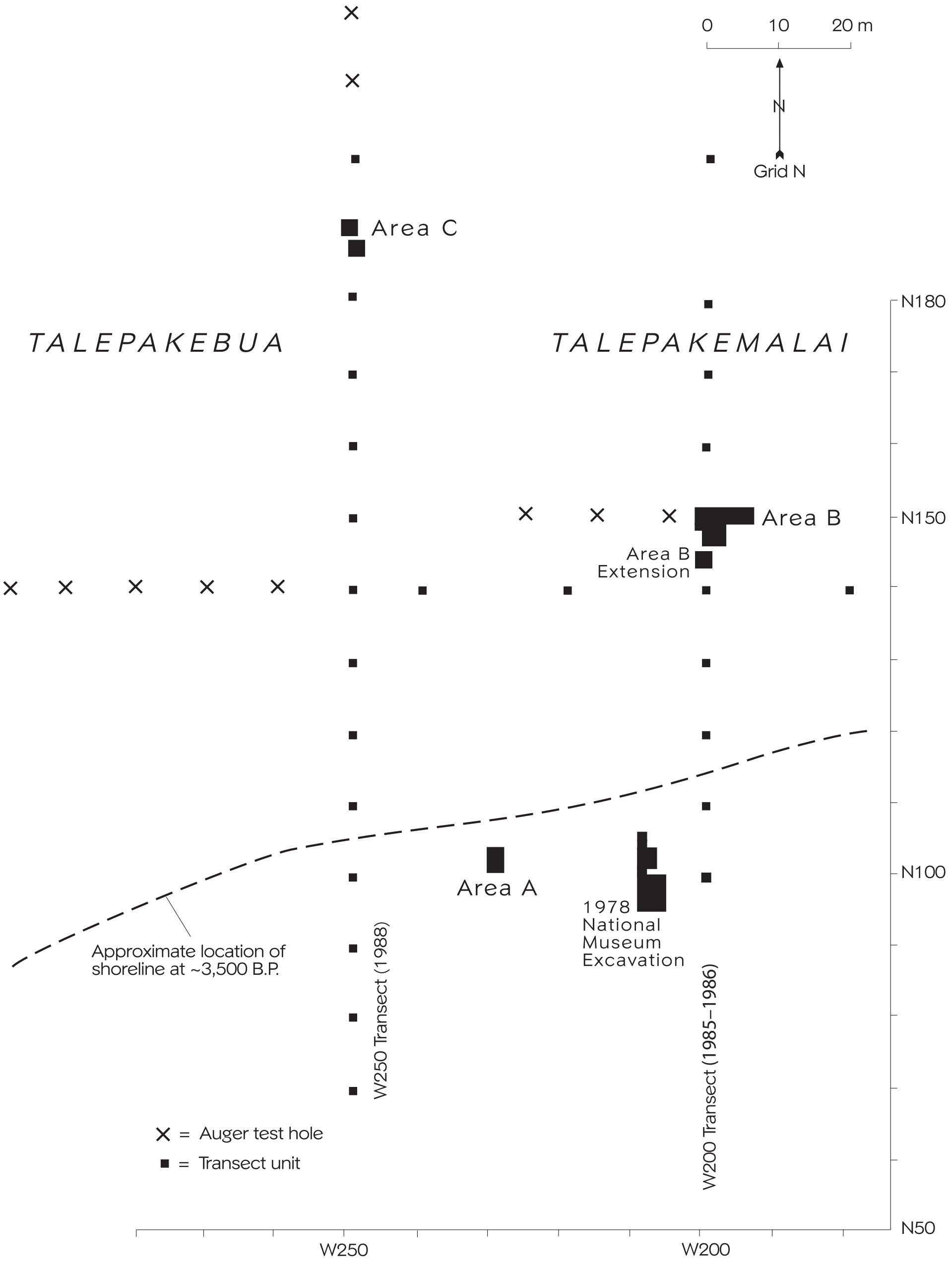


Figure 3.12. Plan of the north portion of the ECA site, showing the locations of the W200 and W250 transects, and of Areas A, B, and C.

Layer I: 0–18/25 cm bs. Color: very dark grayish brown (10 YR 3/2). Sandy loam, extensively reworked through gardening activity, with many roots in the upper portion. Potsherds are small and heavily worn. The contact with Layer II is indistinct and gradational over a 5 cm zone.

Layer IIA: 18/25–45/60 cm bs. Color: white to very pale brown (10 YR 8/2-3). Coarse-grained calcareous sand and reef detritus (small waterworn shells, foraminifera tests, etc.) containing pottery sherds, bone, and molluskan midden. No charcoal flecking present; no evident organic staining of the deposit. The deposit is weakly cemented in places. A sharp contact with Layer IIB was evident both in color and in the degree of cementation.

Layer IIB: 45/60–90+ cm bs. Color: white (10 YR 8/1). In terms of lithology and cultural content this deposit is identical to Layer IIA, but has been strongly cemented throughout, by deposition of calcium carbonate bonds ($CaCO_3$) between individual sand grains. It is this calcium carbonate cement that gives the deposit its brilliant white color.

As excavation proceeded from the base of Layer IIA into IIB, it became increasingly difficult—and eventually impossible—to remove the concreted sediment by troweling, and we resorted to the use of a heavy steel crowbar to break up and pry out the deposit. This method was far from ideal, resulting in some sherd breakage, but could not be avoided. Calcium carbonate cementation of beach sands as in the Area A deposit is a phenomenon noted for other early southwest Pacific coastal sites, such as the Lapita-age deposits on Niuatoputapu Island (Kirch 1988a). The deposition of $CaCO_3$ cement between sand particles is due to leaching of the carbonates in the upper sands by rainwater and downward percolation and deposition. At about 1 m bs the deposit became so strongly cemented that even the efforts of our strongest workman with the steel crowbar were inadequate to break up the sediment, and excavation had to be terminated. Although the frequency of sherds had decreased at this depth, they were still present; therefore the base of excavation is probably not the actual base of the cultural materials.

Cultural Content at Area A. Area A yielded an assemblage of 1,493 ceramic sherds. In this entire assemblage, only two sherds carried dentate-stamped decoration, and there were no instances of incising. One dentate sherd is from a carinated, wide-mouthed bowl and has a simple motif with lime infilling. The second sherd, which is red-slipped, exhibits a single dentate-stamped line with a right-angle bend.

The majority of the ceramic assemblage is quite uniform, with a predominately red paste and calcareous sand temper. Red slipping is present on several sherds. The pottery is low-fired and inoxidized carbon cores are common. The primary vessel shape represented is a large jar with a restricted orifice and strongly everted rim. Identical pottery was recovered from the waterlogged portions of the site sampled by Area B and the W250 transect, but in those localities it is a minor type found in association with a variety of other paste-temper combinations as well as vessel forms. What makes the Area A assemblage unique is the restriction to a narrow range of variation.

Aside from ceramics, another artifact class recovered in significant numbers from Area A is small-to-medium diameter *Conus*-shell rings, of which 18 were excavated. This high concentration of shell rings is a second feature that differentiates Area A from other parts of the ECA site.

Area B and W200 Transect Excavations (1985–1988)

The excavation of transect Unit W200N150 (TP-14) during the early days of the 1985 season led to the discovery of waterlogged sediments containing well-preserved ceramics and other cultural materials in association with the bases of wooden posts. The expansion of this test unit to a 12-m^2 areal block was designated *Area B*; this was further increased to 24 m^2 in 1986. During the 1986 season, we excavated a series of additional 1 m units along the W200 transect line (from N100 to N200), thereby situating the Area B block within a detailed stratigraphic context. Finally, in 1988 an additional 4-m^2 extension to Area B was excavated in order to procure tightly controlled samples of shell midden and ceramics. The layout of all of these excavations is shown in Figure 3.12. Because Area B and the W200 transect are closely integrated, I describe the results from both of these operations together in this section.

Area B and W200 Transect Stratigraphy. The stratigraphy along the W200 transect is summarized in Figure 3.13, proceeding from Unit W200N100 at the approximate crest of the paleobeach ridge (2.01 m asl), out to W200N200 (1.20 m asl). The stratigraphy of Unit W200N100 was essentially the same as described for Area A, consisting of an organically enriched, disturbed garden soil developed on otherwise structureless and lithologically uniform calcareous sands. Beginning in Unit W200N110 and extending through Unit W200N130, however, the stratigraphy became more complex with the presence of a waterlogged fine-silty deposit containing abundant anaerobically preserved plant remains such as coconut and *Canarium* endocarps. The stratigraphic section for Unit W200N120 (TP-18), shown in Figure 3.14, is fairly typical:

Layer I: Color: very dark brown (10 YR 2/2). Disturbed garden soil, with numerous roots. The sandy-loam textured sediment contained much dispersed charcoal (resulting from burning during gardening), along with shell, pottery sherds, bone, and obsidian. Land crab burrows were observed at the interface of Layers I and II, which was otherwise abrupt and clear.

Layer II: Color: white (10 YR 8/1). Massive deposit of medium- to coarse-grained calcareous sand, with considerable $CaCO_3$ concretions in the upper 10–20 cm. Cultural material is present throughout, but less densely concentrated than in Layer I. The lower stratigraphic boundary is fairly straight, and transitional over a ~3–5 cm zone.

Layer III: Color: gray (10 YR 6/1). Fine-grained sand to silt-textured calcareous sediment, with some clay-particle sized lenses in the upper 20 cm; very sticky and plastic. This deposit is entirely waterlogged and contains abundant anaerobically preserved wood fragments, coconut shell, and other seeds and seed cases. Also present are sand-dwelling bivalves such as *Quidnipagus* and Veneridae spp., in death position with both valves intact, indicating that this layer was deposited in a sub-tidal environment. Finely dispersed charcoal flecks are also present throughout the deposit. The basal contact into Layer IV is gradual.

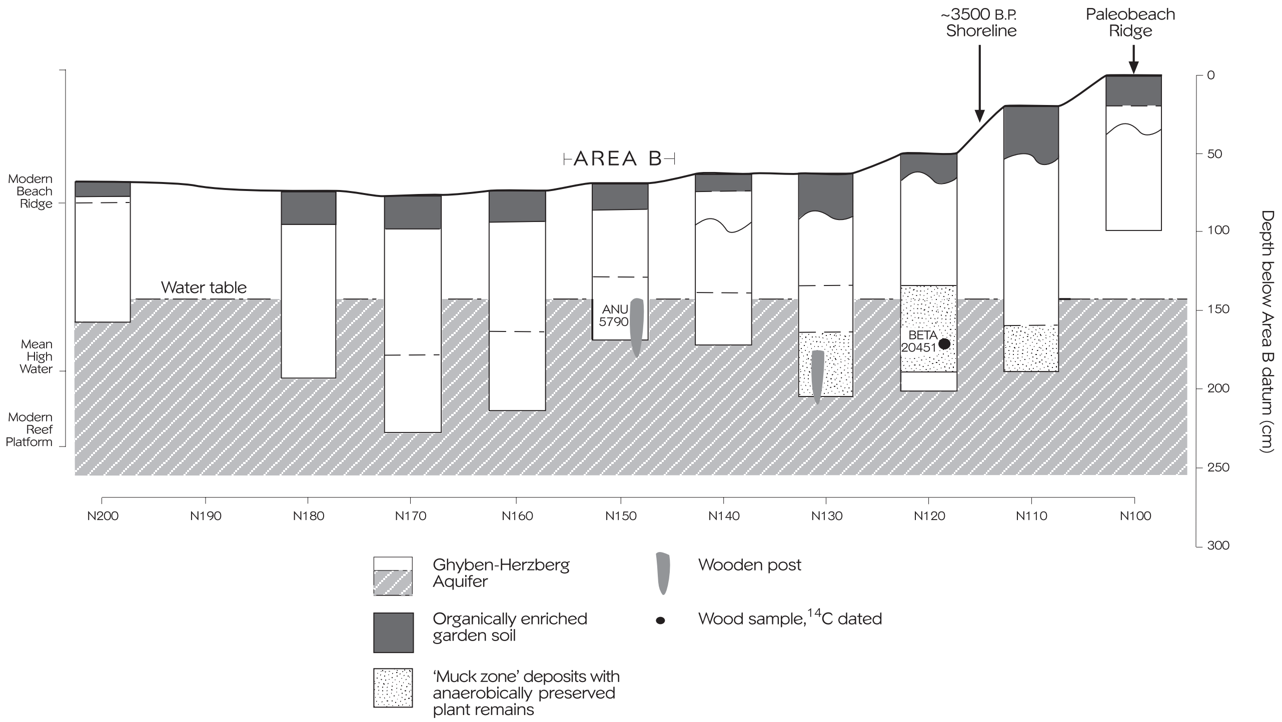


Figure 3.13. Diagram of the W200 transect, showing the relative elevations of excavated units and key features of stratigraphy, as well as the location of dated radiocarbon samples.

Layer IV: Color: white (10 YR 8/1). Medium- to coarse-grained calcareous sand with reef detritus, similar to Layer II in lithology and structure. Culturally sterile, this represents the sub-tidal reef platform at the period prior to initial Lapita occupation.

Moving north along the W200 transect, the "muck-zone" deposits represented by Layer III in Unit W200N120 disappeared between N130 and N140, to be replaced by a highly concentrated waterlogged deposit of potsherds and other occupation debris, associated with wooden

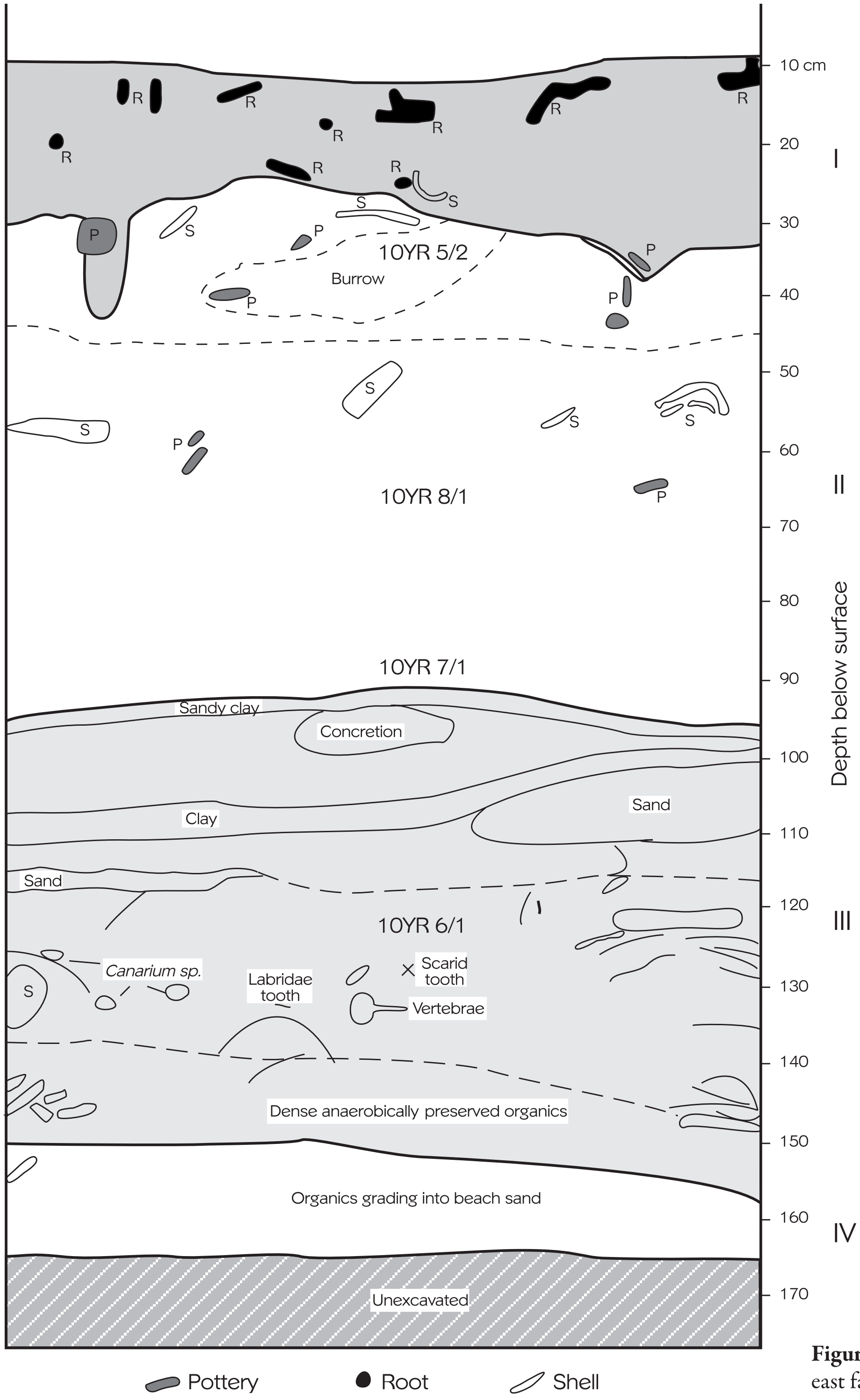


Figure 3.14. Stratigraphic section of the east face of Unit W200N120.

post bases. The stratigraphy in Unit W200N140 (TP-16) is typical:

> Layer I: Color: very dark gray (10 YR 3/1). A heavily reworked, sandy loam garden soil, penetrated by rootlets and incorporating recent charcoal chunks and flecks. This deposit contains potsherds, heavily weathered and eroded, along with shell midden, obsidian, and other cultural materials. The contact with Layer II is gradational over approximately 3 cm.
>
> Layer II: Color: dark grayish brown (10 YR 4/2) to grayish brown (10 YR 5/2) to light grayish brown (10 YR 6/2) at the base. The sandy-loam textured sediment, with some gravel-sized coral inclusions, is low in cultural materials. The deposit is fairly loose, and lacks the concretions present in units further to the south along the W200 transect. Land crab burrows were evident throughout this layer. The contact with Layer III is irregular but fairly distinct.
>
> Layer III: Color: white (10 YR 8/1). Coarse-grained calcareous sand and reef detritus, compact but with no concretions. Some sherds are present, but the density of cultural materials is fairly low. The water table fluctuates over the basal contact of Layer III and IV.
>
> Layer IV: Color: white (10 YR 8/1). Lithologically, this deposit is identical to Layer III, but Layer IV contains a dense concentration of large shell midden (*Tridacna*, *Chama*, *Lambis*, *Spondylus*, and other genera), coral cobbles, branch coral fingers, and reef-detritus gravel. Pottery sherds are most heavily concentrated in a roughly 15 cm zone at the top of this layer, although cultural materials extend down to the base of excavation. (This deposit correlates to Analytic Zone C of the Area B excavation.)

To the north of Area B, the stratigraphy became simplified, consisting of the upper garden zone followed by a thick, structureless deposit of medium- to coarse-grained calcareous sand, which became waterlogged at about 1.45 cm below the Area B datum. The density of cultural materials in the units extending from W200N160 to W200N200 decreased steadily, with the latter unit being largely sterile.

The stratigraphy of Area B was in most respects similar to that described for Unit W200N140. Stratigraphic sections of the main 1985–1986 Area B block are shown in Figure 3.15. The following stratigraphic description was recorded for the east profile of Units W200N144-145 (Area B Expansion) in 1988:

> Layer I: Color: dark gray (5 YR 4/1). Sandy loam, reworked garden soil, penetrated by roots and containing dispersed charcoal. Sherds are heavily worn and eroded, and shell midden is chalky. The basal contact with Layer II is gradational.
>
> Layer II. Color: reddish gray (5 YR 5/2). Medium-grained calcareous sand, with numerous land-crab burrows, containing a low density of cultural materials. The contact with Layer III is highly irregular although relatively sharp and abrupt (< 1 cm transition).
>
> Layer IIIA: Color: white (5 YR 8/1). Massive, structureless deposit of coarse-grained calcareous sand. Some fine, dispersed charcoal flecking is present. The Ghyben-Herzberg aquifer fluctuates vertically through this layer depending upon tidal range, so that the extent of waterlogging is variable. However, land-crab burrows do not extend into this deposit. It is in this layer that the rotted tops of wooden post bases first became evident during excavation. Much cultural material is present, and large sherds exhibiting incised decorations lay horizontally near the top of this layer in the 1988 excavation. The boundary with Layer IV is gradational and not very clear.
>
> Layer IIIB: Color: white (5 YR 8/1). Lithologically, this layer consists of the same coarse-grained sandy calcareous sediment as in Layer IIIA, but it is differentiated by the markedly heavier concentration of shell midden along with gravel-sized coral reef detritus.
>
> Layer IIIC: Color: white (5 YR 8/1). Coarse-grained calcareous sand, with a lower density of shellfish midden than in Layer IIIB, but an increased frequency of *Acropora* branch coral fingers. Significant quantities of anaerobically preserved plant remains also appear in this deposit for the first time. The frequency of pottery and other artifacts is very low, however, and appears to cease completely at the base of the layer.

Several observations regarding the Area B stratigraphy are essential to an understanding of the depositional

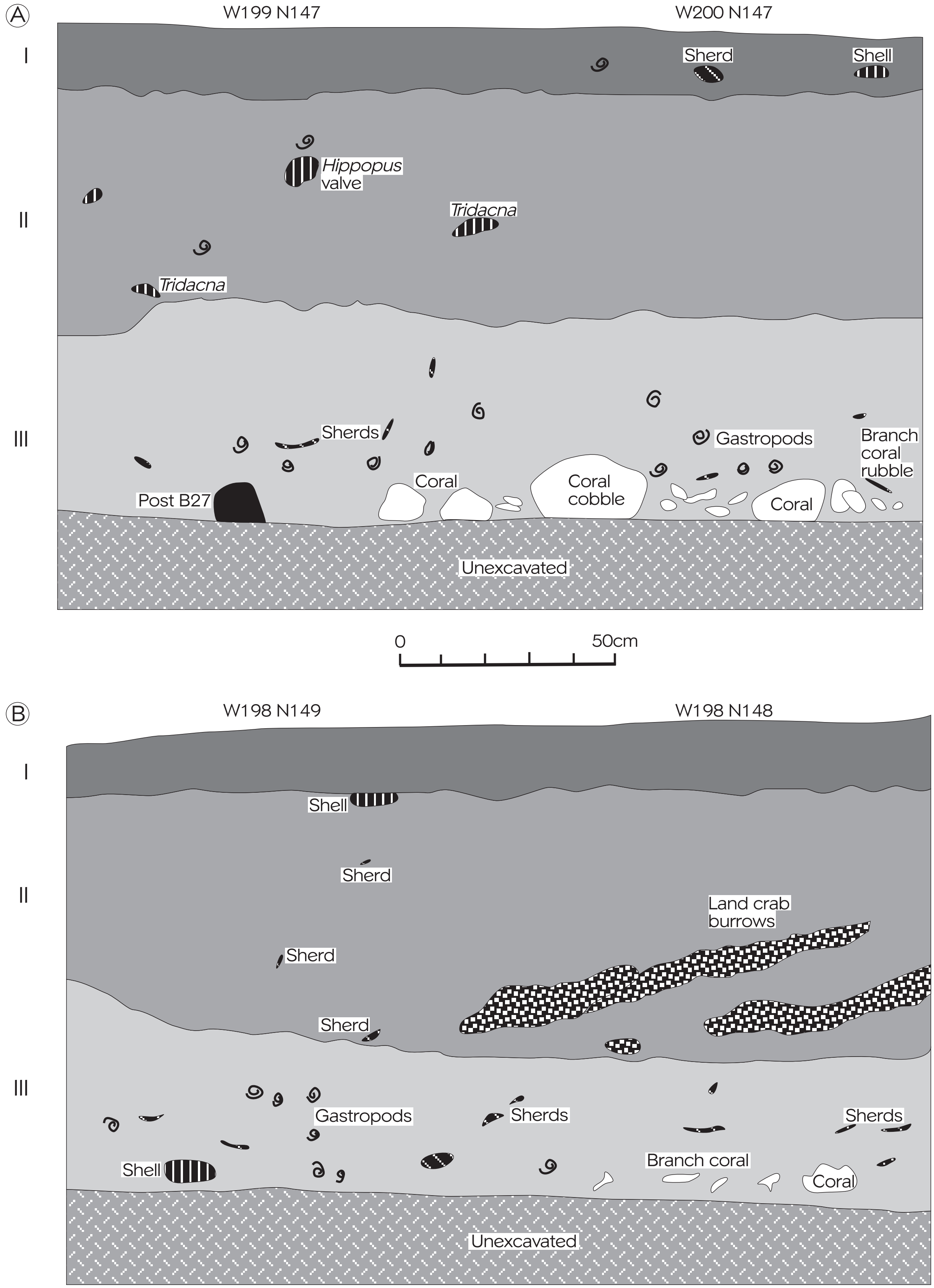


Figure 3.15. Representative stratigraphic sections for Area B at site ECA: *a*, south face of Units W199-200N147; *b*, east face of Units W198N148-149.

history in this part of the site: (1) Layers IIIA to IIIC are essentially identical lithologically, and represent changes in the nature of cultural deposition into the same geomorphological context. Deposition of these sediments occurred sub-tidally, indicated by the presence of large numbers of complete shells of marine bivalves such as *Quidnipagus* sp. and Veneridae spp., which live in sub-tidal, sandy environments. (2) Given that cultural materials tend to lie horizontally within Layers IIIA to IIIC, and that many matching sherds forming large segments of vessels were found together in undisturbed contexts (Figure 3.16), the deposition of cultural materials must have occurred in a sub-tidal situation that was not subsequently disturbed by human activities, or subject to high-energy natural geomorphic processes. Presumably, this is because the occupation at the site occurred on pole or stilt-house platforms, with deposition of pottery, midden, and other materials resulting from purposive and/or accidental dumping of materials off of these house platforms. (3) The Layer II deposit, and to some extent the upper portion of Layer IIIA (the zone of tidal fluctuation of the Ghyben-Herzberg lens), have been heavily disturbed by land crabs (*Cardisoma* sp.), which burrow down to the water table but do not penetrate the waterlogged sands. Over many years, these crabs have depleted Layer II of most of the larger-sized cultural materials, depositing them in their burrow "tips" on the ground surface. Pottery, shell midden, obsidian, and other materials so removed by the crabs became reworked into the upper Layer I garden soil through the repeated gardening that took place over this part of the site. Layer I thus represents a palimpsest incorporating cultural materials removed by post-depositional activity from varying depths and time periods.

In sum, the waterlogged Layers IIIA to IIIC deposits that were sub-tidally deposited have always remained undisturbed, due to their continual aqueous immersion, preventing later disturbance by land crab burrowing. In contrast, the upper deposits of Layers II and I have been significantly disturbed by post-depositional processes, resulting in the depletion of cultural materials from Layer II (and some internal mixing due to burrow collapse), and in the addition and reworking of cultural materials into Layer I.

Referring to the summary W200 transect diagram (Figure 3.13), we can now describe the geomorphological context of the Area B stilt-house occupation. At the time the stilt structures were occupied, they covered a zone about 30 m wide, situated roughly 20 m offshore (north) of the extant shoreline (this shoreline lay between Units W200N110 and W200N100). Dumping of shell midden, pottery, and other debris off of the stilt platforms onto the sub-tidal reef flat resulted in the accumulation of a thick and highly concentrated cultural deposit, which gradually became buried under calcareous sands as the shoreline prograded northward. At the time of occupation, however, the shallow-water reef flat between the stilt structures and the shoreline accumulated a deposit of fine-grained sands

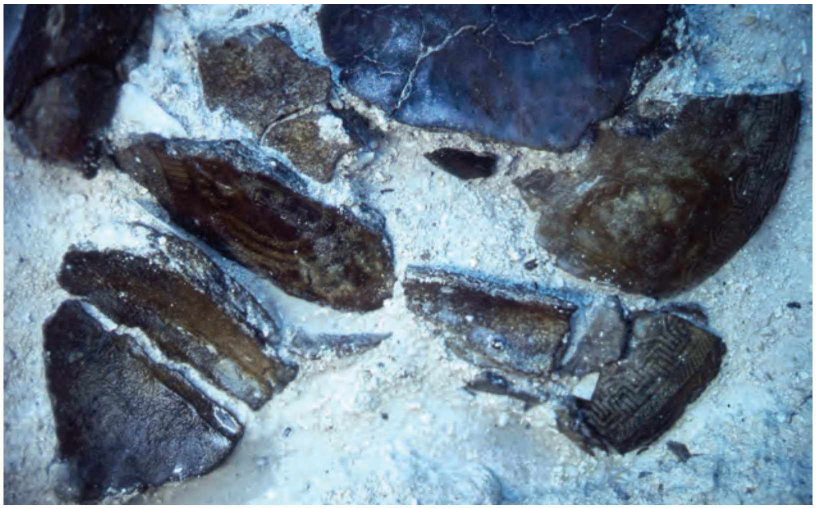


Figure 3.16. A cluster of sherds in situ in Zone C of Area B; several of these sherds came from a pedestal bowl decorated with fine-stamped dentate designs.

and silts (the "muck zone"), trapping large quantities of organic materials, particularly wood, coconut shells, and other plant materials (Figure 3.17). The very fine texture of the sediments indicates a low-energy depositional environment, probably because the pole structures themselves broke the force of wave action before the beach. This pattern of a zone of stilt structures lying offshore, with a "muck zone" in between the beach and houses, was also replicated along the W250 transect.

Area B Analytic Zones. The cultural context of the Area B excavations is best analyzed as a set of *analytic zones* representing litho-stratigraphic units. The concordance between excavation *levels* and these analytical zones is shown in Figure 3.18 for Area B, and in Figure 3.19 for the 1988 Area B extension. Zone A corresponds with Layer I as described above for the Area B Expansion, and is the reworked garden soil deposit. Zone B, which is divided into B1 and B2 (upper and lower respectively), corresponds with the crab burrow-disturbed sandy deposits underlying the garden soil and extending into the zone of tidal

Figure 3.17. Close-up view of anaerobically preserved plant remains in the face of Unit W200N120, within the "muck zone" sediments. Visible here are parts of a coconut shell (*Cocos nucifera*), as well as the endocarp of a seed of *Pangium edule*.

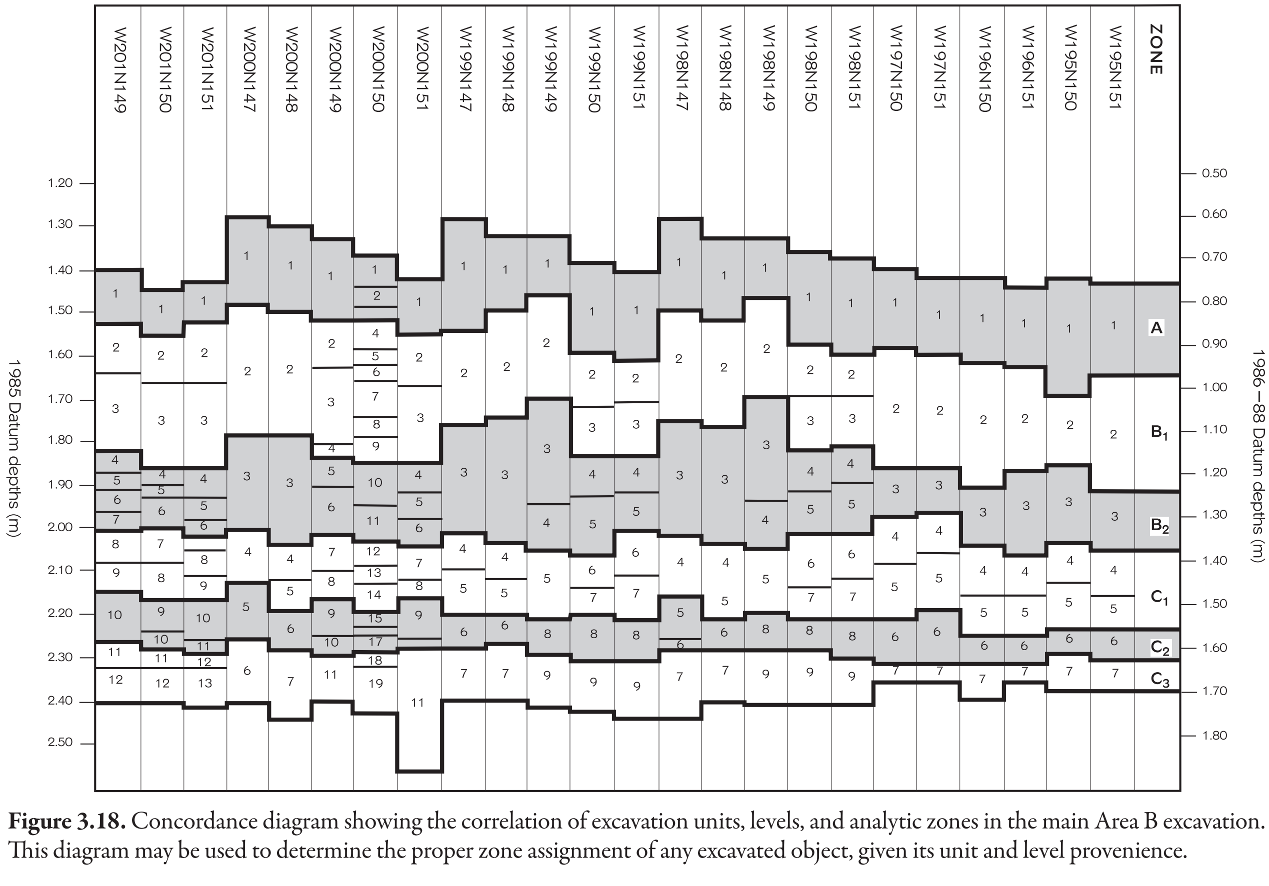


Figure 3.18. Concordance diagram showing the correlation of excavation units, levels, and analytic zones in the main Area B excavation. This diagram may be used to determine the proper zone assignment of any excavated object, given its unit and level provenience.

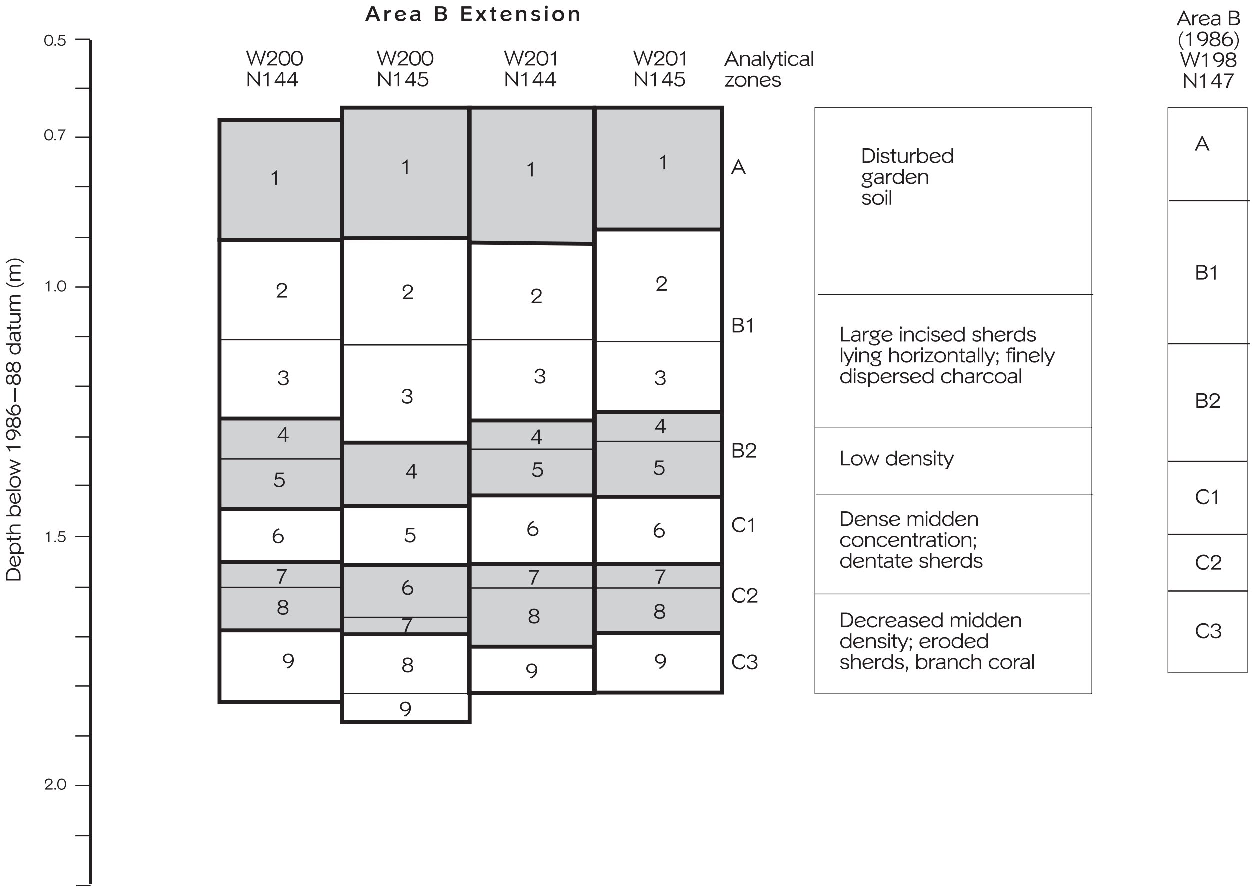


Figure 3.19. Concordance diagram showing the correlation of excavation units, levels, and analytic zones in the 1988 Area B extension excavation. This diagram may be used to determine the proper zone assignment of any excavated object, given its unit and level provenience.

fluctuation of the Ghyben-Herzberg aquifer. Zone C, with three subdivisions (C1, upper to C3, basal), corresponds to the permanently waterlogged deposits (below 1.45 cm below datum, corresponding to 0.45 m above sea level) containing the highest density of cultural materials (Layers IIIA to IIIC). These analytic zones are used here and in following chapters to present the vertical distribution of materials excavated at Area B.

Architecture and Features. The 24-m^2 excavation block at Area B exposed 33 preserved wooden posts or stakes, while the 4-m^2 Area B extension excavated in 1988 exposed an additional six posts and stakes. A horizontal timber was also exposed in Units W198-199N149. Plans of the features are shown in Figures 3.20 and 3.21. Various views of the Area B and Area B expansion excavations, showing the wooden posts, are provided in Figures 3.22 to 3.25.

Metrically, these upright wooden objects can be divided into two size classes: (1) *posts*, with diameters between about 10 and 20 cm; and (2) *stakes*, with diameters between 3 and 10 cm. In Area B, the posts are aligned in two rows running roughly north–south and east–west, which meet in a corner at the conjunction of excavation units W200-199N150-151, marked by a cluster of three large posts. Six small stakes lie immediately west of the corner, and may have supported some kind of adjacent, ancillary construction (a walkway, racks, or similar structures are likely possibilities). The two principal post alignments probably represent main supports for a substantial structure; given that the north–south alignment continues into the 1988 expansion, the sides of this stilt-house structure were greater than 8 m long.

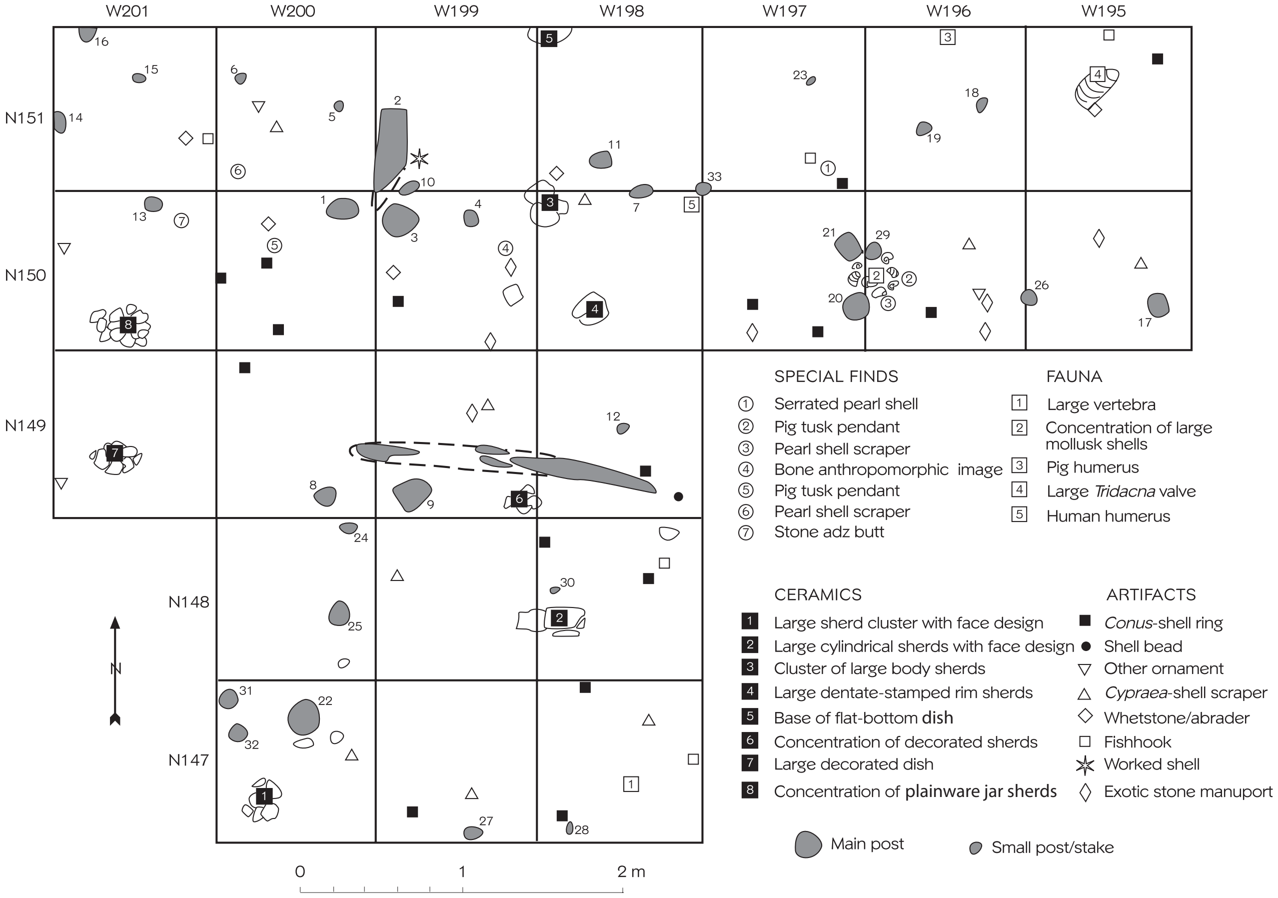


Figure 3.20. Plan of the Area B main excavation, showing the locations of all wooden posts and stakes, as well as the positions of significant sherd clusters and other artifacts.

Posts 1 and 2 from the main corner, as well as a smaller stake, were submitted for radiocarbon dating; Figure 3.26 shows Posts 1 and 2 with the samples removed for dating. Post 1 has a calibrated 2σ (95.4%) age range of 3344–2885 BP, while Post 2 has a calibrated 2σ range of 3335–2869 BP (the radiocarbon dates are further discussed, along with Bayesian modeling of the Area B chronology, in Chapter 5). Posts 1 and 2 were also examined by Prof. D. E. Yen (Australian National University) prior to dating, who identified the wood as *Intsia bijuga*. Gerhard Peekel, a German priest and naturalist who wrote an important flora of the Bismarck Archipelago, observed that *Intsia bijua* is a common foreshore tree, whose "wood is extremely hard and is called 'ironwood'. It is excellent for furniture- and building-timber, . . . resistant to termites" (1984:214–216). Of *Cordia subcordata*, Peekel writes that it is a "widespread, abundant beach tree. . . The brown, black-veined heartwood is very strong" (1984:471). Other posts appeared to us, and to our informants during excavation, as probably being *Cordia subcordata*.

Because permanent preservation of all of these posts posed a significant conservation problem, we felt it preferable to leave these architectural features in situ where they could be re-exposed if an expanded areal excavation is undertaken in the future at Area B; most posts and stakes were therefore not removed. However, Posts 1 and 2 were removed at the close of the 1985 excavation and sent to the Prehistory Department at the Australian National University, where they were conserved by W. Ambrose. Both of these posts have sharpened, pointed bases with adze marks, as seen in Figure 3.26.

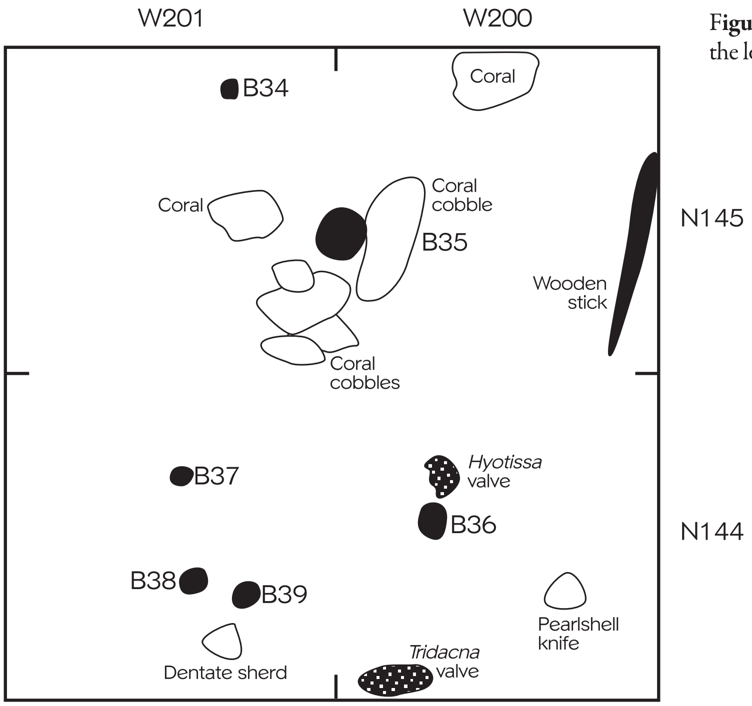


Figure 3.21. Plan of the Area B 1988 extension, showing the locations of wooden posts and other features.

Figure 3.22. View of Area B at the completion of excavations in 1986, with wooden posts exposed but still in situ. Note that Posts 1 and 2 had been removed at the close of the 1985 season, and thus are absent from this photograph.

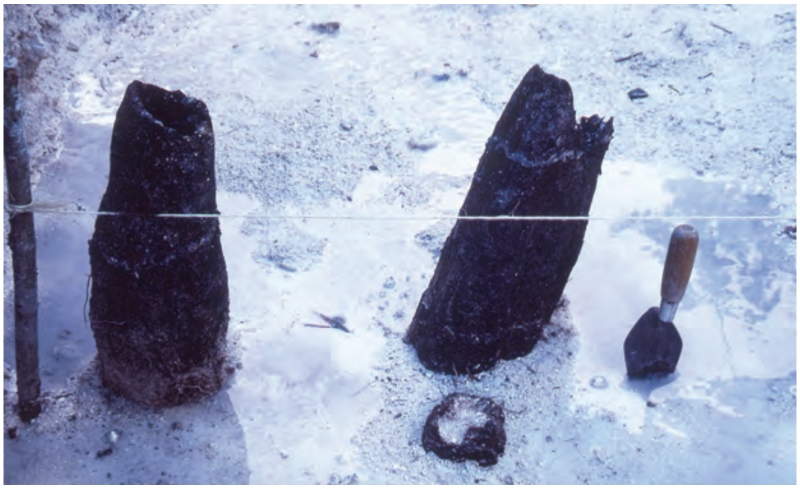


Figure 3.23. Close-up view of Posts B20 and B21 in the east part of the main Area B excavation (view is from the east looking west). The top of a smaller post or stake is also visible.

Figure 3.24. View of the S part of Area B at the close of excavations in 1986, showing the exposed wooden posts in situ, and a horizontal timber in the foreground.

Figure 3.25. The Area B extension at the close of excavations in 1988, with several exposed posts and stakes in situ.

Figure 3.26. Posts B1 and B2 after conservation by freeze-drying, and after sampling for radiocarbon dating. Note that the post bases have been tapered to a point by adzing, presumably for ease of insertion into the reef flat. The samples for radiocarbon dating were removed from the outermost growth rings of the post, and the resulting dates should therefore give a close approximation of the ages of death of the trees, and of construction of the stilt house.

Because the Zone C deposits were deposited sub-tidally onto the sandy reef flat, there are no features in the usual sense of hearths, ovens, or pits. However, as deposition was within a low energy marine environment without significant disturbance, there are a number of clusters of sherds and other materials as shown in Figure 3.20. For example, in Unit W201N149 we exposed an in situ, undisturbed arrangement of sherds representing about two-thirds of a large, intricately decorated flat-bottom dish (Figure 3.7). This vessel had apparently between tossed off the stilt-house platform, presumably after breaking, and landed upside down on the sandy lagoon floor. Although the impact of landing on the sandy flat fractured the vessel into more than one dozen sherds, these were not subsequently dislodged. Similarly, much of a large plainware jar was found in a similar condition in Unit W201N150, along with half of

Figure 3.27. Sherds from a finely decorated cylinder stand as exposed in situ in Zone C of the Area B excavation.

an exquisite cylinder stand with anthropomorphic face design in Unit W198-199N148 (Figure 3.27). Another feature of interest was a dense concentration of large mollusk shells packed closely around the bases of wooden posts 20, 21, and 29.

Spatial Patterns in Area B. The Area B excavation exposed two sides of a rectangular structure, originally supported on wooden stilts or posts, situated over a shallow reef flat. In order to determine whether the distribution of cultural materials in Zone C of Area B might reflect patterns associated with this structure (such as differential density of materials to one side of the post alignments), I plotted the distribution of a variety of classes of materials (both artifacts and faunal remains) by grid unit. Figure 3.28 is a perspective density plot of the Area B excavation (as viewed from the northwest corner of Area B), showing the distribution of plain body sherds, while Figure 3.29 depicts the distribution of decorated body sherds. In Zone C3, there is a high concentration of plain sherds in the vicinity of the putative corner of the stilt house, while the decorated sherds display a fairly uniform distribution. In Zone C2, a different pattern emerges, with both plain and decorated sherds displaying higher concentrations in the southern portion of the main excavation, extending beyond into the 1988 Area B extension. Finally, in Zone C1, which has the highest overall concentration of ceramics, there are fairly dense “pockets” in both the south and east portions of the main excavation, while the 1988 Area B extension displays a relatively low density.

The distribution of lithic flakes (primarily obsidian, but also including some chert flakes) is shown in Figure 3.30. In Zone C3, two units presumably situated to the exterior of the stilt-house structure (on the north and west) display slightly elevated densities, while in Zone C2 there is a similar high-density unit on the west side of the north–south post alignment. Zone C1 shows the highest overall density of lithics (correlating with the vertical distribution of ceramics), with the highest concentrations again to the north and west of the stilt-house alignment. This pattern may reflect knapping taking place on the elevated stilt-house platform, with debitage falling or being tossed off the edges of the platform.

Cultural Content of Area B. Area B yielded a large assemblage of ceramics and non-ceramic portable artifacts, as well as faunal materials (Table 3.2). The greatest density of materials occurs in Zone C, the undisturbed waterlogged deposit. Ceramics, obsidian flakes, and vertebrate fauna increase steadily in quantity from Zone C3 to Zone C1, whereas shell midden is fairly uniformly distributed. The Zone C3-1 deposit is directly associated with the wooden stilt-house architecture. Zone B, above the Ghyben-Herzberg lens, has a considerably lower density of all classes of cultural material. Zone A also has a low density; the materials contained in this reworked garden soil were deposited largely through the

Table 3.2. Summary of cultural content of Area B, Site ECA (by analytic zones)

Class	A	B_1	B_2	C_1	C_2	C_3	Total
Ceramics							
Plain Body Sherds	1512	2882	2580	5604	4481	3949	21008
Decorated Body Sherds	96	222	230	655	417	240	1860
Plain Rim Sherds	21	38	53	91	56	84	343
Decorated Rim Sherds	96	157	207	504	376	221	1561
Ceramic Disks		2			3	9	14
Non-Ceramic Artifacts							
Obsidian Flakes	399	422	309	483	244	213	2070
Adz/Adz Fragment			1	2	1		4
Abraders	1		1	2	3	1	8
Scrapers & Peelers	5	22	28	46	29	22	152
Fishhooks	2	4	3	6		3	18
Fishhook Preforms	25	20	27	26	26	8	132
Shell Rings	6	8	11	28	20	14	87
Other Ornaments	2	5	4	20	17	5	53
Coral Oven Stones	5	69	7	12	108	18	219
Manuport/Volcanic Stone	9	18	49	103	39	87	305

burrowing actions of land crabs that have removed materials from lower depths (especially Zone B). Zone A must be discounted as a primary occupation unit in any analysis of the Area B materials.

The Zone C materials were deposited sub-tidally as a result of discard from and accumulation around the stilt-house structure. Following the abandonment of this structure, and initial progradation of the shoreline to the north, the Zone B materials were deposited intertidally or supra-tidally in a beach front or foreshore microenvironment. Despite this change in the environment and mode of deposition (and consequent lack of waterlogging of the Zone B deposits), the vertical stratigraphy in Area B does present an intact temporal sequence, which is important for the analysis of change in ceramic style and other aspects of Lapita material culture in Mussau.

In Area B, there is a clear pattern of temporal change in the decorated ceramics, with a progression from an early emphasis on fine dentate stamping, through a middle phase with an increase in coarse dentate stamping, to the late deposits marked by a dominance of incised decoration, a temporal sequence mirrored by the *horizontal* stratigraphic progression from south to north along the W250 transect (see below). The Area B sequence similarly reveals major shifts not only in decorative technique, but in vessel form, temper, and other attributes.

The Zone C deposits at Area B—associated with the large stilt structure—are notable for the presence of a variety of shell objects. These include many exquisitely executed *Spondylus*-shell beads and pendants, *Nautilus*-shell discs, *Conus*-shell and *Tridacna*-shell rings, large *Conus* "rectangular units," and other objects. The concentration of such numbers of these shell objects in Area B is noteworthy. This is especially so in light of the presence, in Zone C, of a number of elaborately decorated Lapita ceramic vessels, including pedestaled bowls, and dishes bearing anthropomorphic designs. Area B also yielded a unique bone sculpture, a small anthropomorphic image carved from sea mammal bone (see Chapter 13). This concentration of unusual or unique objects and

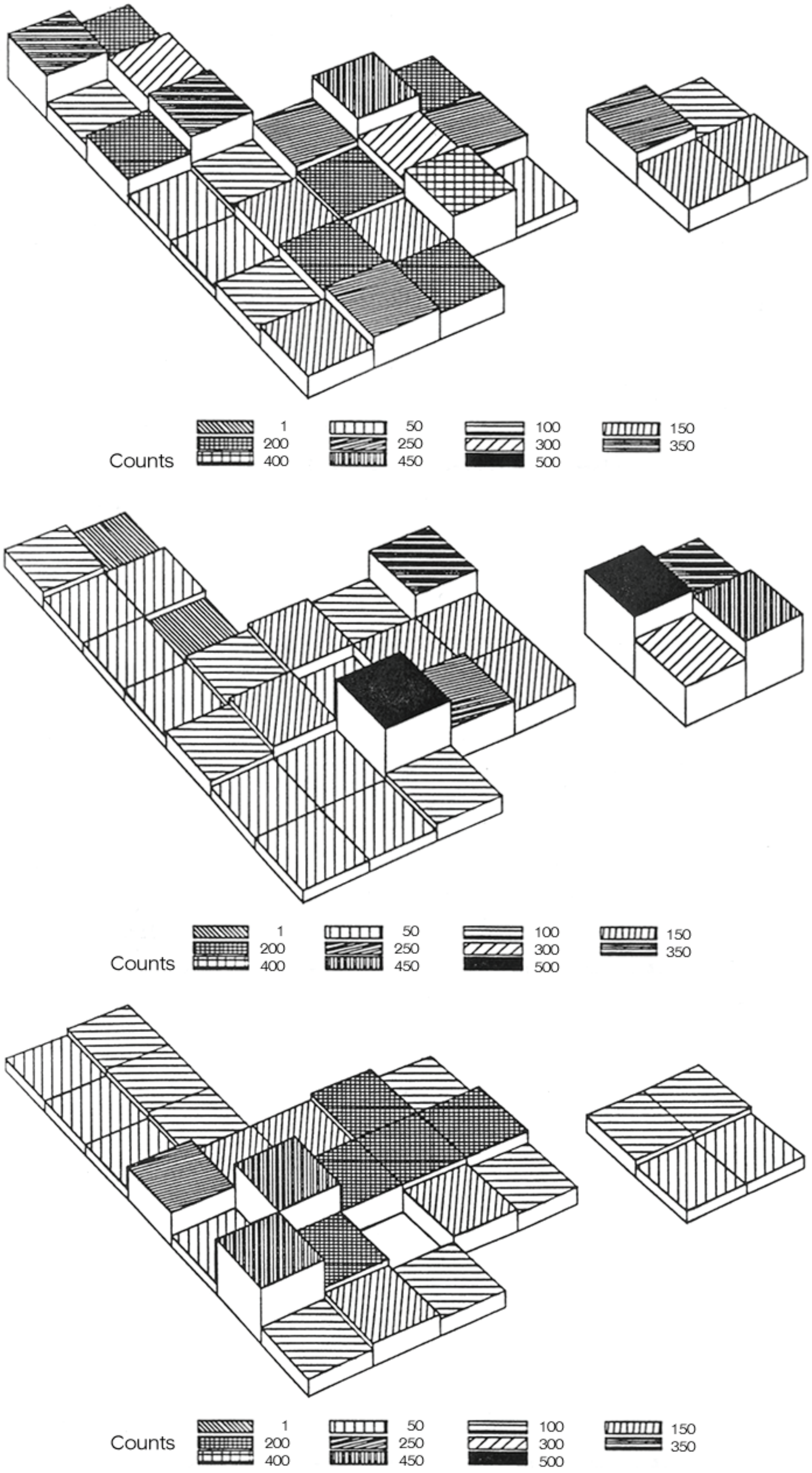


Figure 3.28. Spatial distribution (density) of plain body sherds in Zone C of Area B and the Area B extension; perspective is from the northwest.

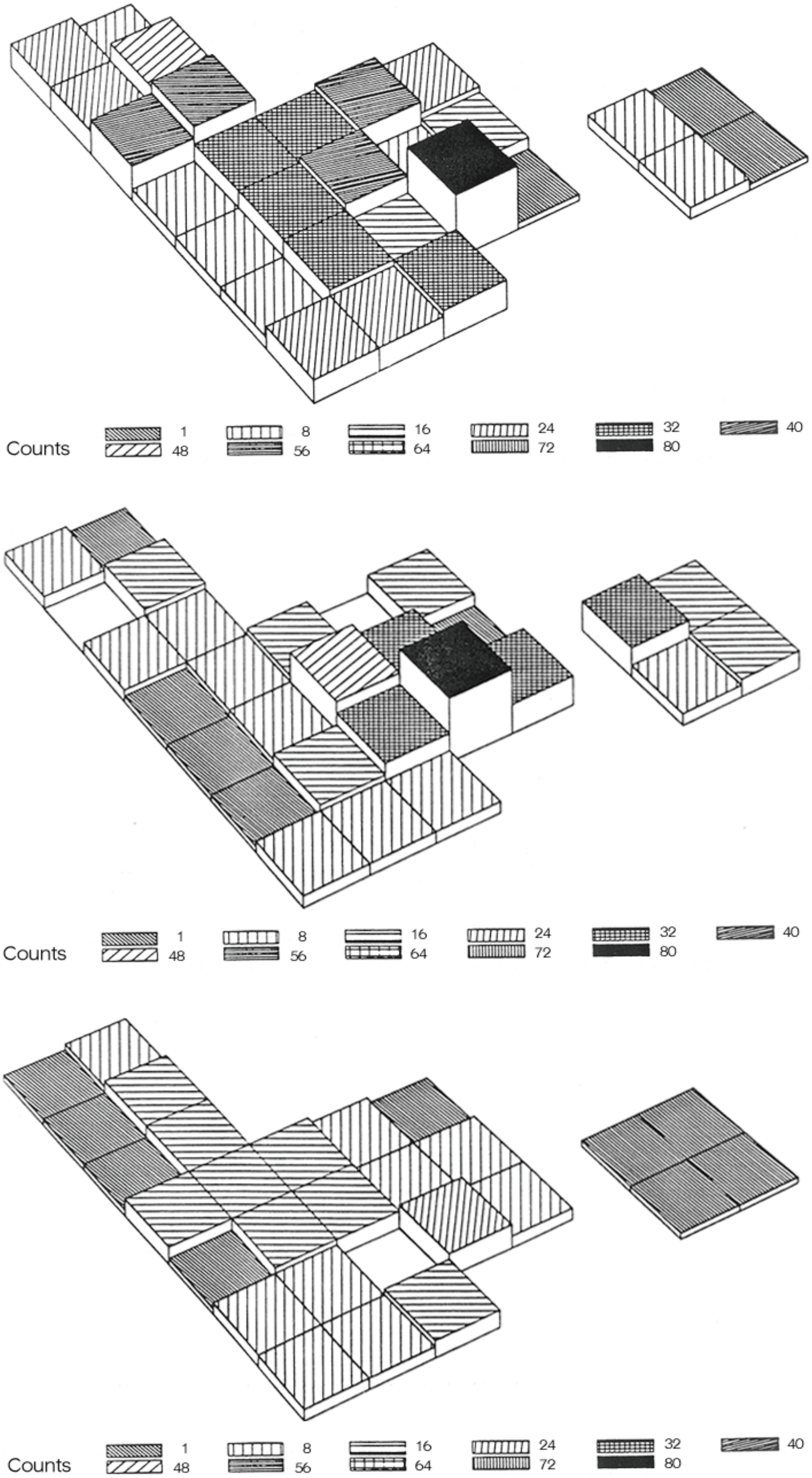


Figure 3.29. Spatial distribution (density) of decorated body sherds in Zone C of Area B and the Area B extension; perspective is from the northwest.

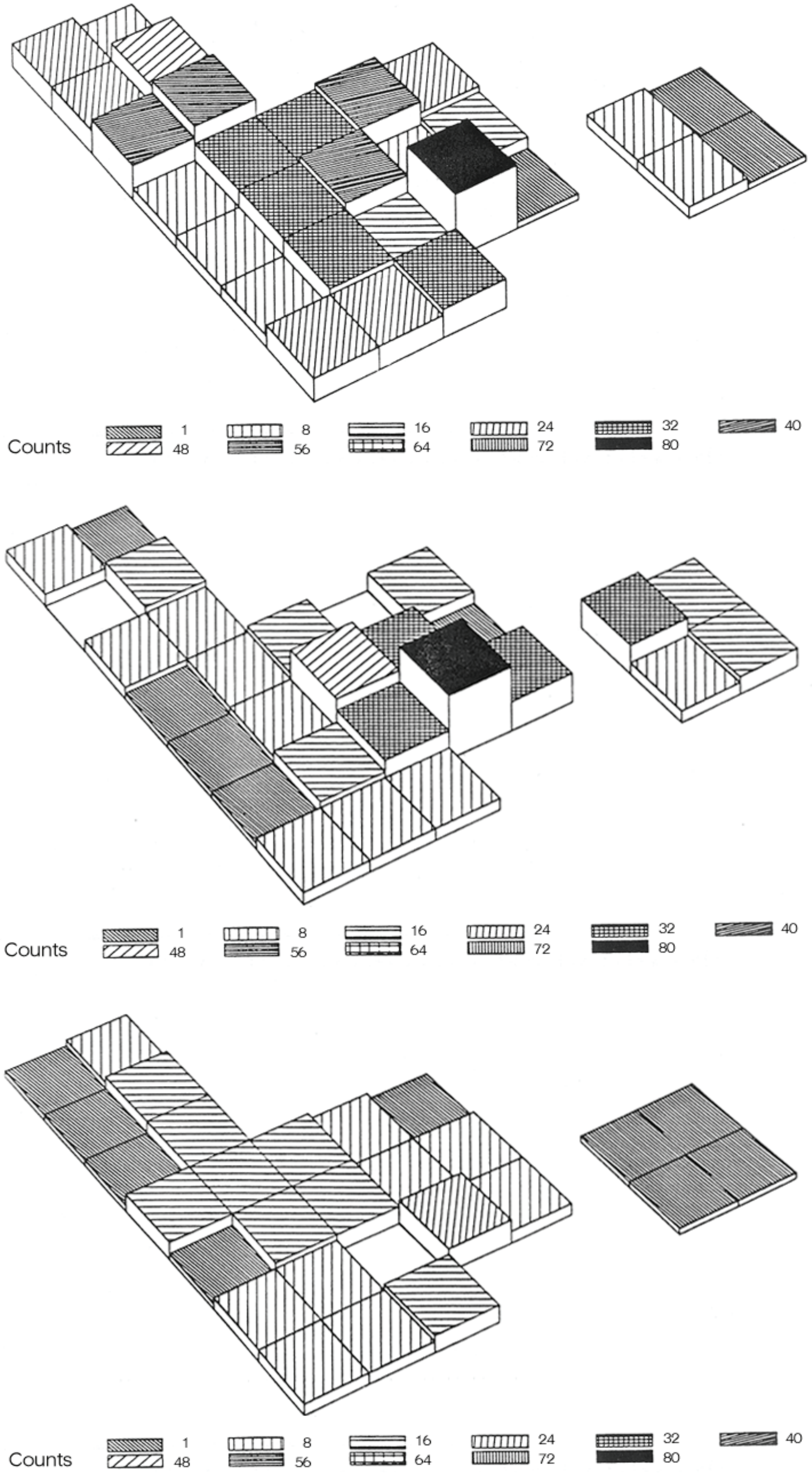


Figure 3.30. Spatial distribution (density) of lithic flakes (primarily obsidian) in Area B and the Area B extension; perspective is from the northwest.

ceramics—unparalleled elsewhere in the ECA site, or indeed at other Lapita sites excavated to date—suggests that the Area B stilt house was a special-function structure. However, the Zone C deposits also contain heavy concentrations of shell and bone midden, oven stones, and food-preparation equipment such as scrapers and peeling knives. Thus food preparation and consumption was also a major activity at this structure, possibly the resulting of feasting events.

The W250 Transect (1988)

The W250 transect lies 50 m west of Area B and, as with the W200 transect, extends from the Lapita-period beach terrace (1.73 m above sea level) marked by a 0.7 m elevation drop north across a low flat to N200 at 1.03 m, a total distance of 130 m (see Figure 3.12). The southern portion of the transect, between W250N70 and W250N110 (situated on the higher ground of the paleobeach terrace), consists of dark gray-brown loam littered with shell midden and potsherds, supporting a vegetation association of second-growth scrub *Pandanus*, *Morinda*, and other shrubs, ferns, and grasses reflecting repeated root-crop gardening. Proceeding north beyond W250N110 and across the former shoreline, the soil transitions to a lighter brown sandy loam, lacking surface shell midden and sherds, covered in climax forest vegetation. Since it lacks organic enrichment from human occupation, the Eloaua people regard this sandy loam as infertile terrain for gardening.

We cleared the W250 transect with bush knives, and took a series of profile elevations with a telescopic level. After tying these elevations to the Area B datum, a new permanent datum peg was established for use during the W250 transect excavations. As with the 1986 Area B excavations, our hand-operated bilge pumps kept the W250 pits dry, while the pump outflow was used to wet-sieve the excavated sediment. During the W250 transect excavations we also took systematic 1 liter sediment samples from each excavation level for flotation and fine wet-sieving through 0.125 inch mesh screens in the field laboratory.

W250 Transect Stratigraphy. The W250 transect provides a stratigraphic profile extending 130 m from the beach terrace and Lapita-period shoreline in the south, to the former reef flat on the north. A diagrammatic overview of this stratigraphic transect is shown in Figure 3.31. Here I provide descriptions of four units

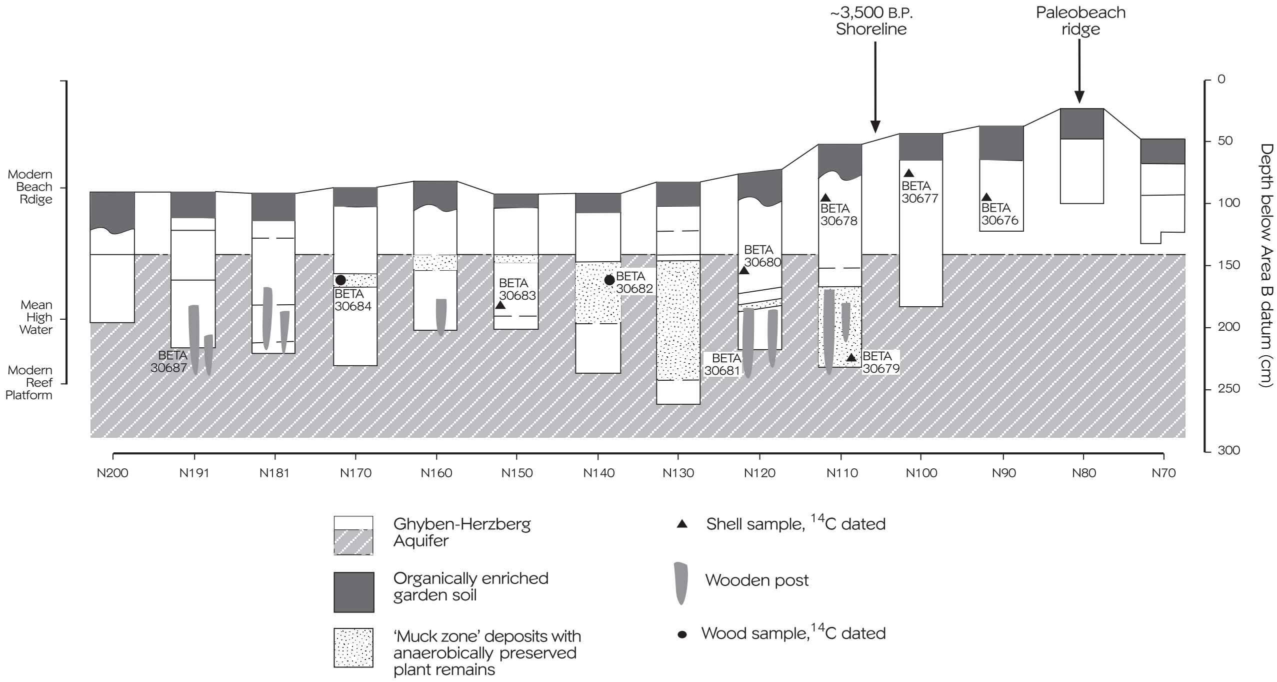


Figure 3.31. Diagram of the W250 transect, showing the relative elevations of excavated units and key features of stratigraphy, as well as the location of dated radiocarbon samples.

that represent the range of stratigraphic variation across the transect: W250N80, W250N120, W250N150, and W250N200.

Unit W250N80. This unit lies at the highest point of the paleobeach terrace (1.73 m asl), and therefore occupies the same geomorphic zone as Area A and as TP-9 (W400N72). As with Area A, the stratigraphy in W250N80 was simple, consisting of only two sedimentary deposits:

> Layer I: 0–20/25 cm bs. Color: dark brown (7.5 YR 4/2). Sandy loam with a thick root/fern rhizome mat in the upper 5–10 cm, heavily reworked by gardening. Sherds in this layer are typically small and weathered. The contact with the underlying sand deposit is gradational over a 3–4 cm zone.
>
> Layer II: 20/25–75+ cm bs. Color: white (5 YR 8/1). Structureless deposit of coarse-grained calcareous sand and reef detritus, becoming more gravelly textured with increasing depth. Sherds and shell midden become less frequent with depth, and were not recovered below 50–60 cm, although this does not correspond with any evident lithological break. Layer II becomes strongly cemented at the base of excavation at about 75 cm bs.

The stratigraphy of Unit W250N80 is in all respects highly similar to that of Area A. Furthermore, the ceramic assemblage recovered from Units W250N70 through W250N100 also closely matches that from Area A, being dominated by large, plainware jars with restricted orifices and strongly everted rims.

Unit W250N120. The ground surface here is 54 cm lower than at W250N80, suggesting that the former unit was originally north of the Lapita-period shoreline; this was confirmed by excavation. The east face of W250N120 is shown in Figure 3.32, and the stratigraphic profile was as follows:

> Layer IA: Color: dark reddish brown (5 YR 3/2). Sandy loam, reworked by gardening. Many rootlets present in the upper part of the layer. Grades into Layer IB.
>
> Layer IB: Color: reddish brown (5 YR 5/3). A zone of leaching at the base of Layer I; coarse-grained calcareous sand, stained gray.
>
> Layer II: Color: white (5 YR 8/1). Massive, structureless deposit of coarse-grained calcareous sand, containing a high density of shellfish midden. The deposit is heavily cemented with calcium carbonate bonds between individual sand particles in the upper part, but becomes less cemented to loose with increasing depth. The boundary with Layer III is gradational.
>
> Layer III: Color: light gray (5 YR 7/1). Coarse-grained calcareous sand with some fine silt-clay sized particles mixed in. This deposit contains anaerobically preserved plant remains, as well as cultural materials such as pottery and bone. The contact with Layer IV is very abrupt and smooth.
>
> Layer IV: Color: white (5 YR 8/1). A thin deposit of coarse-grained, loose calcareous sand containing cultural material. The contact with Layer V is very abrupt and sharp.

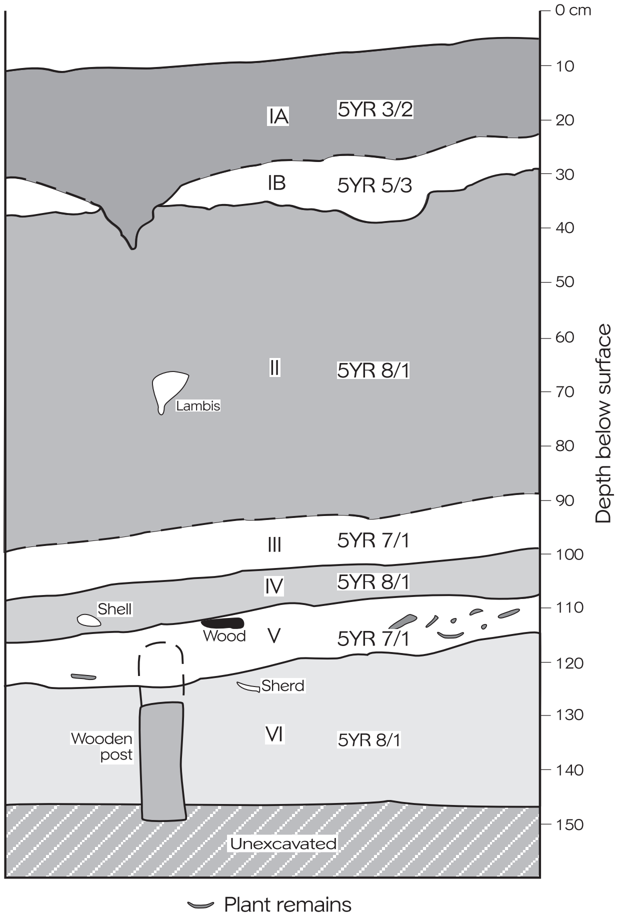


Figure 3.32. Stratigraphic section of the east face of Unit W250N120.

Figure 3.33. Concentration of sticks and anaerobically preserved plant remains, adjacent to a vertical wooden post, in the "muck zone" sediments in Unit W250N120.

Layer V: Color: light gray (5 YR 7/1). A densely compacted layer of fine clay-silt textured calcareous sediment, lacking any larger-sized inclusions. The deposit is full of preserved wood and a variety of anaerobically preserved plant remains. Two wooden posts passed through this layer down into Layer VI, and were surrounded by a mass of rattan-like tough, flexible sticks (ca. 1.5–2 cm diameter), as shown in Figure 3.33. These sticks and the posts trapped a dense accumulation of plant remains (seed cases, nuts) in a pocket of fine-grained silt-clay. The thick deposit of plant remains accumulated around the posts in situ. Layer V slopes steeply from the southeast to northwest; the lower stratigraphic boundary is very abrupt and sharp.

Layer VI: Color: white (5 YR 8/1). A loose deposit of coarse-grained calcareous sand containing large midden shells but very little bone, and only a few water-rolled sherds. Post 2 continued down through this layer.

Excavation was terminated in W250N120 at 140 cm below surface, when the high volume of water flowing into the pit overwhelmed the hand pumps and threatened to collapse the sidewalls. The tops of the two wooden posts were removed for radiocarbon dating and wood identification.

The depositional sequence in W250N120 began with deposition on the intertidal flat immediately seaward of the shoreline at the time of initial Lapita occupation (Layer VI). This intertidal zone incorporated a few water-rolled potsherds and some shell midden. The construction of a pole or stilt structure is associated with the next depositional unit (Layer V), and a mass of organic material was trapped and buried in the fine sediment that accumulated around the post bases. Abandonment of the stilt structure probably occurred during or after the deposition of the next two, relatively thin sedimentary layers (IV and III). Layer II, with a high density of shell midden, represents a shift from an intertidal depositional environment to a beach ridge, and postdates the progradation of the shoreline in a northerly direction.

Unit W250N150. This unit lies 45 m north (and seaward) of the mid-Holocene shoreline associated with initial Lapita occupation of ECA, at an elevation of 1.02 m above sea level. The stratigraphic profile of the east face, shown in Figure 3.34, was as follows:

Layer I: Color: dark brown (7.5 YR 3/2). Silty-loam, A horizon, heavily penetrated with rootlets; somewhat reworked through gardening. The contact with the underlying Layer IIA is abrupt and sharp.

Layer IIA: Color: reddish yellow (7.5 YR 7/6). This appears to be a zone of organic staining due to the leaching of the A horizon and downward percolation of organic materials.

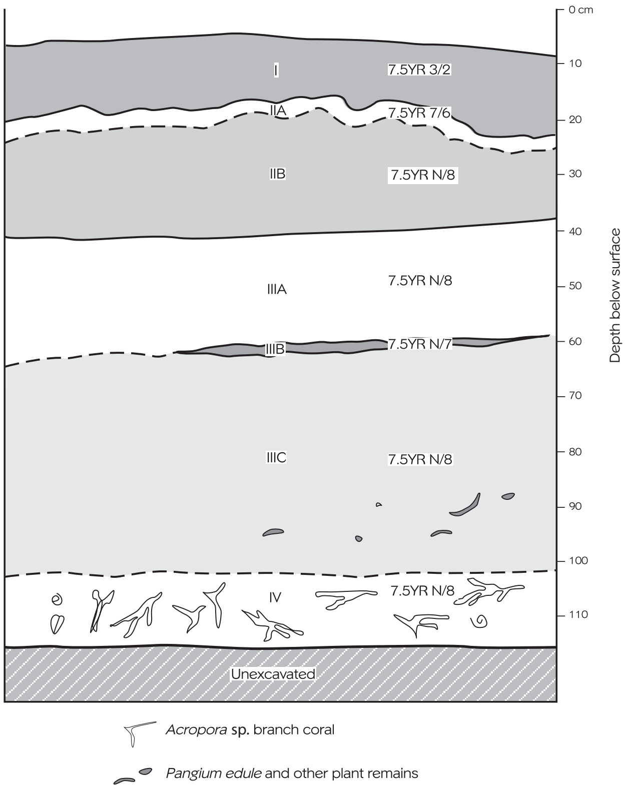


Figure 3.34. Stratigraphic section of the east face of Unit W250N150.

Layer IIB: Color: white (7.5 YR N/8). A massive, structureless deposit of medium- to coarse-grained calcareous sand, heavily cemented. The contact with Layer III is gradational over about 1.5 cm.

Layer IIIA: Color: white (7.5 YR N/8). Structureless deposit of coarse-grained calcareous sand with a slight fine-fraction admixture of silt-clay. The contact with Layer IIIB is abrupt.

Layer IIIB: Color: light gray (7.5 YR N/7). A thin lens of very fine, silt-clay sized calcareous sediment, sloping gently toward the north. Abrupt contact with Layer IIIC.

Layer IIIC: Color: white (7.5 YR N/8). Thick deposit of coarse-grained calcareous sand, containing considerable cultural material, including anaerobically preserved plant remains in the lower portion of the deposit. The contact with Layer IV is gradational over a 3–5 cm zone.

Layer IV: Color: white (7.5 YR N/8). Coarse-grained calcareous sand with numerous water-rolled *Acropora* branch coral fingers. Various entire sand-dwelling bivalves, such as *Quidnipagus* sp. and Veneridae spp., were recovered in death position, indicating a sub-tidal, reef platform depositional environment.

The depositional sequence in W250N150 suggests initial occupation on a sub-tidal reef flat composed of coarse-grained sands with reef detritus including *Acropora* branch coral (Layer IV). A thick deposit of cultural material including sherds, shell midden, and plant remains (Layer IIIC) accumulated on top of the reef platform, with the main source of non-cultural sediment being calcareous sands. Further sand accumulation occurred with progradation of the shoreline past the N150 line and toward the present shoreline.

Unit W250N200. This unit marks the northern end of the W250 transect, and was situated 10 m north of the Area C excavation, in dense climax forest not presently utilized for gardening. The stratigraphic profile of the east face, shown in Figure 3.35, was as follows:

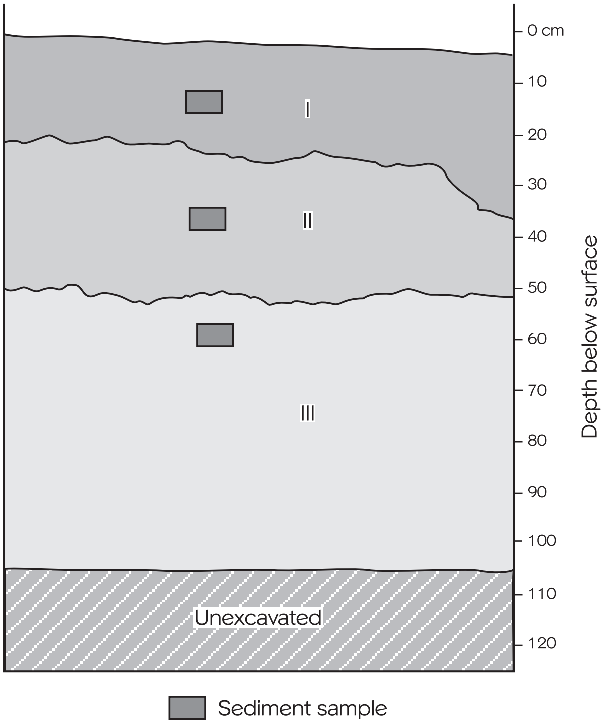


Figure 3.35. Stratigraphic section of the east face of Unit W250N200.

> Layer I: Color: dark grayish brown (10 YR 4/2). Present A horizon with numerous rootlets. The contact with Layer II is gradational.
>
> Layer II: Color: light gray (10 YR 7/1). This mottled zone has been heavily reworked by the burrowing of land crabs, whose burrows were evident during excavation. The deposit of coarse-grained calcareous sand was essentially culturally sterile. The contact with Layer II was abrupt but irregular.
>
> Layer III: Color: white (10 YR 8/1). Coarse- to medium-grained, compact, calcareous sand, containing many entire *Quidnipagus* bivalves in death position, indicative of a sub-tidal depositional environment. Limited cultural material was recovered from the upper part of the deposit, and the frequency of sherds and other cultural debris declined with increasing depth.

The W250N200 unit appeared to be near the northern limit of cultural activity over the former reef platform. The low density of sherds and other materials appears to mark the outer fringe of midden dumping from the stilt-house structure exposed in Area C.

Wooden Posts. Wooden posts were discovered in five of the W250 transect units, schematically indicated on the transect diagram (Figure 3.31). The posts are discretely distributed into two areas or zones. The first of these is in Units W250N110 and W250N120, immediately north of the mid-Holocene shoreline; five posts were exposed in these two units. Their stratigraphic positions at the base of the cultural deposits—set into the underlying intertidal reef platform—indicates that at the time of early Lapita occupation they supported one or more pole structures situated about 10–20 m offshore. These posts correspond with a peak in the density of ceramics, obsidian, oven stones, and other indicators of occupation (see Cultural Content, below), indicating that they supported habitation structures. The ceramic assemblage is characterized by a mix of fine and coarse dentate-stamped sherds, as well as pedestal sherds with cutouts. In general, the ceramic assemblage associated with the W250N110-120 posts is similar to that from Zones C_3–C_2 of Area B, and the house(s) that stood along this part of the W250 transect were probably a part of the same settlement pattern as the Area B structure. Most likely there were multiple pole-house structures paralleling the original shoreline at a distance of between 10 and 40 m offshore. The dating of wooden posts and other materials from the W250 transect is discussed in Chapter 5.

The W250N130 through W250N150 units revealed no posts; however, another set of wooden post bases occurs from N160 to N191. (Unit W250N170 did not contain a vertically positioned post, but did yield a large horizontal timber which may have derived from the collapse of a stilt house.) A total of five substantial posts, each in vertical position, was exposed by this set of units, while expansion of the W250N191 unit into Area C (described below) exposed an additional 20 posts and stakes. These posts were set in coarse-grained sands containing water-rolled branch coral (*Acropora* sp.) along with many sand-burrowing marine bivalves (*Quidnipagus* and other species in the family Veneridae). These bivalves occurred as sets of intact valves in upright death position, indicating that they had died in situ in the sandy matrix surrounding the posts, thus corroborating our interpretation of the depositional environment at the time the wooden post structures were constructed as having been continually sub-tidal.

The cultural materials that accumulated around the wooden post bases in Units W250N160 to N191 display another peak in the density of oven stones, obsidian, ceramics, and other materials, thus signaling another set of habitation structures. The nature of the ceramic assemblage, however, differs from that associated with the structures in the N110-120 zone described above. Here the ceramics are dominated by thin-walled jars with everted rims, decorated primarily by incising and by notching or pinching of the rims (see Chapter 11). This pottery corresponds to the upper part of the Area B sequence (Zone B). We thus interpret the pole or stilt-house structure(s) in the area of W250N160-191 as a later construction, probably after the original shoreline had begun to prograde northward. This interpretation is supported by the radiocarbon dates from the W250 transect and from Area C (see Chapter 5).

Cultural Content Along the W250 Transect. The spatial distribution of several classes of artifacts exhibit similar patterns along the south-to-north course of the 130 m long W250 transect. Figure 3.36 shows the density distributions of undecorated sherds, lithic flakes (primarily obsidian), and coral oven stones. All of these materials exhibit a bimodal distribution pattern, with density peaks centered

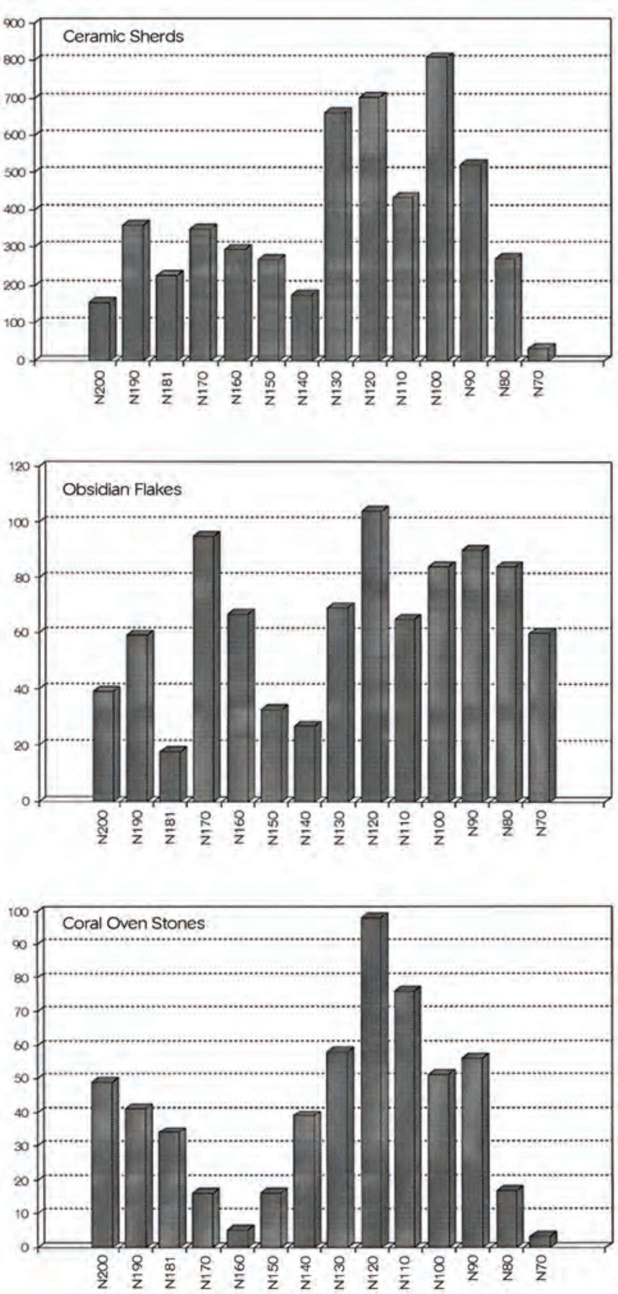


Figure 3.36. Distribution of ceramic sherds, obsidian flakes, and coral oven stones along the W250 transect.

on Units W250N110-120, and on Units W250N181-190. These peaks correspond to the two sets of preserved wooden post bases that we interpret as representing temporally distinct phases of stilt-house construction and occupation. As would be expected from an over-water platform habitation—with midden and trash disposal directly off the platforms into the surrounding shallow water—the density of cultural materials is highest immediately around the posts, tapering off to either side. These patterns indicate that the preserved post bases supported dwelling structures, upon which domestic activities such as oven use and food preparation, use of pottery, shell artifact manufacture, and other tasks took place.

The distribution of anaerobically preserved plant remains along the W250 transect units exhibits a single zone of high concentration, between Units N110-130, corresponding to the main area of fine silt-clay sediment (the "muck zone"), which was so rich in organic remains. Unit W250N130, especially, produced a large assemblage of preserved seeds and nuts, including large numbers of *Canarium* sp. almond, *Dracontomelon dao*, *Spondias dulcis*, *Pandanus* spp., and *Cocos nucifera*. All of this plant material accumulated in the fine sediment around the stilt-house posts, presumably as cultural refuse of the house's occupants.

Worked shell of *Trochus niloticus* and of the two large cone species, *Conus litteratus* and *C. leopardus*, which provided raw material for the manufacture of fishhooks (*Trochus*) and of several kinds of ornaments or exchange valuables (*Conus*), were recovered along the length of the W250 transect. This material, however, was especially concentrated in the N100-120 section, again associated with the earlier phase of stilt houses.

The W250 ceramic assemblage also displays a marked distribution along the course of the transect. At the southern end of the transect, sherds with fine dentate stamping dominate the ceramic assemblage. A considerable increase in the frequency of coarse dentate stamping occurs in the middle of the transect, while the N end in the vicinity of the Area C stilt house is dominated by sherds decorated with incised designs. The changing frequency distributions of decorative technique and vessel form along the W250 transect correspond closely with the vertical, stratigraphic sequence revealed by the Area B excavation, confirming that a true *temporal* progression is being tracked along the course of the W250 transect.

Area C Excavations (1988)

Excavation of Unit W250N190 exposed four wooden posts in waterlogged deposits yielding thin-walled potsherds characterized by notched rims and fine incised decoration. Based on our prior knowledge of the ceramic sequence in

Area B, I realized that we had encountered a relatively late Lapita occupation, postdating the ceramic transition from primarily dentate-stamped ceramics to incised pottery. Given the concentration of posts (two of them quite massive), it also seemed likely that there had been a substantial pole-house structure in this locality. I therefore decided to open up several contiguous units, designated Area C.

The unconsolidated sands in Area C were very loose and the sidewalls of the excavations continually threatened to collapse as we penetrated into the waterlogged levels, making it impossible to expose a large area. Area C was therefore limited to two 4 m^2 blocks separated by a 1 m baulk, as shown in the plan (Figure 3.37). Furthermore, because of the continual danger of sidewall collapse (which indeed occurred several times), excavation and pumping had to proceed rapidly. Although these were less than ideal conditions, we managed to excavate all eight units down to 1.25 m below surface, at which depth in situ reef detritus was exposed.

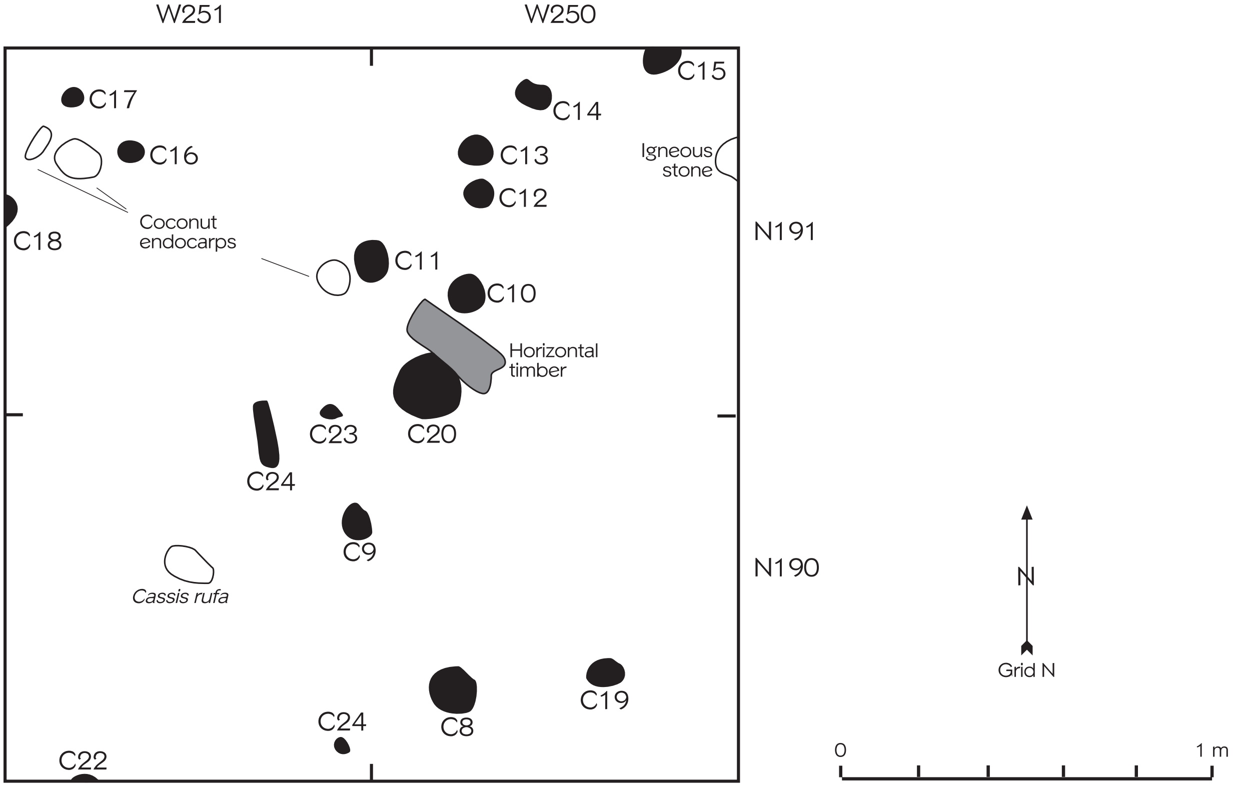
Area C Stratigraphy. In Area C the stratigraphy was similar to that described for Unit W250N200 (see above), with a dark brown A horizon formed under the heavy forest cover, overlying light gray to white calcareous sands. Between 20 and 60 cm below surface the sands were weakly cemented, but became loose and unconsolidated once the Ghyben-Herzberg aquifer was reached. The excavation of W250N190 revealed that the deposits between the surface and about 60 cm below surface were essentially culturally sterile. Therefore, in the expansion units comprising Area C, these upper sands were removed by shoveling and were only cursorily sieved to ensure that no cultural materials were missed. Below 60 cm excavation proceeded according to normal procedures.

As there were no visible lithological, textural, or color distinctions in the calcareous sandy deposit, excavation was conducted by arbitrary levels. During excavation it appeared that the levels between about 60–80 cm below surface yielded a high density of obsidian flakes (many of large size), along with incised and notched-rim pottery and shell midden. From 80–100 cm the density of cultural materials decreased notably. Then from 100–120 cm there was another concentration of cultural materials including incised and notched rim pottery (along with a few classic dentate-stamped Lapita sherds), along with large midden shells clustered around the bases of the many wooden posts and stakes. This lower zone also included a high density of anaerobically preserved plant materials. For analytical purposes, we have divided the excavation levels into four zones, as follows: Zone A, the sterile upper sands to 60 cm; Zone B, from 60–80 cm; Zone C, from 80–100 cm; and Zone D, from 100–125 cm (Table 3.3).

Wooden Posts. Twenty posts or stakes were exposed in the eight excavation units comprising Area C. Although no alignment or patterning could be detected in the limited area exposed, several of the posts are quite large, with diameters of 15–20 cm. These undoubtedly were structural timbers designed to support some kind of pole house. Two of these posts were radiocarbon dated with a difference in age of 250 years. It is possible that the posts exposed in the Area C blocks may not have all been cut and set in position at the same time. Given that the vertical distribution of cultural materials observed during excavation suggested two phases of deposition, it may be that the posts also represent two phases of stilt-house construction.

Cultural Content. The vertical distribution of cultural materials in analytical zones B, C, and D reveals significant differences. Basal zone D is marked by a high frequency of anaerobically preserved plant remains (886 itemized specimens, not including *Cocos nucifera* endocarp, and wood fragments), and by high densities of both vertebrate and invertebrate faunal materials. Zone B shows the highest densities of ceramics (more than twice the total in Zones C and D combined), obsidian flakes, and coral oven stones. These differences suggest that the activities occurring on the stilt-house structures in the vicinity of Area C may have changed over time. The earlier phase is marked largely by midden dumping, whereas the later phase is represented by a broader range of artifacts indicative of pottery use, shell artifact manufacture, lithic use, and cooking (oven stones).

The ceramic assemblage from Area C (all zones) is fairly uniform, marked by a high percentage of thin-walled sherds, deriving primarily from large jars with constricted orifices and everted rims. The rim lips are usually decorated with fine tool notching or finger-pinching (crenate), and red slip is common, especially on the upper parts of the vessels. Fine incised decorations also dominate. Despite the overall consistency of the assemblage, there are some differences between zones which appear to be significant. For example, whereas jars predominate throughout the



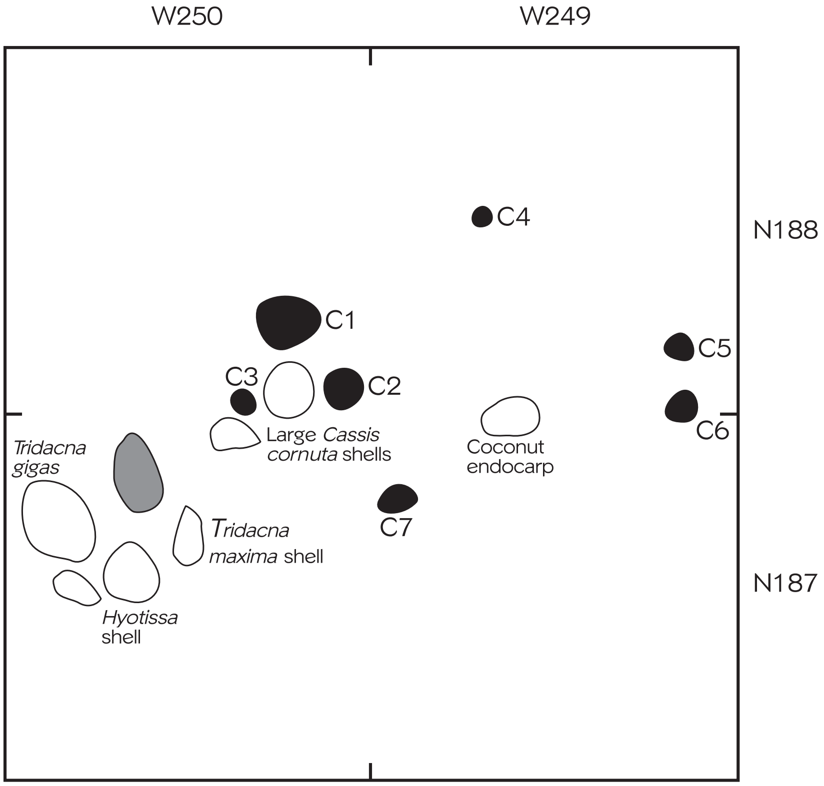


Figure 3.37. Plan of the 1988 Area C excavations, showing the positions of wooden posts and stakes, and other features.

Table 3.3. Summary of cultural content of Area C, Site ECA (by analytic zones)

Class	B	C	D	Total
Ceramics				
Plain Body Sherds	522	209	202	933
Decorated Body Sherds	7	24	15	46
Plain Rim Sherds	5		3	8
Decorated Rim Sherds	35	13	12	60
Non-Ceramic Artifacts				
Obsidian Flakes	127	41	38	206
Abraders	2			2
Fishhooks	1	1		2
Fishhook Preform	1			2
Coral Oven Stones	80	6	13	99
Manuport/Volcanic Stone	1	1	1	3

Area C sequence, there are a few bowls represented in the deeper zones C and D. The only two sherds with dentate stamping from Area C were both recovered in Zone C; both were water-rolled and eroded, in sharp contrast with the non-eroded incised and notched-rim sherds from the same zone. This suggests that the dentate sherds, which had been subjected to water action, had been deposited on the reef platform prior to the deposition of the incised pottery. While the Area C pottery is almost exclusively decorated with incised designs, it is noteworthy that the *motifs* displayed with the incised technique are in many cases the same as those on the dentate-stamped pottery from other parts of the site. Two examples of shell-impressed decoration are also represented in Area C, both from the upper Zone B context.

The Area C pottery assemblage exhibits close similarities with that from Site EKQ on the northeastern part of Mussau Island. Both assemblages represent a late phase in the local evolution of Lapita ceramics, marked by a reduction in the range of vessel forms (almost exclusively confined to large, thin-walled jars), and by the restriction of decorative technique to incising.

Sedimentology of the Talepakemalai Site

The discovery in 1985 that the ECA site encompassed both paleobeach terrace and lagoonal depositional environments necessitated a detailed investigation of the site's dynamic geomorphological history. In part, this history could be reconstructed through field observation of paleo-shoreline indicators as well as the stratigraphy of units excavated along the W200 and W250 transects. Additional data were obtained from laboratory analysis of sediment samples collected from key stratigraphic layers. These samples, when compared with modern control samples taken from active lagoon and seaward beaches, provided information on the mode of deposition at the ECA site. Thirty-one archaeological sediment samples and 16 modern beach and reef/lagoon flat control samples were analyzed by Melinda S. Allen in the University of Washington geoarchaeology laboratory.

Field and Laboratory Methods

Field sampling of archaeological sediments followed methods outlined by Stein (1985, 1987), with samples taken from discrete depositional layers (i.e., not crossing stratigraphic boundaries). Samples were collected into sterile polyethylene bags after the stratigraphic section of particular excavation units had been drawn; sample locations were indicated by depth and notated on the stratigraphic drawings.

Modern Control Samples. Four sets of modern control samples were collected, all from Eloaua Island. (1) In 1985 we obtained general samples (GS-1 to -3) from the foot of a seaward beach, and two from the top and foot of a lagoon beach, respectively. (2) In 1986, we collected four samples along a measured transect across the seaward reef flat in front of the Talubagalim School, located due west of the ECA site and fronting the Malle Channel. These samples (designated RT-1 to -4) were obtained from the seaward beach slope (RT-1), the "muck zone" containing organic materials 15 m from the beach (RT-2), the "seagrass zone" 50 m from the beach (RT-3), and the outer zone marked by the presence of dead branch coral, 80 m from the beach (RT-4). (3) In 1988, we took four samples along the slope of the seaward beach in front of Ave Male's hamlet, with the elevation of samples above the reef flat determined by Lietz telescopic level. The positions of these samples (designated SB-1 to -4), and the topographic profile of this seaward beach, are shown in Figure 3.38A. (5) Also in 1988, we took five samples along the modern Eloaua lagoon beach on the west side of the island near site ECA. As with the previous sample set, these lagoon beach samples (designated LB-1 to -5) were precisely plotted along a topographic transect, as depicted in Figure 3.38B. These control samples, from a seaward beach, seaward reef flat, and lagoon beach, provide comparative data for the interpretation of the archaeological sediment samples.

Analytical Methods. Sediment color was described using the Munsell system (both moist and dry). Hydrogen ion content (pH), which indicates relative acidity or alkalinity, was determined using an automatic Altex 70 pH meter, following the procedures of Jackson (1958). Pretreatment to remove organic matter, prior to grain-size analysis, followed the method of Jackson (1958), with the substitution of sodium hydrochlorite for hydrogen peroxide.

Following pretreatment, samples were oven dried at 100° C. A solution of sodium hexametaphosphate (a dispersing agent) and distilled water was added to the dried sediment; flasks were mechanically shaken for 5 minutes, then allowed to sit overnight to insure that flocculation was not a problem. Samples were wet-screened using a 4ϕ geologic sieve to separate the sand fraction from the silt and clay fractions. The sand fractions were oven dried and mechanically shaken for 15 minutes through nested geologic sieves with mesh sizes of -2, -1, 0, 1, 2, 3, and 4ϕ. The resulting sand fractions were weighed on an analytic balance to the nearest thousandth of a gram.

The silt-clay fraction was placed in 1,000-ml cylinders and sufficient sodium hexametaphosphate solution was added to fill the cylinders. The pipette method of Shackley (1975) was used to determine grain size for this finer fraction. The time-consuming pipette method was used only for the 1985 and 1986 samples. The 1988 samples were analyzed only by mechanical sieving.

Statistical analysis of grain-size data was performed using a computer program developed by the University of Washington geoarchaeology laboratory, which calculated and plotted frequency and cumulative percentage plots by ϕ size, as well as providing summary textural designations, sample kurtosis, and sorting characteristics (based on Folk 1974).

Analysis of Modern Control Samples

Analytic data on the four sets of modern control samples are available in Table S3.1 (in Supplementary Materials available online), while frequency and cumulative plots of grain-size distributions for these samples are shown in Figure 3.39.

General Sediment Samples. The three 1985 control samples are similar in many characteristics (e.g., white color, alkaline pH averaging 8.4), and in textural terms can be described as gravelly or slightly gravelly sands, with moderate to very poor sorting. The coarsest sample is that from the foot of the lagoon beach, which was very poorly sorted and had the highest percentage of gravel (12.03%).

Eloaua Reef Flat Transect Samples. The seaward reef flat transect samples collected in 1986 consist of a series extending from the seaward beach out across the reef flat, a distance of 80 m. These samples show much more variation than in the general sediment samples from 1985. For example, sample RT-2 from the modern "muck zone" is characterized by relatively higher quantities of silt and clay, and is a gravelly muddy sand (the organic content is also reflected in its light gray color). Sample RT-3, from the seagrass zone, lacks any gravel-sized component, and

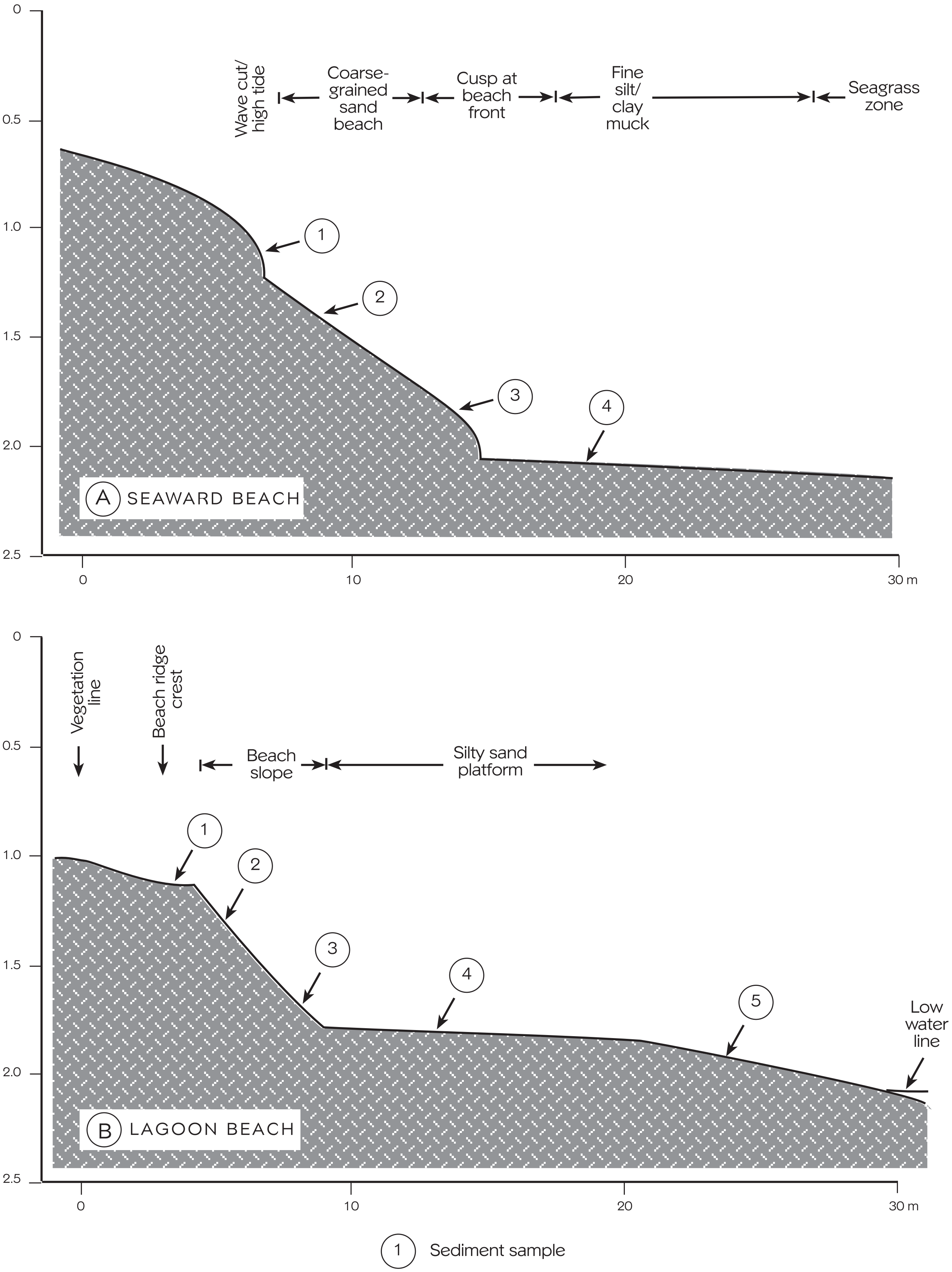


Figure 3.38. Topographic profiles of modern Eloaua Island beaches, showing the locations of control sediment samples: *a*, seaward beach and location of samples SB-1 to -4; *b*, lagoon beach and location of samples LB-1 to -15.

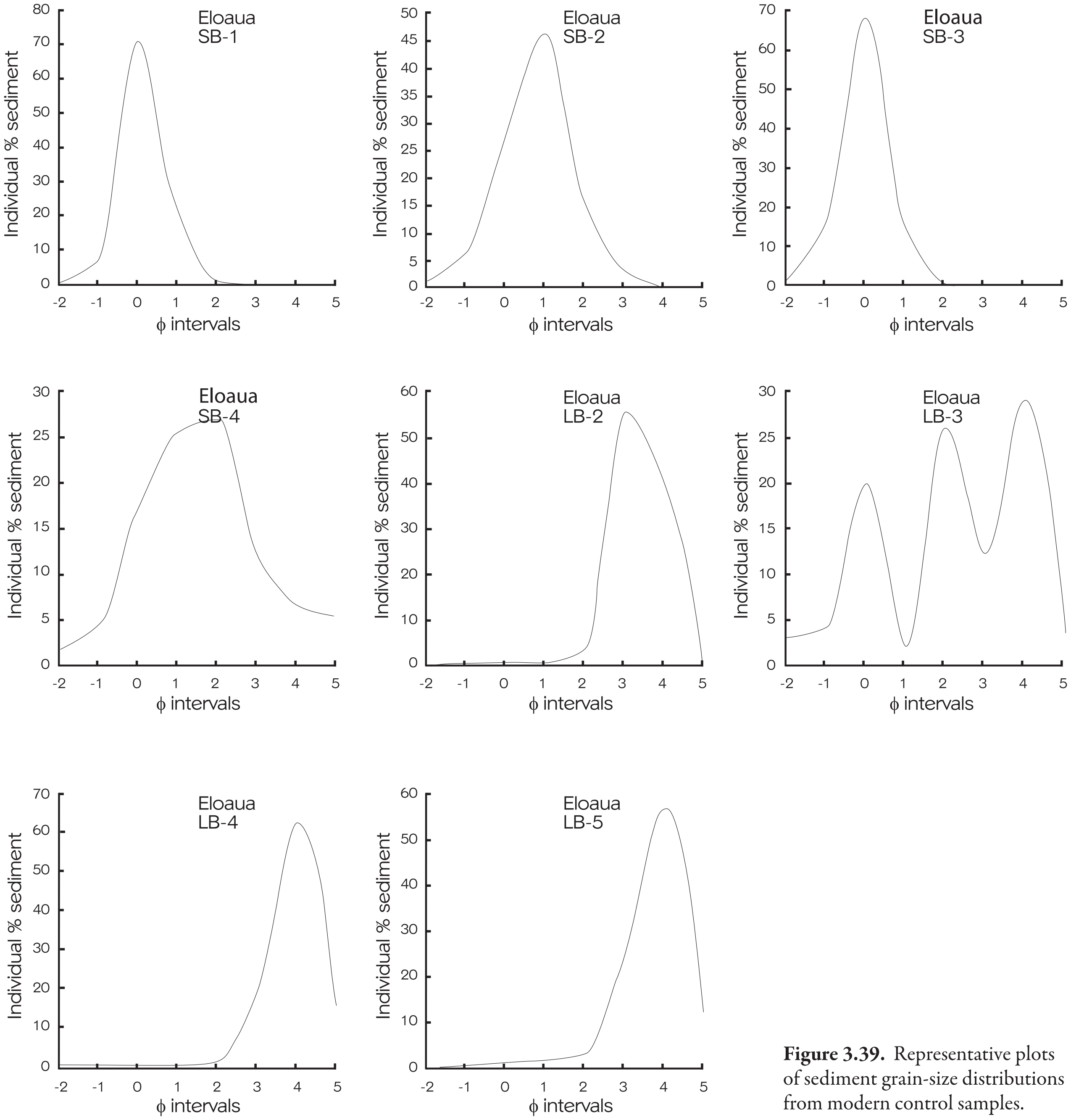


Figure 3.39. Representative plots of sediment grain-size distributions from modern control samples.

is largely made up of silt and clay. Sample RT-4, from the zone of dead coral near the active reef margin, has the highest gravel component (25.12%) of any sample, although it also has significant quantities of silt and clay; not surprisingly, then, it is very poorly sorted.

Seaward Beach Samples. The 1988 seaward beach samples provide data on the variation across an active seaward beach front. Texturally, all four samples are gravelly sands. The greatest variation is between the sediment at the foot of the beach, which contains the highest percentage of gravel (16.46%) and very little silt-clay, and the sediment from the sandy flat fronting the beach, which has the lowest amount of gravel (5.69%) and the most silt-clay (5.51%).

Lagoon Beach Samples. The five 1988 lagoon beach and adjacent sand flat series provides data on variation across an active lagoon shore. This series differs from the seaward beach series in the overall lower quantity of gravel, and higher quantity of fine particles. Only the sample from the foot of the lagoon beach (LB-3) is characterized as a gravelly sand, while those samples (LB-1 and -2) from the higher beach slopes are slightly gravelly sands. In contrast, the samples from the lagoon flat fronting the beach are slightly gravelly muddy sands, with extremely little gravel and reasonably high quantities of silt-clay (11.76 and 15.13%).

In sum, there are sufficient differences among the modern control samples to be able to distinguish between the depositional environments of seaward and lagoon beaches and their adjacent sandy flats. Seaward beach sediments are characterized by greater amounts of larger clastics (especially in the sand and gravel size ranges) than lagoon beach sediments, reflecting the higher energy levels associated with wave action along the seaward coastlines. Also characteristic are the sediments of the seagrass flats with their very high silt-clay fractions, and those of the dead coral outer reef flat zone with the highest percentages of gravel (and very poor sorting overall). The analyses of our Eloaua control samples presented above also fit well with the range of variation in sediment sizes described for other atoll systems, such as that of Ifaluk described by Tracey and others (1961; see also Wiens 1962). They provide a set of modern analogs that may be used to interpret the archaeological samples from site ECA.

Analysis of Archaeological Sediments

Archaeological sediment samples from site ECA were taken both along the W200 transect line (sampled in 1985 and 1986), and along the W250 transect line (sampled in 1988). In interpreting these samples, it must be noted that both the W200 and W250 transects are oriented approximately north–south, perpendicular to the orientation of the slope up to the paleobeach ridge (1.75–2.35 m above sea level), which is interpreted as the shoreline at the time that the ECA site was first occupied. Thus, as one progresses from south to north along either transect, one moves from the paleobeach ridge down across the former shoreline feature, and out onto what was formerly a sandy flat. At the same time, there is a time-transgressive facies within each vertical excavation unit, which will reflect the dynamic changes occurring over time at each micro-locality.

The W200 Transect Series. Analytic data for 13 samples collected along the W200 transect are available in Table S3.2 (in Supplementary Materials available online), and selected frequency and cumulative distribution plots are provided in Figure 3.40. In Table S3.2, the samples are arranged by excavation unit and by stratum, proceeding from S to N along the W200 transect.

The first three samples are from Unit W200N100, which was excavated into the crest of the paleobeach terrace (elevation 2.01 m above sea level). Here the deeper Layer II sediment, with 16.49% gravel but very little silt or clay (and hence a gravelly sand), is a good match with a modern seaward beach sediment (such as control sample SB-3), consistent with our interpretation of this deposit as the active beach zone at the time of deposition. The upper deposits in W200N100, especially Layer IA, have a much greater percentage of fine particles, reflecting the later development of an organic soil on top of the paleobeach ridge (note also the dark color and lower pH). Layer IA is the modern garden soil cultivated by the Eloaua villagers for sweet potatoes and manioc.

The next set of samples comes from Layer II of Unit W200N110 (TP19), at 50 cm below surface (upper) and 90 cm below surface (lower). This excavation unit is situated near the foreslope of the former paleobeach terrace. Here the sediments are again quite coarse, reflecting a fairly active zone of beach deposition. The lower sample, in particular, is characterized by a high percentage of gravel (46.30%), higher than that in any of the modern control samples (note that it does not have as much silt-clay, however, as in the modern "dead coral" zone sample, RT-4). This may reflect shoreline conditions during the mid-Holocene higher sea-level stand, when the reef flat fronting the ECA site would have been exposed to a slightly higher water level and greater wave energy at high tide than is the case at present.

Another set of four samples, taken from the face of Unit W200N147, is representative of the sequence of sediments within Area B. Layer I, a gravelly muddy sand, is the organic, reworked garden soil which caps the area today (note the very dark gray color). Layer II, a gravelly muddy

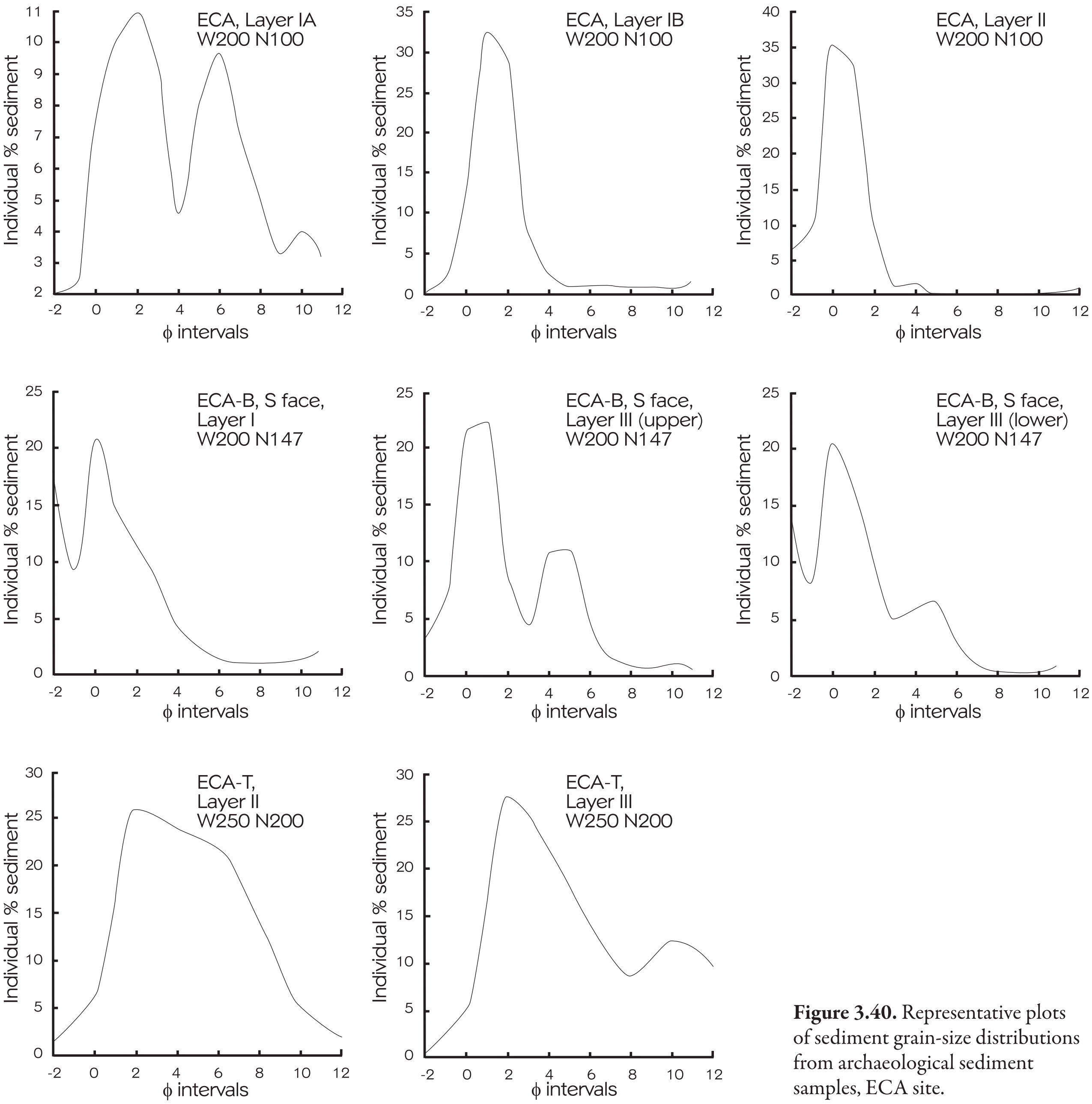


Figure 3.40. Representative plots of sediment grain-size distributions from archaeological sediment samples, ECA site.

sand but with fewer gravel-sized particles and a lighter gray color, shows a grain-size distribution characteristic of an active beach zone (similar to control sample GS-2). The two samples from Layer III (the waterlogged zone of Area B) are both gravelly muddy sands that are very poorly sorted, with a considerable range in particle sizes from gravels through silt-clays. The Layer IIIA sample is a good match with control sample RT-2, from the modern "muck zone" in front of Eloaua village, while the IIIB sample is a relatively close fit with RT-4, the "dead coral" zone. These samples support our interpretation that the Area B stilt house was originally constructed over an open reef flat (marked by the presence of much dead *Acropora* branch coral). Over time there was a facies change as the "muck zone" migrated seaward, probably in consort with a gradual seaward (south-to-north) progression of the active beach front. Thus the samples from W200N147 show a local micro-facies progression over time from (1) open reef flat, to (2) a "muck zone" characterized by a higher percentage of fine particles (incorporating organics and anaerobically preserved plant remains), to (3) an actively prograding beach slope, and finally to (4) an organically enriched soil developing on the old beach terrace.

The final set of three samples comes from W200N170, some 20 m north of the Area B excavations. Here again the transition from Layer III to Layer II is best interpreted as a shift over time from a more exposed, open reef flat (Layer III) to a prograding beach deposit (Layer II), and eventually to the formation of an organically enriched soil deposit (Layer I), correlating with the gradual south-to-north progradation of the shoreline through this locality.

The W250 Transect Series. Analytic data for 17 samples collected along the W250 transect are available in Table S3.3 (in Supplementary Materials available online), and selected frequency and cumulative distribution plots are provided in Figure 3.40. In Table S3.3, the samples are arranged by excavation unit and by stratum, proceeding from south to north along the W250 transect.

Unit W250N80 is situated on the paleobeach terrace, S of the slope representing the former shoreline. Layer II, a structureless sand deposit, displays sediment characteristics that compare favorably with a lagoon beach sediment (such as control sample GS-2). Some 30 m to the north, Unit W250N110 is immediately north of the former shoreline feature. The deepest stratum, Layer IV (ca. 120–170 cm below surface), was described in the field as a "fine silt-clay with anaerobically preserved plant remains and upright [in situ] posts." It is not surprising that the sediment sample from Layer IV is a gravelly muddy sand with characteristics not unlike the modern "muck zone" control sample (RT-2). Layer III (100–120 cm) is similar, with a slightly lower frequency of gravel-sized particles. Layer II (25–100 cm), however, displays a different set of sediment characteristics, being a gravelly sand with a much lower frequency of silt-clay. Thus in the W250N110 unit there is a facies change over time from a typical "muck zone" that would have fronted the original foreshore when this was perhaps 20–30 m to the south, to a beach foreshore at a later point in time. This is in keeping with our geomorphological interpretation of a south-to-north progradation of the shoreline along the axis of the W250 transect.

A similar time transgressive change is evident in the samples from Unit W250N130. The deeper Layer IX sample (150–180 cm below surface) represents a slightly gravelly muddy sand with considerable silt-clay content, whereas the higher Layer III sample (35 cm bs) shows a change to a gravelly sand with very little silt and a higher gravel content, typical of a beach slope (compare control samples SB-3 and LB-3). Thus again, there was a temporal shift from reef flat to beach foreshore.

In Unit W250N140, the two analyzed samples show a temporal progression from a gravelly muddy sand in Layer IV (110–150 cm below surface) to a slightly gravelly muddy sand with much higher silt-clay content in the overlying Layer III (60–110 cm). This is then overlain by Layer II, described in the field as a "structureless massive deposit of coarse-grained calcareous sand." The W250N140 temporal progression reflects the gradual "migration" of the "muck zone" along a south-to-north course, with Layer III representing this zone when it was concentrated in the vicinity of this unit, and Layer II representing the beach foreshore that eventually replaced and covered it over.

Moving farther to the north along the transect, we took four samples from Unit W250N150, which even more clearly than in W250N140 shows the temporal migration of the "muck zone" along a south-to-north track, as reflected in the micro-facies of this unit. The deepest deposit exposed in excavation, Layer IV (100–120 cm below surface), was described in the field as a coarse-grained sand "containing numerous water-rolled *Acropora* branch coral fingers," and having *Quidnipagus* and Veneridae bivalves in death position. This description is matched by the sediment texture with a high percentage (19.35%) of gravel, indeed the highest percentage of gravel from any sediment sample taken along the W250 transect. The closest analog here is the "dead coral" zone from the seaward reef transect (control sample RT-4). Both our field description and the analytical data strongly suggest that Layer IV represents the original reef flat. Layer IIIC (60–100 cm below surface), which was subsequently deposited over the Layer IV reef flat, has a significantly reduced gravel component (only 3.25%) and increased silt-clay content. In the field we noted that this stratum contained anaerobically preserved plant remains, and thus represents the onset of the "muck zone" as it moved gradually from S to N. Layer IIIA (40–60 cm) is an even more poorly sorted sediment, with a greater range of gravels to silt-clays. This is capped by Layer II (20–40 cm), which, while also very poorly sorted, shows a shift toward more gravel and less silt-clay fraction.

With Unit W250N170 one is now about 60 m north of the original position of the shoreline associated with the mid-Holocene higher sea-level stand. Here we sampled the two deepest strata, which again show the progression of the muck zone over the underlying reef flat. Layer IV (90–150 cm below surface), a very poorly sorted, gravelly muddy sand, represents the original reef flat in this locality. Layer III (75–90 cm), which is quite thin in this unit and contained anaerobically preserved wood, coconuts, and other plant remains, shows a very high silt-clay content (31.22%) and very little gravel. It is most similar to the seagrass zone of the seaward reef transect (control sample RT-3) and may indeed have been a patch of reef flat dominated by seagrasses. This was later covered by a thick deposit of structureless coarse-grained sand (Layer II, not analyzed), representing the final stage of beach progradation.

The final three samples from the W250 transect are from Area C and from a unit 10 m north of Area C. These are all either gravelly muddy sands or gravelly sands, with characteristics similar to the modern sand flat samples, especially that from the seaward beach transect (sample SB-4). This suggests that the Area C vicinity was a sandy, tidally exposed flat at the time of stilt-house occupation, an interpretation consistent with our field observations.

Sea-Level Change and Depositional History at Talepakemalai

The discovery of preserved wooden post bases and other organic materials in a waterlogged depositional context at Area B of the ECA site was the first indication that Lapita settlements in the Bismarck Archipelago had incorporated stilt or pole-structure architecture constructed over shallow reef environments. Subsequently, other sites such as Apalo (FOJ) in the Arawe Islands, the Kreslo site (FNT) off New Britain, and the reef flat pottery sites on Buka and in the New Georgia group of the Solomon Islands confirm that this was a widespread Lapita settlement pattern in Near Oceania (Felgate 2001; Gosden and Webb 1994; Specht 1991; Summerhayes and Scales 2005; Wickler 1995; see also Kirch 1997:162–188). Understanding the depositional history of such sites requires a geomorphologically informed research and excavation strategy, along with a consideration of evidence for local changes in relative sea level and sediment budgets. The transect excavation strategy utilized at ECA has permitted a reconstruction of the micro-geomorphology and depositional sequence for the period from the mid-second millennium BC until about two thousand years ago. Initial attempts to interpret the site in terms of a model of relative sea level stability were contradicted by the field evidence, such as the relative elevation levels of the paleobeach terraces in relation to modern sea level, and evidence for wave cut notches, demonstrating that the progradation of the coastal terrace on Eloaua Island could only be explained by a drop in sea level. This view was reinforced by a spate of studies during the late 1980s indicative of a mid- to late-Holocene higher sea level in the southwestern Pacific.

A rapid rise in sea levels following the end of the Pleistocene is a global phenomenon that has been widely recognized for some time (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) modeled some of the global diversity in these Holocene curves, and suggested that a +1–2 m stand existed in the South Pacific during this period. Substantial geomorphic and radiometric evidence from a variety of islands supports this interpretation of a +1–2 m high sea level during the period between about 4,000 and 2,000 years BP. In Fiji, 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." This conclusion is supported by work by Miyata and others (1990), and similar results are presented by Ash (1987) for Viti Levu island. On Mangaia in the southern Cook Islands, Yonekura and others (1988) report evidence for a +1.7 m stand between 3,400 and 2,900 years BP. 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 6,000 to 5,500 years BP and lasting as late as 1,200 years BP, an interpretation confirmed by more recent research by Hallmann and others (2018). In Western Samoa, Rodda (1988) summarizes various evidence for Holocene higher stands, while Isla (1989:361–363) reviews a comparable range of evidence for several Pacific islands. In developing a morphodynamic model for landscape change and coastal terrace formation at the To'aga site on Ofu Island, American Samoa, Kirch (1993) synthesized these and other data relating to this Holocene high-stand. The radiocarbon chronology for To'aga suggests that the drop in sea level from the mid-Holocene high-stand down to the modern level occurred sometime around 2000 BP. Continuing geomorphological research has provided additional evidence to support such an interpretation for a mid-Holocene higher sea level stand throughout much of the southwest Pacific (Allen 1998; Dickinson 1998a, 1999, 2001, 2014; Dickinson and Green 1998; Dickinson et al. 1994, 1998; Fujimoto et al. 1996).

While we have not directly dated this higher sea level during the mid-Holocene in Mussau, the presence of wave-cut notches along the exposed limestone cliffs of Eloaua, Boliu, and other islands of the group corresponds well with a +1–2 m higher stand. In 1988, we measured several wave-cut notch profiles, discussed and illustrated in Chapter 2. All of these are indicative of a higher sea level of about +1–1.5 m. Gosden and Webb (1994) similarly discuss coastal cliff profiles in the Arawe Islands off New Britain, which have an older solution or wave-cut notch about 1 m above the present high-water mark. While we could find no means to directly date these notches in Mussau, they can be no older than Holocene in age, given coastal erosion rates.

In sum, a widespread and consistent pattern of radiometrically dated shoreline features provides evidence for a higher sea level ranging about +1–2 m over the southwestern Pacific, from at least 5,000 years BP, and lasting until sometime between 2,000 and 1,000 years BP. This is matched by the evidence of wave-cut notches along the Mussau islands. After about 2,000 years BP sea level fell (perhaps fairly rapidly) to its present position. This mid- to late-Holocene sea level curve thus provides an important dimension for a model of coastal terrace formation at Talepakemalai.

Progradation, resulting in the formation of a coastal terrace such as that at ECA, can be defined as the "progressive formation of new land by sedimentation irrespective of the tendency of sea level movement" (Chappell 1982:71). Sea level changes, 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, minus the loss of sediment from transport. In the case of Talepakemalai, there is no significant source of terrestrial sediment. Rather, the terrace has been formed wholly from calcareous sands and larger clastics of biogenic reef origin (coral heads and shingles, shell fragments, branch coral fingers, etc.). The rapid progradation of the Eloaua coastal flat during the first millennium BC, resulting in the burial of the stilt-house occupation deposits, requires a *mechanism* for a substantial increase in marine biogenic sediment load. This mechanism lies in the rapid drop in sea level, which exposed the outer reef edge and reef platform to wave erosion, generating an increased quantity of calcareous sediment.

The occupation sequence and depositional history of the ECA site, in relation to the controlling geomorphic mechanisms of relative sea level change and increased sediment budget, can be summarized as follows (also depicted diagrammatically in Figure 3.41). The age ranges for each stage are based on Bayesian modeling of the extensive radiocarbon dates from site ECA, discussed fully in Chapter 5.

Stage 1, 3,300–3,200 Years BP

At the time of initial settlement at Talepakemalai, the active beach ridge ranged from 0.70 to 1.35 m higher than the modern beach ridge, and was situated in the vicinity of Units N80-N100 between the W200 and W250 transects. This paleobeach terrace reflected the then higher sea level stand of about +1 m. Construction and occupation of stilt-structures over the sub-tidal, sandy reef flat, which began at about N110 and continued northward, resulted in the deposition of a dense accumulation of shell midden, ceramics, oven stones, and other cultural materials underneath

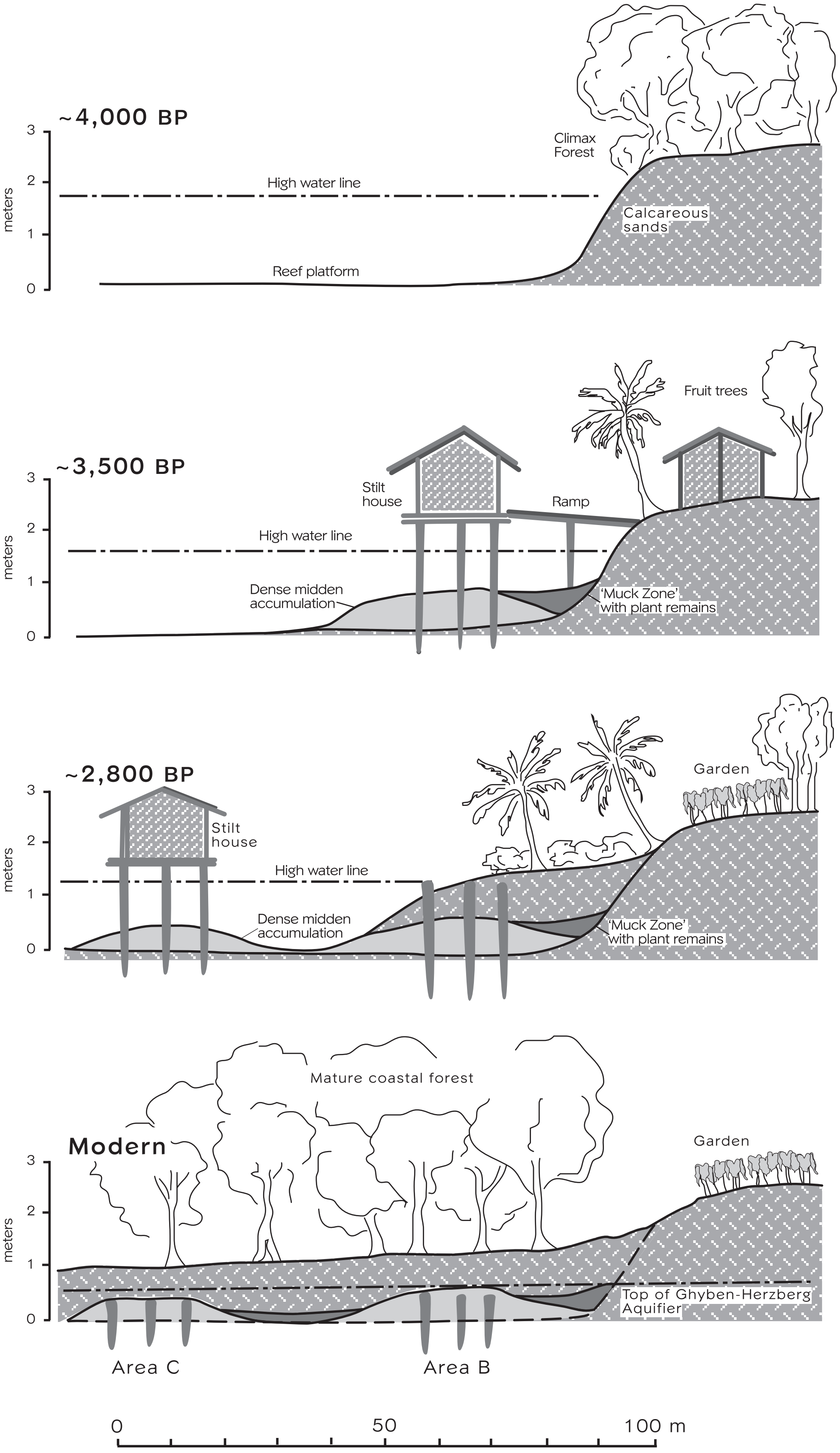


Figure 3.41. A diagrammatic representation of the probable stages of geomorphological evolution of the Talepakemalai site, from about 4000 to about 2800 BP.

and surrounding these structures. A zone of fine-grained sediments was also deposited in the low-energy sub-tidal environment between the stilt houses and the beach, trapping organic remains such as wood, coconut, and seeds. Interestingly, a modern analog for this kind of low energy sub-tidal depositional environment, which traps organic materials such as discarded coconut half shells, is provided by the seaward foreshore fronting the modern Eloaua Village (Figure 3.42). On the paleobeach terrace itself, cultural activities resulted in the incorporation of plainware sherds, midden, and other materials into the loose calcareous sands (exemplified by the Area A excavations).

Stage 2, 3,200–2,900 Years BP

By this date, which represents the later occupation phase at Talepakemalai as marked culturally by the dominance of incised ceramics, coastal progradation had commenced and the beach had migrated northward to cover the remains of the original zone of stilt houses. A new zone of stilt-house structures now stood between about N160 to N190, with a similar pattern of midden and ceramic deposition beneath the structures. A thin "muck zone" organic deposit again accumulated between the beach and the stilt structures. Cultural activities along the now-prograded beach resulted in the deposition of incised ceramics into the beach sands over the now buried earlier (Area B) occupation zone (as reflected in the vertical distribution of cultural materials in the Area B sequence).

Stage 3, Post-2,900 Years BP

Around 2800 to 2700 BP, the stilt houses at Talepakemalai seem to have been abandoned altogether, as progradation increased in tempo, and the sand spit connecting the formerly separated north and south parts of Eloaua Island became joined. As progradation proceeded, the deposits on the former reef flat that had been sub-tidally deposited were flooded by the Ghyben-Herzberg aquifer, thus preserving them in a waterlogged, anaerobic condition. This low-lying, newly prograded terrain was colonized by coastal vegetation such as *Pandanus*, *Pisonia*, *Calophyllum*, and other trees. Disturbance of the buried cultural deposits was limited to the burrowing actions of land crabs, which, fortunately, did not penetrate into the Ghyben-Herzberg aquifer. The organically enriched cultural deposits situated on the older, higher beach terrace (in the vicinity of the modern airfield), however, were cultivated in a pattern of relatively short fallow shifting cultivation. This repeated gardening resulted in extensive disturbance and mixing of the occupation materials situated on the higher, original beach terrace.

Figure 3.42. View of the seaward foreshore fronting Eloaua Village, at low tide, with the fine-grained "muck zone" sediments exposed (part of Emussau Is. visible in the distance). The vertical posts are the remains of an abandoned stilt-house dwelling. Note the presence of numerous coconut half shells (endocarps), wooden timbers, and other organic remains lying on and in the fine-grained sediments at the foot of the gentle beach slope. A similar depositional environment presumably characterized the ECA site at the time of its Lapita occupation.

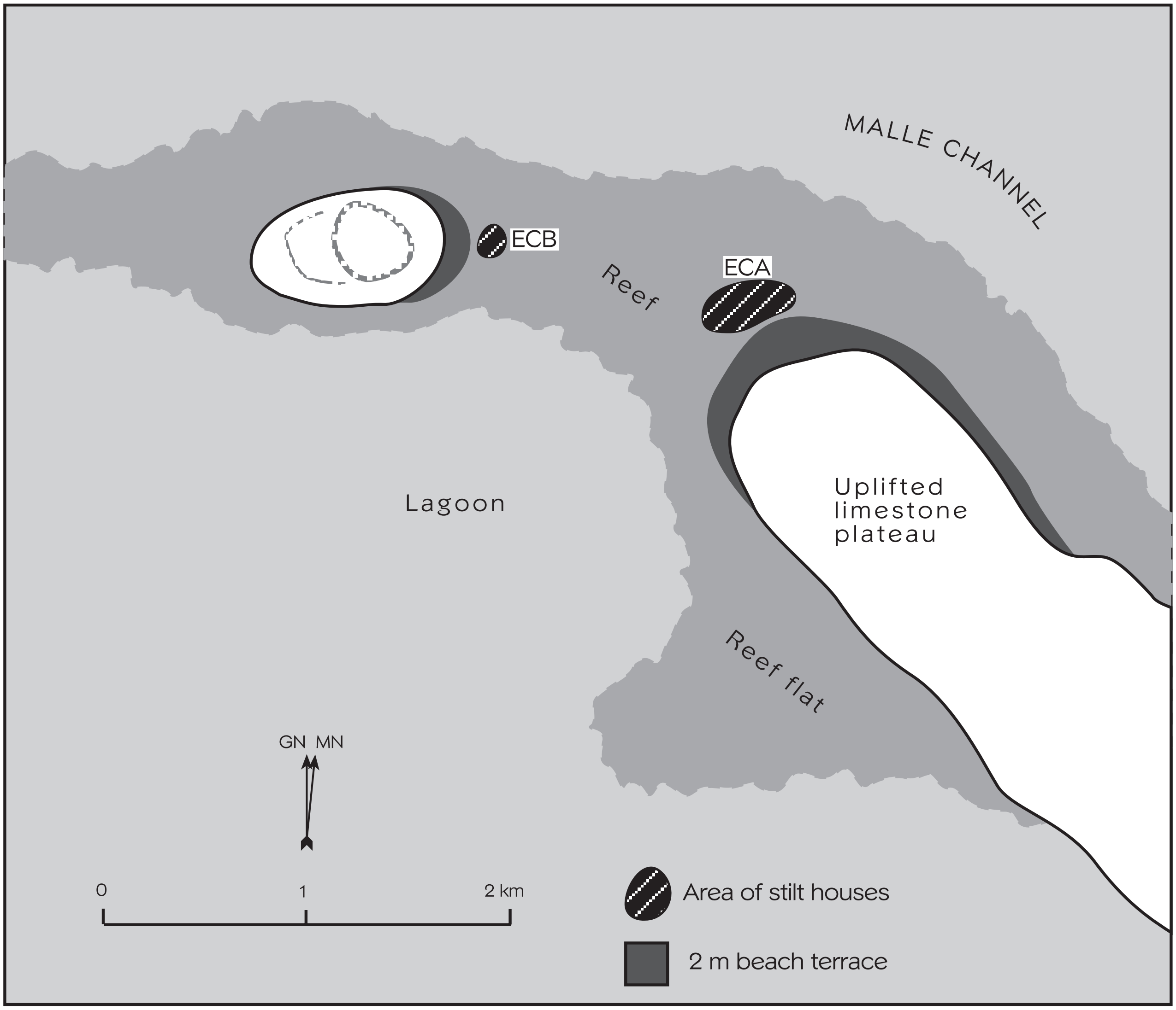


Figure 3.43. Suggested configuration of the NW part of Eloaua Island during the period of Lapita occupation at Talepakemalai (ca. 3500–2800 BP). Note that at this time there were two separate islands, with an area of shallow reef flat separating them. The Talepakemalai and Etakosarai (ECB) sites would have been intervisible across this reef flat.

In addition to portraying the depositional sequence at Talepakemalai along a series of diagrammatic transects, as in Figure 3.41, we can suggest what a map of the original coastal topography of this part of Eloaua Island would have looked like at approximately 3,300 to 3,100 years BP. As seen in Figure 3.43, Eloaua was divided into two separate islands, with a broad, sub-tidal sandy reef flat lying between. The northern end of the main Eloaua Island was occupied by the Talepakemalai Lapita settlement, while across the channel on the southern shore of the smaller island was another Lapita settlement, represented by the Etakosarai (ECB) site (see Chapter 4).

CHAPTER 4

Excavations at Other Lapita and Post-Lapita Sites of Mussau

Patrick Vinton Kirch, Marshall I. Weisler, and Nick Araho

Although our efforts throughout the three field seasons in Mussau were directed primarily toward the excavation of Talepakemalai (ECA), we also investigated twelve other sites, either with systematic transect excavations or more limited test pits (see Table 1.1). The ECB site on Eloaua, and the EKE site on Boliu, both containing Lapita ceramics, were excavated fairly extensively; less extensive sampling was carried out at the EHB Lapita site on Emananus. Several rockshelters on Eloaua and on the main island of Mussau were tested, with site EKQ in particular containing a deep sequence with late Lapita (primarily incised) ceramics. We also tested several late, post-Lapita midden sites on Eloaua (EHK), Emussau (EKS), and Mussau (EKU) islands. Although we fell short of our goal of obtaining an unbroken cultural sequence linking Lapita to the ethnographic contact period, these excavations nonetheless provide significant information on the later time periods of Mussau prehistory.

This chapter provides an overview of these excavations, as context for the analyses of faunal materials, ceramics, and non-ceramic artifacts presented in subsequent chapters. More extensive details on these sites, including additional plans and stratigraphic sections, may be found in Kirch, ed. (2001). Figure 4.1 is a map of the southern portion of the Mussau Islands, showing the locations of the sites described in this chapter.

The Etakosarai Site (ECB)

The ECB site was reported by Egloff (1975:15), who excavated two 1 x 2 m test pits there in May, 1974. Egloff's report on the site was minimal:

> The excavations at ECB indicate that the deposits are quite shallow, having a depth in most places of no greater than 15 to 25 cm. What deposits there are at ECB appear to be restricted to an irregular midden approximately 20 metres in diametre. Also, the sherds recovered at the site are quite battered due to the shallow and exposed nature of the deposit [1975:15].

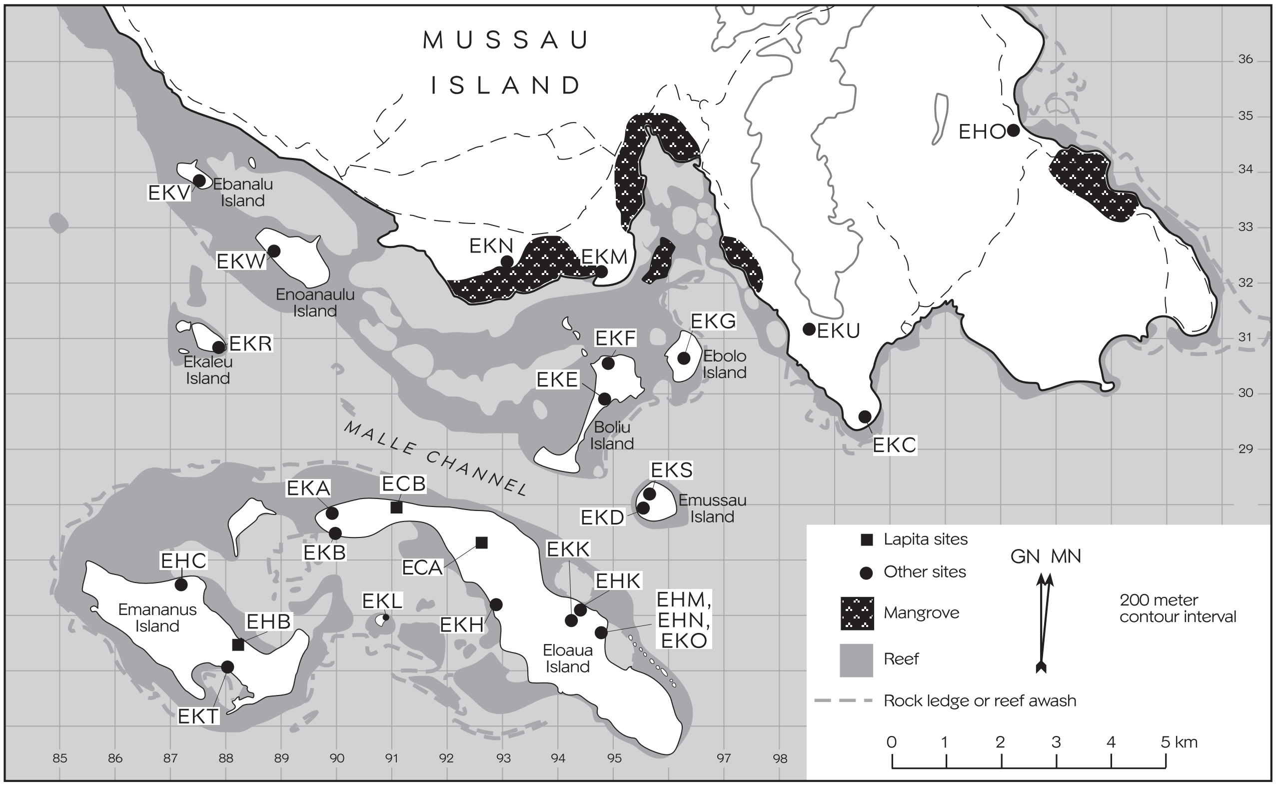


Figure 4.1. Map of the southern part of Mussau Island and the offshore islets, showing the locations of archaeological sites.

Egloff's two test pits yielded a total of 359 potsherds plus 24 "special" sherds, 0.7 g of bone, and 40.7 g of obsidian (Egloff 1975:Table 7). He combined the ceramics from ECA and ECB in his analysis, noting no evident differences between the two assemblages, describing both as falling "well within the accepted range for the Lapita style" as then known from the Watom and Ambitle Island sites (1975:25).

In 1985 Kirch relocated the ECB site with Ave Male's assistance, determining that it was substantially larger than the 20 m diameter mound described by Egloff. Although the deposits did appear to be relatively shallow and disturbed by gardening, additional test excavations were warranted, in order to better understand the site's stratigraphy, determine its extent and size, obtain materials for radiocarbon dating, and increase the sample of cultural materials. During the 1985 season Kirch excavated six 1 m^2 units along a single transect bisecting the site. In 1986, Kirch assigned Terry Hunt the task of extending the excavations at ECB. Hunt dug an additional 13 units, bringing the total sample size up to 19 m^2. The following account combines the results of the 1985 and 1986 seasons at ECB.

ECB Site Setting

Site ECB is situated in the western part of Eloaua Island, at a place known as Etakosarai ("place of red soil"), just west of a trail that crosses the island at its narrowest point. In 1985 the traditional landowner was Aimalo Lavatea of Lomakanauru, whose family had made gardens there for many years The site's surface, which had been planted in manioc, was littered with large midden shells, obsidian flakes, and sherds (including many bearing both dentate-stamped and incised decorations) that had been brought to the surface by digging with dibble sticks. The gardened area was about 50 x 60 m in extent (Figure 4.2). The surrounding vegetation consisted of second growth with *Pandanus*, *Casuarina*, *Morinda*, *Macaranga*, and some immature *Calophyllum*. One of Egloff's 1974 test excavations had not been backfilled, allowing us to determine the location of at least one of his units.

The site occupies gently sloping terrain that rises from the cross-island trail for an elevation gain of about 1 m. The trail itself is situated on low-lying sandy ground, and Kirch suspected that the slope on which the site lies was probably a mid-Holocene paleobeach terrace. To the west of the site this terrace adjoins an uplifted block of elevated limestone that rises to an elevation of 51 m above sea level. At the time that ECB was occupied, the low-lying marshy terrain lying between ECB and ECA (about 1 km to the east) most likely was an open reef or sand flat, certainly awash at high tide if not continually under water. Thus the ECB and ECA sites faced each other across this reef or sand flat, with Eloaua comprising two separate islands at that time. With sea level fall to the modern level (probably around 2000 BP) this flat accumulated a deposit of calcareous sand between 0.5 and l m above sea level, supporting a typical halophytic vegetation association of *Pandanus*, *Terminalia*, *Calophyllum*, *Barringtonia*, and other taxa.

A contour map and plan of the excavated units at ECB is provided in Figure 4.3. We estimated that the area containing cultural materials covers about 3,000 m^2.

The 1985 Transect Excavations

From August 25–27, 1985, six 1 m^2 tests were excavated along a single east–west oriented transect running from the low-lying terrain east of the area of surface sherd scatter and up across the sloping garden. The transect units were not equally spaced, because we had to work around the active manioc plantings, but from east to west the units spanned a total distance of 90 m. Our excavations demonstrated that cultural materials were concentrated on the higher ground west of the trail, with almost nothing recovered in the test unit at E40N0, which was positioned on the low-lying terrain that we inferred to be the old reef flat.

The 1986 Excavations

In 1986 we reestablished the 1985 east–west transect line, so that additional test units could be positioned on the same grid. As seen in the site plan (Figure 4.3), these were spaced at regular 10 m intervals running north and south of the baseline, to form a grid of units that we anticipated would allow for an assessment of spatial patterns of artifact and midden distribution over the site.

Despite minor variations from unit to unit, including the overall depth of cultural deposit, the stratigraphy was more or less consistent over the entire area excavated. A representative profile, of Unit E1S21, is illustrated in Figure

Figure 4.2. View of the Etakosarai site (ECB) during the 1986 excavations.

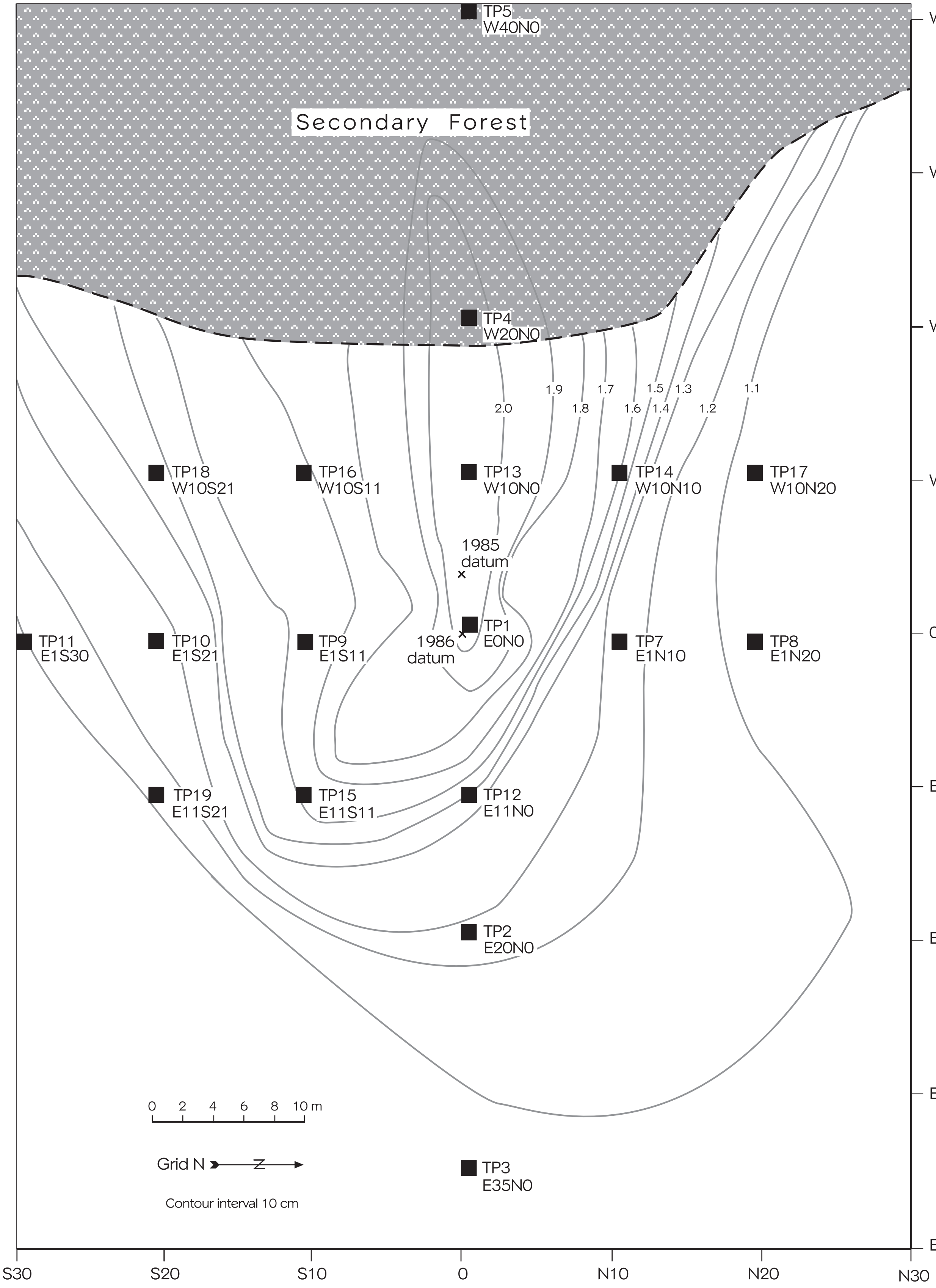


Figure 4.3. Plan of the Etakosarai site (ECB), showing the location of units excavated during the 1985 and 1986 field seasons.

4.4. The four main layers distinguished in this and other units are as follows:

> Layer I: Typically 10–15 cm thick. Dark brown (7.5 YR 4/2) sandy loam, A horizon, much reworked by gardening. Numerous rootlets and scattered charcoal from garden burning. Sherds in this deposit are typically small and heavily worn or eroded. The boundary with Layer II is diffuse.
>
> Layer II: Ranges from 5–15 cm thick. Reddish-yellow (7.5 YR 6/6) sandy loam, fine grained. Considerable shell midden. The boundary with Layer III is fairly sharply marked.
>
> Layer III: Thickness varies considerably over the site, but is typically from 30–60 cm thick in the central part of the tested area. The sediment is light gray (10 YR 7/2), medium-grained sand, and contains abundant shell midden. This deposit is frequently heavily cemented with $CaCO_3$ concretions, apparently due to repeated wetting and drying from the fluctuating water table. In several units it was necessary to use an iron crowbar to break up the concretions.
>
> Layer IV: This is the basal, culturally sterile deposit, consisting of white (10 YR 8/1), coarse-grained calcareous sand with some waterworn shells and coral rubble. Toward the E end of the transect, this deposit also included numerous Tellinidae shells with both valves intact, indicating a sub-tidal depositional environment.

Layer IV represents the paleobeach terrace deposit that accumulated during the mid-Holocene higher sea level stand, and was the original surface on which the Lapita occupation at ECB was established. Layer III seems to be a largely intact cultural deposit that accumulated on this beach slope, while Layer II is best interpreted as a post-occupation accumulation of beach sand, which was probably under a stable vegetation cover for some time. This was subsequently disturbed and reworked by gardening, creating the Layer I/II distinction.

No features of any kind (such as earth ovens or pits) were encountered during our excavations, leading us to conclude that the Lapita occupation at ECB probably consisted of stilt houses situated on a sloping beach fronting the sandy reef flat to the east. The Layer III deposit thus accumulated as detritus dropped or discarded from these houses. Unlike the situation at ECA, no wooden posts or other non-carbonized plant materials have survived at ECB, because the deposits lie above the Ghyben-Herzberg aquifer and are therefore not anaerobic.

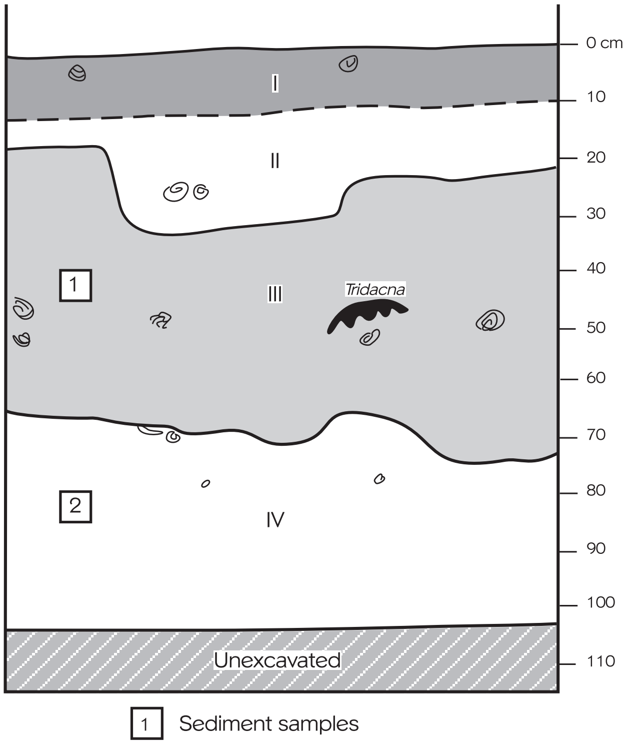


Figure 4.4. Stratigraphic profile of the north face of Unit E1S21 at the ECB site.

Sediment Analysis

Four sediment samples were collected during the 1985 test excavations at ECB, three samples from test unit 1 (Layers IA, IB, and II), and one sample from test unit 2 (Layer II). Samples were analyzed using the same methods described in Chapter 3 for sedimentology of the ECA site. The samples from test unit 1, located near the paleobeach ridge, display a temporal progression from a very poorly sorted, slightly gravelly muddy sand (mean $\phi = 1.77 \pm 2.59$), white (10YR 8/2) in color represented by Layer II, to a very poorly sorted, gravelly muddy sand (mean $\phi = 1.64 \pm 3.15$), yellowish brown (10YR 5/4) in color. This is capped by the organically enriched gardened soil covering the site today, Layer I, texturally also a gravelly muddy sand (mean $\phi = 4.24 \pm 4.51$) that is extremely poorly sorted and incorporates much more silt-clay than the underlying sands; this deposit is also much darker in color (10YR 3/2, very dark grayish brown). Layer I has a pH of 7.74, whereas the underlying sand deposits have pH levels of 8.09 and 8.14 respectively. The Layer II deposit in test unit 2, situated at the foot of the former paleobeach ridge and therefore representing a tidally exposed sand flat at the time of deposition, is characterized as a very poorly sorted, gravelly muddy sand (mean $\phi = 2.10 \pm 3.42$), white in color (10YR 8/2), with a pH of 8.03. This sample, with a relatively high percentage of silt and clay fractions, compares well with the sand flat modern control samples (e.g., sample LB-4, see Chapter 3). In sum, the sedimentological analysis of samples from ECB is consistent with our field geomorphological interpretations.

Cultural Content of Site ECB

The ECB excavations yielded a sizable cultural assemblage, including both dentate-stamped and incised decorated potsherds. Non-ceramic artifacts include several abraders, a number of scrapers/peelers, three shell fishhooks and several *Trochus*-shell hook preforms, 16 *Conus*-shell rings, and a number of other items. We recovered 244 manuports at ECB, with an average density of 12.8/m^2, almost exactly the same density as at Area B of ECA (12.7/m^2). The faunal assemblage is dominated by fish and turtle bones, with a few bird bones, one Odontocete bone, and three pig bones. Radiocarbon dates on both charcoal and shell from site ECB are reported in Chapter 5, where they are calibrated with Bayesian modeling.

The Etapakengaroasa Site (EHB)

The EHB site, on Emananus Island, was first reported by Allen and others (1984:9–10), who were taken there by "a local resident [Saupa] who produced a classically decorated, large Lapita rim sherd, which he had found in the hole left by a fallen tree." They reported the locality name as Karasa. In 1985 we were told the name was Erauwa, but we were later informed that the correct toponym is Etapakengaroasa. Allen and others (1984:10) found a second Lapita sherd as well as some sherds with incised decoration, and obsidian; they speculated that excavations might "clarify the relationship of the incised and dentate stamped Lapita pottery." Kirch conducted test excavations at EHB in 1985, and further transect units were excavated by Terry Hunt in 1986.

EHB Site Setting

Etapakengaroasa is situated on the northeast side of Emananus Island, on the lagoon shore, a short distance east of a small hamlet occupied in 1985 by Pastor Ororea and his family (UTM coordinates 788300E 9825500S). Geomorphologically, the site consists of a narrow (55 m wide) paleobeach terrace that lies at the base of a steep slope rising up the island's upraised limestone plateau. This terrace, which has a slightly higher berm (1.35 m above sea level) on its seaward edge, presumably formed during the mid-Holocene higher sea-level stand. Today the lagoon shore in front of the terrace consists of a mangrove swamp, but this is unlikely to have existed at the time the site was occupied. An elevation profile across the site (Figure 4.5) shows the structure of the beach terrace and berm in relation to the mangrove swamp.

The terrace was in old second growth and coconut, but had been repeatedly gardened in the past; a new garden had been cleared in 1985 about 75 m east of our test pits. In addition to gardening disturbance, land crabs (*Cardisoma* sp.) have extensively bioturbated the site's deposits. Crab burrows were everywhere across the site; the ground surface was littered with fire-cracked volcanic oven stones, shell midden, sherds, and obsidian flakes which had been brought to the surface by the crabs. Based on the surface distribution of cultural materials, Kirch estimated that the EHB site covers approximately 1,150 m^2.

Excavations and Stratigraphy

Although the extensive crab burrowing did not bode well for undisturbed stratigraphy, Kirch decided to test EHB during the 1985 season in order to obtain a sample of pottery and other cultural materials for comparison with those from ECA. Two test pits were excavated on September 1–2. Two radiocarbon dates obtained from these 1985 tests indicated that the Lapita occupation at EHB was relatively early, which was confirmed by an analysis of the ceramics, which are marked by a high frequency of very fine dentate stamping. Kirch decided

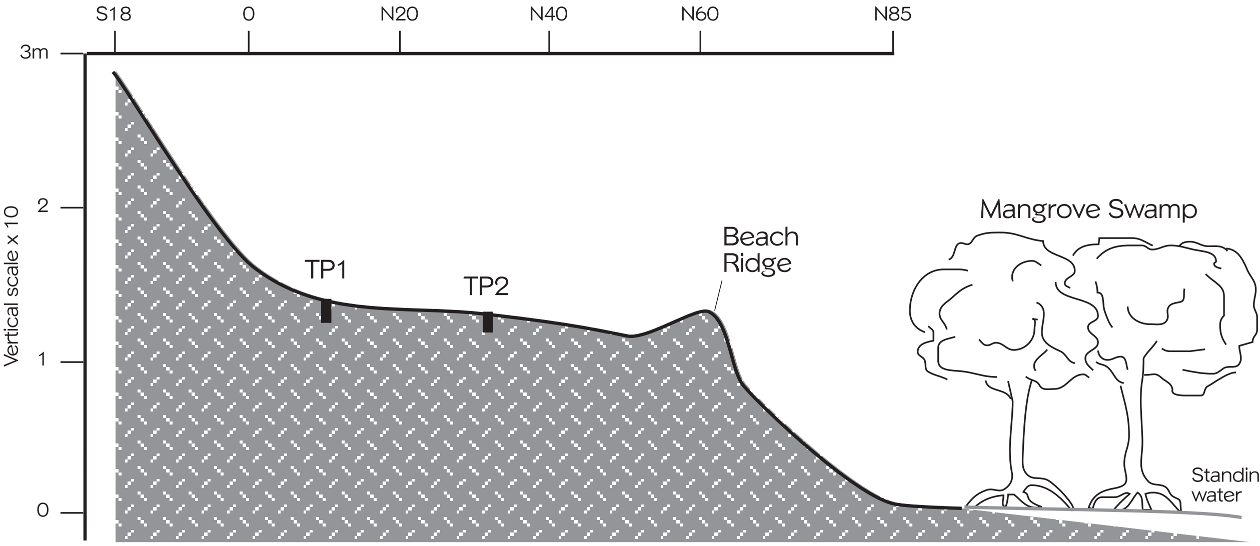


Figure 4.5. Elevation profile across the EHB site, as measured by telescopic leveling in 1985.

that additional excavations should be undertaken in 1986, primarily to expand our sample size of the ceramic assemblage and associated cultural materials. Hunt excavated seven more 1 m^2 units between October 28 and November 4, 1986, bringing the total excavated area to 9 m^2, a roughly 0.8% sample of the total area with surface cultural material.

1985 Test Excavations

We first cleared a transect through the second growth covering the site, running from the mangroves across the beach terrace to the slope of the limestone escarpment, a total distance of 85 m. An elevation profile was taken along the transect with a Lietz level and stadia rod (Figure 4.5). Two test units were gridded out, 20 m apart, along this transect line. Unit 1, about 50 m inland of the terrace berm, was excavated to a depth of 95 cm below surface, when the water table was reached and the mucky sediment could no longer be screened. The entire depth of deposit here, which consisted of a dark grayish brown sand loam (10 YR 4/2), had been disturbed by land crab burrows. Unit 2, closer to the berm, was excavated to 65 cm below surface with great difficulty, due to considerable calcium carbonate cementation of the calcareous sand below 20 cm. We were able to break through this cemented deposit only by using a 2 m long iron crowbar. At 65 cm the cemented sand became coarse-grained and was mixed with coral rubble (*Acropora* branch coral fingers), and showed signs of recrystallization, probably due to continual wetting by the fluctuating Ghyben-Herzberg aquifer. Even with the crowbar, this deposit was virtually impossible to excavate; the unit was terminated at 70 cm below surface.

1986 Transect Excavations

In late October 1986, Hunt set up a datum on the coastal trail that runs along the terrace berm, gridding out seven test units along two intersecting transects. Hunt's north–south transect (which ran along the crest of the berm) had four units spaced at 20 m intervals, while his east–west transect (which intersected the north–south transect at Unit 0N20W) had three units spaced at 10 m intervals. Hunt's site map only showed the excavation units, and no other features of topography, nor did it precisely link his transects to Kirch's 1985 test pits. However, Hunt's notes indicate that Unit 0N20W was positioned 6.10 m south of Kirch's Unit 2.

Hunt reported the stratigraphy as being more or less uniform over the entire 40 by 60 m area covered by his two transects. Representative profiles of the 0N10W and 0N20W transect units are shown in Figure 4.6. Three layers were defined:

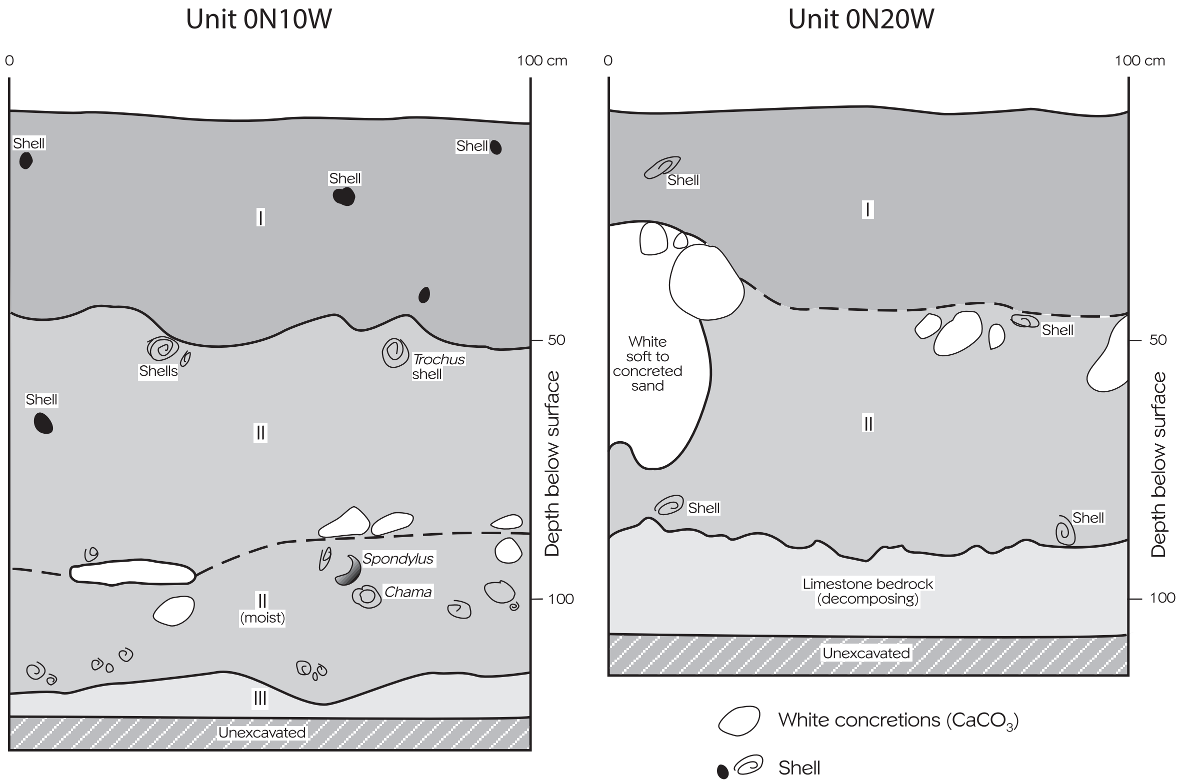


Figure 4.6. Stratigraphic sections of Units 0N10W and 0N20W at the EHB site.

Layer I: 0–25/40 cm below surface. A dark grayish brown sandy loam (10 YR 3/2), organically enriched with abundant rootlets. This layer has been extensively reworked due to gardening activity. The contact with Layer II is diffuse and varies in depth.

Layer II: 25/40–100/125 cm. A gray to dark grayish brown (10 YR 5/1 to 10 YR 4/2) calcareous sand, with frequent $CaCO_3$ concretions in the upper part of the layer, in some cases covering almost the entire unit. The concretions decrease with depth, and the lower part of the Layer II deposit is within the zone of tidal fluctuation of the water table, and thus continually moist. Most of the cultural material was derived from Layer II. This layer is also extensively penetrated by crab burrows.

Layer III: 100/125+ cm. A coarse- to medium-grained white (10 YR 8/1) to light gray (10 YR 7/1) sand, not cemented and continually wet. Mixed with the sand are *Acropora* branch coral fingers, waterworn coral pebbles, and numerous *Quidnipagus* and small *Tellina* bivalves in death position (both valves intact), indicating that Layer III was deposited subtidally.

This relatively simple stratigraphy suggests that the Lapita occupation began over a tidal lagoon flat just offshore from the upraised limestone slope of Emananus Island. Presumably, the settlement consisted of stilt houses as at ECA although no preserved posts were found at EHB. Potsherds, shell midden, and other cultural debris accumulating under and around the houses gradually formed the Layer II deposit, trapping fine lagoon sands that form the matrix of this sediment. Layer I developed through the post-depositional reworking of the Layer II midden deposit by gardening.

Because there is no meaningful internal stratification within Layer II, and also because of the extensive land crab disturbance which has led to considerable mixing, we have treated the cultural deposit at EHB as a single assemblage. We did, nonetheless, check for any significant trends in ceramic change by depth, with a negative result.

Cultural Content of Site EHB

The two seasons of excavations at EHB yielded 7,552 ceramic sherds (of which 523 were diagnostic sherds), 783 non-ceramic objects, and 553 vertebrate faunal specimens. The pottery includes a significant quantity of sherds with fine dentate stamping, as well as pedestal feet, both traits indicative of the earlier part of the Mussau ceramic sequence (see Chapter 11). The majority of non-ceramic artifacts comprise flakes and cores (395 specimens), and manuports (336 specimens). Radiocarbon dates on marine shell from EHB are reported in Chapter 5.

The Boliu Site (EKE)

On September 18, 1985 while returning by boat from a trip to Palakau, Kirch landed on Boliu Island and discovered two archaeological sites (EKE and EKF). The EKF site, situated on the island's northern perimeter behind a small mangrove swamp, did not appear promising for excavation, being heavily bioturbated by land crabs. The extensive EKE site situated on the narrow neck of low-lying land in the island's center, however, presented an attractive prospect for excavations. A series of large, undulating shell midden mounds (up to 1.5 m high) suggested relatively deep cultural deposits. On the surface of these mounds Kirch found several *Terebra*-shell adzes, a *Trochus*-shell armband fragment, some obsidian flakes, and two small potsherds of a dark reddish color with a dark mineral temper. Shell midden littered the surface, with large *Anadara*, *Tridacna*, *Strombus*, and *Trochus* shells being especially common.

The landowner, Joseph Kuiavua, whose house stood near the site, was willing to allow excavations. However, it was not until the 1988 season that the Boliu site was finally investigated. As discussed in Chapter 1, one major objective for this final season was the excavation of a site with potential to elucidate the post-Lapita occupation period in Mussau. Our initial choice was a large shell midden on Ekaleu Island (site EKR), but we could not obtain permission to work there. The EKE site on Boliu seemed an equally good choice; Jason Tyler was assigned the task of directing this excavation. Tyler worked at EKE from October 16 until November 24, 1988. Kirch was present during the initial period of site mapping and opening up of the first transect units, following the progress of Tyler's excavations until he left Mussau on October 29. Tyler was also assisted by Nick Araho of the PNG National Museum during the first two weeks of excavations at EKE. Tyler did not prepare a report on his excavations, and the following account was prepared from his field notes.

EKE Site Setting

Boliu Island, one of the smaller offshore islands with a surface area of about 1 km^2, lies between Eloaua and Mussau islands. Extensive reefs and seagrass beds surround Boliu; there is a large lagoon basin to the west, making it an excellent base for fishing and shellfish gathering. The island is shaped like a barbell (Figure 4.7), with blocks of upraised reef limestone at the southwest and northeast ends, connected by a low-lying spit of unconsolidated calcareous sands (on which EKE is situated). The southwestern limestone block has a maximum elevation of 20 m, while the northeastern block rises to 26 m above sea level. Both of these elevated blocks have steep escarpments and relatively level plateau, the latter with a thin soil veneer intensively cultivated for taro, yams, and manioc. A single large *Syzigium* fruit tree stands sentinel on top of the northeast block; a low-density midden scatter was observed near it, which was also test excavated (see below). The northern coastline is rimmed with a small mangrove swamp, with the EKF site lying between these mangroves and the limestone escarpment.

Sea cliffs surround most of the southwestern uplifted block. A typical incised notch marking the mid-Holocene +1.5 m sea level stand is visible there; a cross section of this was measured and is illustrated in Chapter 2 (see Figure 2.16). This high-stand played a significant role in the island's recent geomorphological history, for the low-lying sandy spit that connects the two uplifted limestone blocks would have been tidally awash at the time of Lapita occupation. The fall in relative sea level to its modern stand resulted in deposition of the calcareous sands and silts that make up the spit, accreting simultaneously from the southwest and northeast, eventually joining the two separate islets together.

The EKE site covers most of the low-lying sand spit between the two uplifted blocks, as shown in Figure 4.7. Tyler made a surface topographic map of much of this area, with a contour interval of 10 cm (Figure 4.8). As can be seen from the map, walking eastward from the island's western

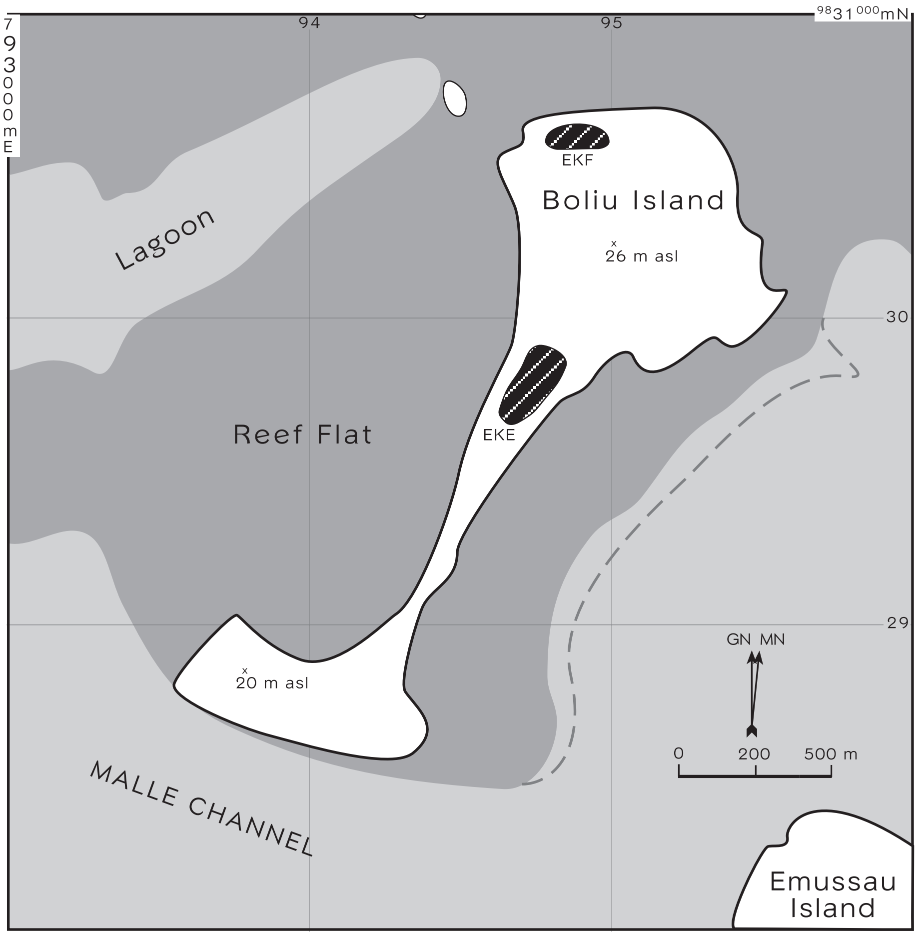


Figure 4.7. Map of Boliu Island, showing the location of sites EKE and EKF.

shoreline following the N250 transect line, one first crosses a low sandy flat (ca. 0.2–0.4 m above sea level) covered in typical strand vegetation (*Messerschimidia*, *Scaevola*, *Pandanus*, *Casuarina*), about 40 m wide. There is an abrupt rise in elevation from about 0.4 to 1.2 m above sea level. On top of this rise the ground surface changes from loose sand to a grayish-black loam, rich in charcoal and other organic materials and littered with large numbers of gastropods and bivalves, many showing typical breakage patterns due to meat extraction. It is evident that one is now standing on a deposit that is at least partly anthropogenic, made up in large measure of shell midden and other cultural materials. During our initial reconnaissance, we found several *Terebra*-shell adzes, obsidian flakes, and other artifacts in this area. Although much of this elevated ridge is nearly level, there are also three or four discrete mounds that rise above the surrounding terrain; these can be clearly discerned on the topographic map, with grid centers at roughly E115N375, E160N335, E150N285, and E200N175. These mounds appeared to have been culturally deposited, probably as midden dumps, a hypothesis confirmed by our excavations in two of them. Continuing along the N250 line, at about 130 m from the starting point on the island's west coast, one reaches another major topographic break, a drop from 1.2 m back down to about 0.4 m above sea level, and another sandy flat largely devoid of surface cultural materials. This low-lying sandy flat continues until one reaches the island's eastern shoreline another 120 m distant.

Excavation of Site EKE

Reconnaissance survey showed that EKE was both extensive (with an area of about 2 ha) and likely to be complexly stratified. Areal excavations were not within the scope of our project; Kirch judged that the best approach would be to apply the transect testing method used at site ECA. A potential drawback might be the difficulty of precisely

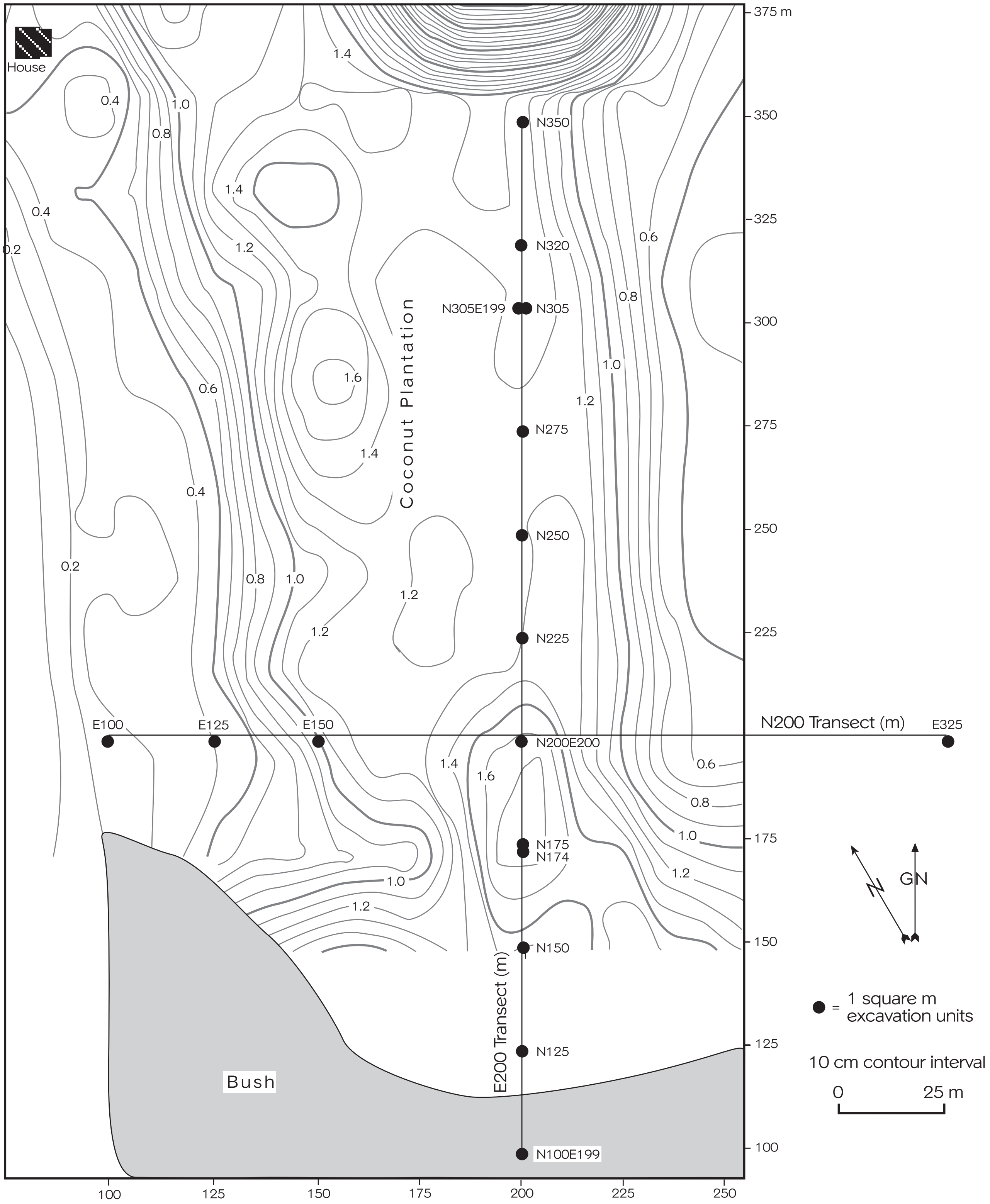


Figure 4.8. Plan of the EKE site showing the main N–S and E–W transects, location of test excavation units, and other features.

correlating stratigraphic zones from unit to unit (especially as we had a spacing interval of 25 m between units), but sampling more of the total site area was judged to be more important than concentrating on one or two smaller sample areas.

After clearing the low brush growing under coconut, *Inocarpus*, *Syzigium*, and other large trees a grid was laid out, oriented so that it was aligned with the main axis of the sandy spit that makes up the central part of Boliu Island (Figure 4.8). Surface elevations were taken with a Lietz level at 10 m intervals, using the high tide line on the island's west coast as a datum. We chose the E200 line as the primary transect for initial excavations, as this ran north–south down the center of the 1.2 m high "midden flat" that made up the site, and also bisected the highest of the discrete mound features, with a high point of 1.7 m above sea level in the vicinity of E200N175. A second, east–west cross-cutting transect was chosen along the N200 line. Elevation profiles along these two transect lines are shown in Figure 4.9.

Test units (each 1 m^2) were excavated at 25 m intervals along the E200 transect from N350 to N100, as shown in Figure 4.8. In two locations (at N305 and N174-175) a second unit was opened up adjacent to the original transect unit, to create a 1 x 2 m excavation block, in order to increase the sample size of cultural materials and to clarify aspects of stratigraphy. Along the N200 (east–west) transect line, we excavated three units between E100 and E150, and a fourth unit at E325. After these transect units were completed, an additional 1 m^2 test was excavated at E117N372, in the top of another evident shell midden mound situated east of Joseph Kuiavua's house, an area where *Terebra*-shell adzes had been found on the surface. Finally, another test pit was dug on top of the elevated limestone plateau north of the site, where a small midden deposit was observed in the vicinity of a large *Syzigium* fruit tree. In all, a total of 19 m^2 was excavated at the EKE site.

The E200 Transect

The stratigraphy and cultural content of the EKE site is best described by proceeding along the E200 transect from south to north, as the deposits can be grouped into roughly four horizontal zones.

The southern part of the transect covers the area from N100 to N150 along the E200 grid line, at the base of the island's southwestern limestone escarpment. In the vicinity of E199N100, limestone outcropping was visible on the surface, and the total depth of soil was only 30–40 cm, when cemented reef limestone was exposed in the base of the excavation. Shell midden was sparse; the only artifact recovered was a *Trochus*-shell ring fragment. Twenty-five m to the north, the concentration of shell midden began to increase, with a few worn sherds and some obsidian; the depth of deposit increased to 65 cm below surface. In the E200N150 test, a significant concentration of calcareous-sand tempered, reddish plainware sherds appeared at about 60 cm, continuing until near the base of the excavation at 140 cm. These ceramics did not include any decorated sherds, and most of the material is calcareous sand tempered, with some red slip, in most respects similar to the Lapita plainware assemblage from Area A at site ECA.

Unit E200N175 was situated atop the largest of the shell midden mounds with a surface elevation of about 1.7 m above sea level, some 30 cm higher than the surface elevation at E200N150. This excavation, which penetrated to a total depth of 200 cm below surface, yielded a more complex sequence than the three units to the south. In order to obtain a larger sample and clarify the stratigraphic sequence, Unit N174E200 was opened up adjacent to the first test. This revealed that the deposits containing calcareous-sand tempered Lapita plainware—which had been exposed in E200N150 to the south—continued beneath the high shell midden mound, which had later capped them with about 120 cm of post-Lapita shell midden deposition. Thus two separate occupation phases were present at the E200N174-175 locale.

Stratigraphy. The stratigraphic profile of the west face of Unit E200N175 is shown in Figure 4.10, and a view of the completed excavation in Figure 4.11. The main depositional units were as follows:

> Layer IA. 0–70 cm below surface. Very dark brown (10YR2/2) loam with much shell midden, with a "greasy" texture due to the high concentration of fine charcoal and organic materials. Within this layer, at about 20 cm below surface, was a thick bed of concentrated, large shells, probably a single dumping event.

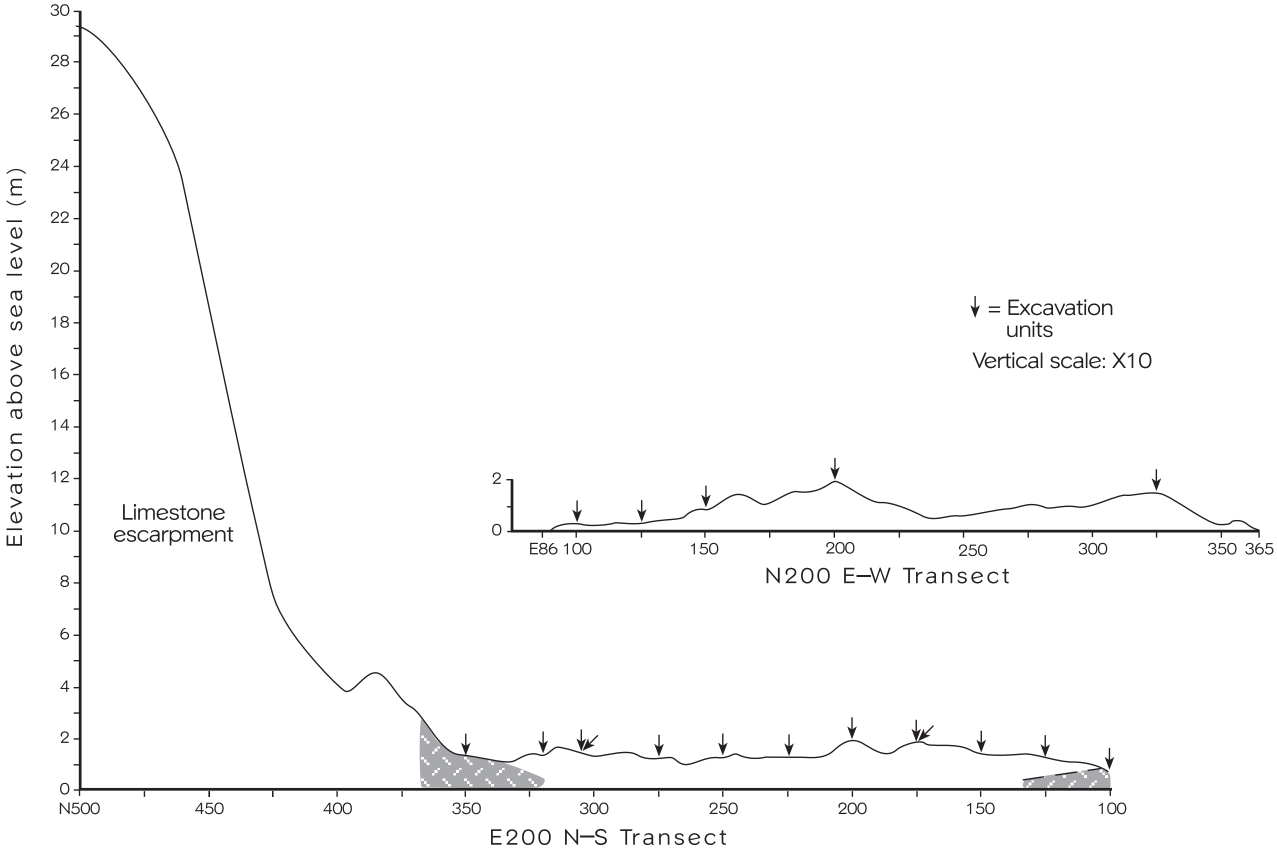


Figure 4.9. Elevation profiles along the N–S (E200) and E–W (N200) transect lines at site EKE. Vertical scale exaggerated X 10.

Layer IB. 70–120/130 cm below surface. The transition to this lower part of the shell midden deposit is gradual with no sharp break. In this lower zone the midden was very dark grayish brown in color (10YR3/2), and not as "greasy" as in the upper component, but still contained large midden shells.

Layer IC. At the base of the deposit, just above the interface with Layer II, was a zone about of light brown to gray sediment containing some clay mixed with calcareous sand. This transitional zone is likely to represent an old soil surface (A horizon), which may have been vegetated and stable for some time prior to the deposit of Layer I. Although in the profile this zone appears to be only 5–10 cm thick, the excavation notes indicate that it spanned as much as 20 cm in some parts of the unit. Calcareous-sand tempered pottery first appears in this deposit.

Layer II. 130–150 cm below surface. Coarse-grained calcareous sand, white (10YR8/2) in color, with very little shell but a significant quantity of reddish, calcareous-sand tempered plainware ceramic sherds. There were pockets of heavily concreted ($CaCO_3$) sand distributed throughout the layer.

Layer III. 150–180 cm below surface. Fine-grained calcareous sand, white (10YR8/1) in color, with small Veneridae bivalves included. Ceramics and other cultural materials were scarce, and largely confined to the upper part of the deposit, but did include a single dentate-stamped Lapita sherd. This sand deposit was tested to 200 cm below surface, and proved to be completely sterile below 180 cm.

Two major depositional episodes are evidenced. During the earlier period, represented by Layers II and III, this area was an open beach foreshore; the presence of abundant venerid bivalves in Layer III indicates that it was deposited subtidally (these shells were naturally deposited,

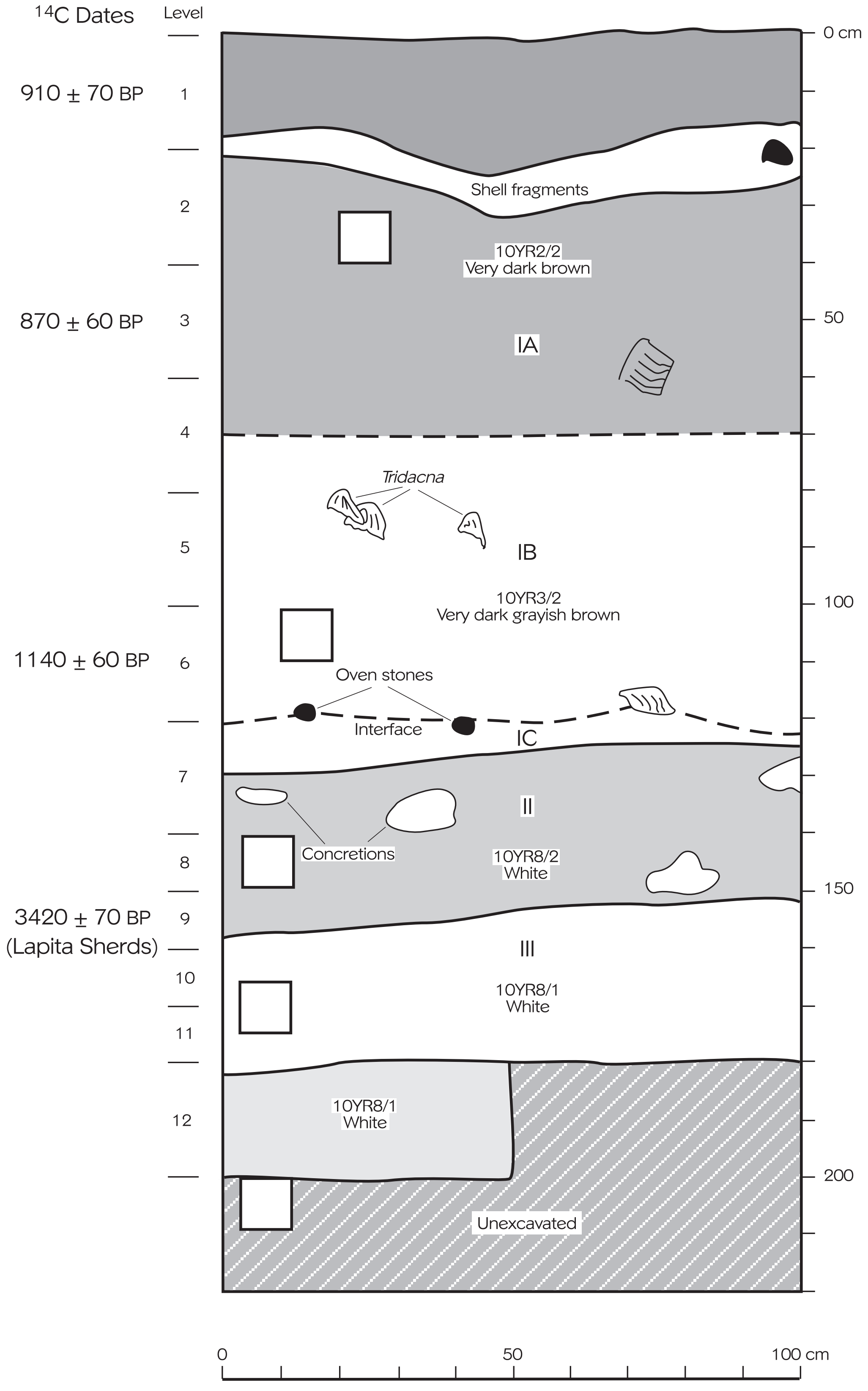


Figure 4.10. West face of Unit E200N175 at the EKE site. See text for discussion.

Figure 4.11. View of EKE Unit E200N175 after excavation.

not midden material). A Lapita-period occupation was associated with this depositional phase, likely involving one or more stilt-house structures as no features indicative of an on-ground occupation were exposed (and the area would have been tidally awash). The interface (Layer IC) containing some clay content between Layers II and IB represents a period of landscape stability when no deposition took place. This probably postdates the drop in sea level from the mid-Holocene +1.5 m stand, and thus the progradation of the shoreline north of this area. The incorporation of a significant quantity of calcareous pottery in this zone could well have resulted from the burrowing activities of terrestrial crabs. After some time, deposition at this locus began again, now in the form of shell midden dumping and occupation in the immediate vicinity (given the high charcoal content and presence of oven stones). Deposition was fairly rapid, and led to a vertical accumulation of more than 1 m of shell midden deposit.

Cultural Content. Table 4.1 summarizes the stratigraphic distribution of some of the main categories of cultural materials in the EKE site. Important changes are associated with the transition from Layers II to IB. Calcareous-sand tempered pottery, present in significant quantities in Layers III and II, as well as in the transitional IC deposit, are absent in Layers IB and IA. Significant numbers of burned coral oven stones occur in throughout Layer I, indicative of cooking activities in the vicinity. The differential concentrations of shell midden are also notable. Radiocarbon dates on marine shells from Unit E200N175 are reported in Chapter 5, where they are calibrated with Bayesian modeling.

Unit E200N200. Moving north along the E200 transect line the next unit was situated on the slope of the same large midden mound sampled by E200N174-175. Not surprisingly, the stratigraphy was somewhat similar here to that found 25 m to the south. In E200N200 the upper 40–50 cm consisted of a black to dark brown, "greasy" textured shell midden (Layer I), which then changed to a brown sand and clay loam mixture (Layer II) to a depth of about 100 cm below surface. *Terebra*-shell and *Tridacna*-shell adzes, along with small quantities of a dark red, non-calcareous tempered ceramic ware were recovered from these layers. A sample of *Laevicardium* midden shell (Beta-30694) from the base of Layer II was radiocarbon dated, yielding a conventional age of 540 ± 70 BP, suggesting that this entire deposit may have accumulated rapidly, quite possibly as "sluff" or wash down the slope of the midden mound (see Chapter 5 for further analysis of radiocarbon dates from site EKE).

Table 4.1. The cultural content of Unit E200N175 at site EKE

Category	Layer IA/IB	Layer IC	Layer II	Layer III
Ceramic sherds	6	74	47	20
Flakes	5	10	4	
Shell adzes	3			
Worked *Trochus* shell	12	12		9
Total bone (NISP)	125	38	16	2
Pig bone (NISP)	8			
Oven stones	50	28		

After a transitional zone of light brown sand (Layer III), the profile changed first to white, coarse-grained calcareous sand (Layer IV), followed by white fine-grained sand containing numerous venerid bivalve shells (Layer V), to a total overall depth of 200 cm below surface. These lower deposits (Layers IV and V) thus correlate with the lower layers in E200N174-175, and like the latter, contained quantities of calcareous-sand tempered Lapita plainware.

Deposits from N225 to N275. Units N225, N250, and N275 along the E200 transect are completely off the high shell midden mound, on the relatively level flat about 1.2 m above sea level. In these three units, the stratigraphic sequence was essentially identical, with only minor variations, consisting of: (1) a relatively thin upper deposit of dark gray to black, "greasy" textured shell midden (typically only 20–25 cm thick), with *Terebra*-shell adzes and a few non-calcareous sand tempered sherds; (2) overlying grayish-brown to white calcareous sands containing calcareous-sand tempered, reddish plainware, and also including a few sherds with incised decorations. Again, this sequence is consistent with an interpretation of an earlier Lapita-period occupation, followed by a much later occupation characterized by heavy shell midden dumping. In this area, however, the presence of incised sherds in the lower deposits suggests that the Lapita occupation was toward the late end of the Lapita period, perhaps comparable in time to the Area C deposits at site ECA. If the shoreline was rapidly prograding and the sand spit connecting the two parts of Boliu Island was building at this time, the locus of occupation may have shifted from the south part of the transect to this area, thus remaining on the prograding shoreline.

Deposits at the North End of the Transect. The final part of the E200 transect lies from N305 to N350, an area where the ground surface rises slightly as one approaches the base of the steep limestone escarpment. In these test units, the shallow deposits consisted of a thin upper midden (darker in color, but not so concentrated as in units to the south), overlying gray to white calcareous sands containing Lapita plainware ceramics. In Unit E200N305 a dentate-stamped Lapita sherd was also found. In Unit N350E200, which lay at the base of the steep scarp, the deposit was no more than 10–40 cm thick, overlying cemented reef limestone; only one worn sherd and three obsidian flakes were found in this unit. In essential respects, then, the northern part of the E200 transect mirrors the sequence in the far southern part of the transect.

The N200 Transect

The N200 transect cross-cut the E200 transect on an east–west axis, joining at Unit E200N200 (Figure 4.8). The most westerly unit, E100N200, located near the present shoreline on the low sandy flat, was completely sterile. Moving eastward, E125N200 was also on this flat, just below the 1.2 m rise, yielding only a minimal amount of cultural material, including one *Trochus*-shell ring fragment.

Unit E150N200 was situated on the slope itself, at about 1 m above sea level. This was excavated to the water table at 100–120 cm below surface, but no ceramics were recovered. Rather, the upper deposits consisted of shell midden, producing a *Tridacna*-shell adze and a worked pearl shell disc. Thus this part of the EKE site seems never to have had a Lapita-period occupation.

The final unit along the N200 transect was E325N200, near the island's western shoreline, again on a low-lying sandy flat. Here there seems to have been some occupation, as both a *Terebra*-shell adze and a *Tridacna*-shell adze were recovered, along with four small sherds of uncertain type. The water table was reached at only 40 cm below surface, and the deposits may well have been mixed through land crab burrowing.

The Sequence at E117N327 (TP1)

After the transect excavations were completed, an additional 1 m^2 test unit was excavated at grid unit E117N372, into the top of another shell midden mound on which *Terebra*-shell adzes had been found. The excavation reached a total depth of 180 cm below surface, at which depth cemented reef limestone was exposed. The stratigraphy consisted of two components, which graded into each other: (1) an upper deposit (Layer I) from 0–80 cm, of black (10YR2/1), "greasy" textured shell midden, much like that in the upper deposits at E200N174-175, overlying (2) a very dark grayish brown (10YR3/2) loam (Layer II) in which the quantities of shell midden decreased significantly with depth.

Layer I produced seven *Terebra*-shell adzes and a large quantity of shell midden. The only potsherd was recovered from the interface of Layers I and II (80 cm below surface); it is a body sherd with unique punctate decorations. Another *Terebra*-shell adze was found near the base of the excavation, at 160 cm below surface. Although no radiocarbon dates were obtained for this unit, it seems likely that the entire deposit is relatively late, certainly within the last thousand years. The period of deposition probably corresponds to the upper part of the shell midden deposit in E200N174-175.

Test Excavation on the Upraised Plateau (TP2)

While reconnoitering Boliu Island, Tyler observed a small midden scatter on top of the limestone plateau north of the EKE site, in the vicinity of a large *Syzigium* fruit tree. A 1 m^2 test unit was placed about 8 m from the base of the tree. The deposit consisted of a reddish brown soil overlying limestone which was reached at 30–40 cm below surface. Cultural material was confined to the upper 20 cm, and consisted of a substantial amount of shell midden (27 kg), 81 oven stones (2.8 kg), a small quantity of bone, and four small, eroded sherds with non-calcareous temper. The deposit was not dated, but is clearly post-Lapita in age.

Summary

The EKE site has two major phases of occupation, one of Lapita age and cultural affinity, the other dating to the second millennium AD. Given that our objective in excavating the site was to obtain a good sample of the post-Lapita period in Mussau, we were only partially successful, for the Boliu sequence appears to have a lengthy hiatus between these two occupation phases. Nonetheless, a good sample of material culture and faunal materials dating to the mid-second millennium AD was obtained, as well as additional insights into the Lapita period.

Initial human occupation—or at least use—of Boliu Island dates to sometime between approximately 3700 and 3400 BP (see Chapter 5), when the Lapita plainware and a few dentate-stamped sherds were deposited in subtidal sandy deposits at both the north and south ends of the E200 transect. We infer that the +1.5 m higher sea level was in existence at this time, so that the sandy spit now connecting the two upraised limestone blocks making up the island did not yet exist. Boliu was thus two islets, with a narrow channel or tidal flat between them. The deposits of Lapita sherds, obsidian, and other cultural materials at the north and south ends of the transect seem to imply the presence of two small Lapita sites, each just off their respective escarpments, facing each other across a channel perhaps 75 m wide. The quantity of ceramics and other cultural materials, however, is hardly sufficient to suggest that these were permanently occupied hamlets. The dominance of plainware with only a handful of decorated sherds also contrasts strikingly with the situation at even the smaller ECB and EHB Lapita sites. It seems likely that these were thus temporary or intermittently utilized sites, perhaps fishing camps, and/or houses where persons planting tree crops or gardens on the limestone plateaus of Boliu stayed temporarily. Indeed, given that the channel between these two Lapita sites at the north and south ends of the transect would have been tidally awash, an effective fishing strategy might have been to lay a seine net across this channel. Whatever their function(s), these minor Lapita sites add another variant to the range of Lapita settlement types evidenced in Near Oceania.

This kind of relatively ephemeral or temporary use of the area between the two uplifted limestone blocks of Boliu probably continued for some time, even as the sea level fell and the sand spit began to accumulate along the central portion of the E200 transect, as evidenced by the deposition of plainware in this part of the transect, including some incised sherds comparable to those from Area C of site ECA, or from the EKQ rockshelter site. Eventually, perhaps by early in the first millennium AD, the locus seems to have been completely abandoned. Then, by around 700 BP but possibly earlier, renewed occupation commenced, this time associated with shell midden dumping that resulted in the accumulation of several large shell midden mounds. The material culture associated with this phase is not unlike the one ethnographically documented for the German colonial period, with *Terebra*-shell adzes and *Trochus*-shell rings, as well as significant quantities of pig bone (Nevermann 1933; see Chapter 2). Also noteworthy are small quantities of non-calcareous tempered hard-fired red pottery, presumably trade ware (possibly of Admiralty Islands origin).

Eloaua Island Rockshelters

(by Marshall I. Weisler)

The southern portion of Eloaua Island is dominated by a large limestone escarpment, the base of which was eroded by wave action during the mid-Holocene higher sea level stand. Several incised notches, typically wider than they are deep, are found on the southeastern side of the island, offering natural shelters for habitation. Three of these rockshelters, sites EHM, EHN, and EKO, form a cluster (UTM Coordinates 794800E 9825700S) about 50 m inland from the shoreline, inland of a mangrove swamp that separates the locale from the lagoon and reef-protected coast.

Site EHM

A large solution cave 24.5 m deep and 10.4 m in maximum width, site EHM is the southernmost of the cluster, marked by a large *Ficus* tree. The level dirt floor covers 152 m^2. Several courses of coral cobbles and boulders stacked at the entrance were said by informants to have been placed there during World War II to create a hiding place. With a constricted entrance of just over 4 m, the cave opens to a height of 1.4 m, dropping to less than 0.5 m toward the back. The rear third of the cave has active stalactites and is home to several dozen flying foxes (*Pteropus* sp.). Sunlight penetrates the cave to about 9 m, and it is within this area that most cultural material was found. A plan and cross section of EHM are provided in Weisler (2001:Figure 5.1).

Three 1 m^2 test pits were excavated in 20 cm levels, with all sediments dry-sieved through 5 mm screens. One unit was excavated just inside the dripline, another near the center of the lighted area, and the third toward the rear of the cave. The cultural stratum was barely discernible, consisting of dark reddish brown (5 YR 3/4) silt with water-rounded pebble-sized limestone, coral, and shell (see Weisler 2001:Figure 5.2). Limestone pebbles graded to cobble size near the 50 cm base of excavation. No features were encountered and cultural materials were sparse, but somewhat more frequent near the lower half of the stratum.

Artifacts include two obsidian flakes (mean weight, 1.5 g) and two *Tridacna* shell flakes (mean length, 31.25 mm; weight, 6.2 g; both with cortex, one with dorsal flake scars). Five *Anadara* shell valves showed evidence of use along the dorsal margins, which were straight, irregular, or convex. Two base sections of *Trochus niloticus* are probably ring fragments; both show percussion flaking on one or two sides. A *Tridacna*-shell adze blank was made from the margin of a *T. maxima* shell. Two undecorated, shell-tempered body sherds were found near the base of excavation.

A total of 3.2 kg of marine shellfish, identified to 27 taxa, was recovered from site EHM (Weisler 2001:Table 5.1). Seventy-four percent of all shellfish by weight came from Unit 3, closest to the entrance, where there is the most available light. Gastropods totaled 38.4% of all shellfish, with *Strombus maculatus*, *Turbo* cf. *setosus*, and *Trochus niloticus* accounting for most of the weight. The dominant bivalves included *Anadara* sp. and *Tridacna* sp.

The lack of a well-developed cultural stratigraphy, few artifacts and food remains, and no hearth features suggest that the EHM cave site was used only infrequently. No radiocarbon dating was carried out but the ceramics and obsidian source tentatively suggest a post-Lapita occupation.

Site EKO

This rockshelter is located 11 m west of site EHM at the top of a scree slope. The shelter measures 10 m wide and 2.5 m deep inside the dripline (19.5 m^2 of actual useable space) where the ceiling rises from about 1.3 to 3.1 in height (Figure 4.12). A 1 x 2.5 m long trench was excavated in the middle of the site across the dripline. A total of 1.54 m^3 of deposit was excavated in 20 cm arbitrary levels and dry-sieved through 5 mm screens.

Three cultural layers were identified atop a limestone bedrock base. The average thickness of the combined cultural layers was 60 cm along the trench. The upper cultural layers evidenced intensive hearth and earth-oven activity, while ash content decreased with depth and the volume of coral cobbles increased, with boulders present in the lowest layer (Figure 4.13). The stratigraphy of excavation Units 1 to 3, west profile, was as follows:

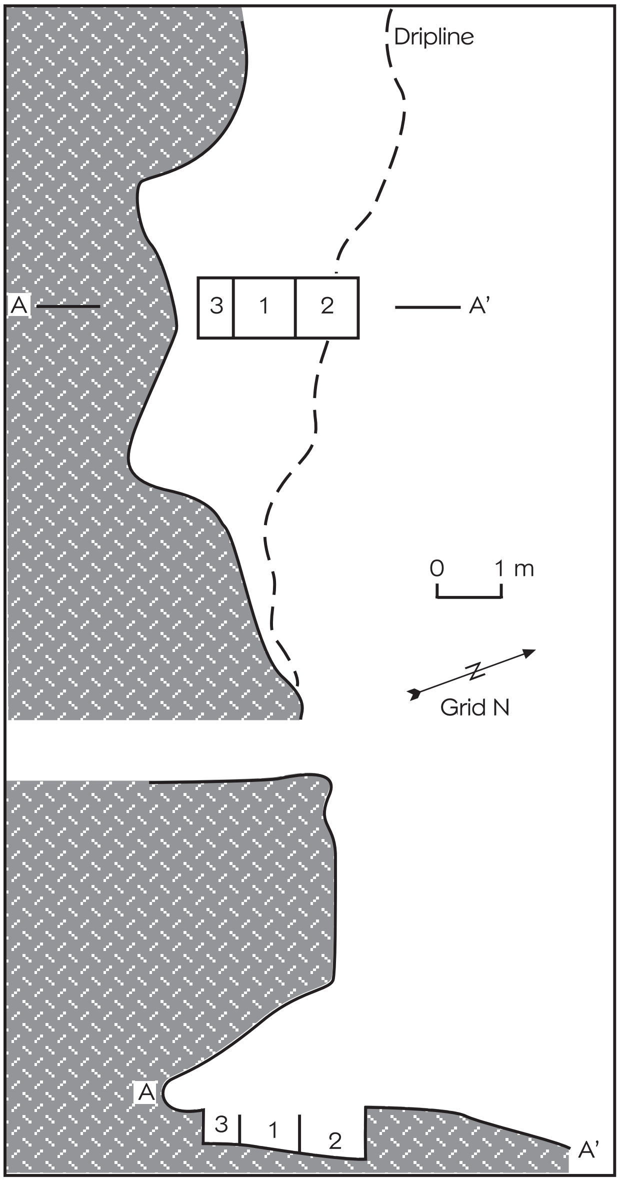


Figure 4.12. Plan and cross-section of site EKO.

> Layer I: Cultural layer, gradual, wavy boundary, very ashy, silty dark gray (10YR 4/1 to 5/1) sediment, with ash pockets, charcoal chunks, and cultural materials. Few limestone cobbles, loose consistency, non-plastic, easy excavation with trowel, dense roots and rootlets; deposit thoroughly reworked by crabs, and hearth and earth-oven activity.
>
> Layer II: Cultural layer, abrupt, wavy boundary, less ash, silty very dark gray to black (10YR 3/1 to 2/1) sediment, with limestone cobbles (few water-round coral sediments < 5 cm) and cultural material; loose consistency, non-plastic; some disturbance, but less than Layer I.
>
> Layer III: Cultural layer, abrupt, smooth boundary, much less ash, mostly subrounded limestone cobbles (some water-rounded) and boulders with a silty dark brown (10YR 4/3) matrix, loose consistency, non-plastic, non-sticky; large shell midden and land snails noted.
>
> Layer IV: Sterile, limestone bedrock.

Artifacts recovered included worked *Anadara* sp. valves, a *Trochus*-shell fishhook blank, three *Trochus*-shell ring fragments, and 37 obsidian flakes. Ceramics were the most numerous artifact class, with 125 sherds weighing 588 g. The assemblage was dominated by undecorated, shell-tempered body sherds. Two sherds have volcanic temper and are noticeably thicker than the shell-tempered sherds. One sherd was dentate-stamped (volcanic sand temper), and five were rim sherds.

Some 11.5 kg of shellfish were recovered, with 32% comprising gastropods (mostly *Lambis lambis*, *Strombus* sp., and *Trochus niloticus*), and 68% bivalves including *Tridacna* sp., *Hippopus hippopus*, and *Anadara* sp. One piece of medium mammal bone and 80 pieces of crustacea were also inventoried.

A shell sample (*Turbo marmoratus*) from Unit 1, Layer III yielded a conventional radiocarbon age of 3200 ± 70 (Beta-25669), calibrated to 3601–3009 BP, suggesting a mid-Lapita age for initial occupation of the rockshelter.

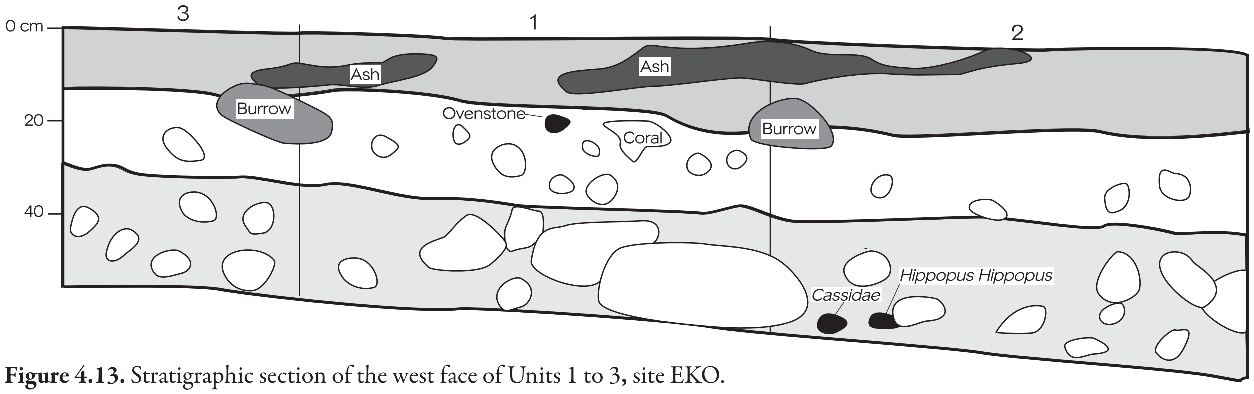


Figure 4.13. Stratigraphic section of the west face of Units 1 to 3, site EKO.

The EKO site was the most intensively utilized of the Eloaua rockshelters. The relatively small size of the site and the presence of Lapita villages a short distance away suggest that the shelter was probably used intermittently by a few people at a time. The artifact assemblage, while larger than that of the surrounding shelters, contains a restricted set of functional classes associated with food preparation. Indeed, the upper layers are thoroughly reworked from hearth and earth-oven activity. While not a major habitation locale, the site adds definition to the Eloaua Island settlement pattern during Lapita times.

Site EHN

This overhang shelter is located a short distance from EKO, just above the mangrove mud flats. The relatively level shelter floor measures 6.6 m wide by 2.2 m deep, sloping abruptly down toward the sea beginning about 1 m beyond the dripline (Weisler 2001:Figure 5.5). A single 1 m^2 unit was excavated in the center of the floor, in 20 cm arbitrary levels by Terry Hunt on October 3, 1986. All sediments were dry-sieved with 7 mm screens. The unit was excavated to a depth of 70 cm below surface, at which depth limestone cobbles were encountered. Two layers were defined: Layer I, a grayish brown (10YR 5-6/2), fine, "powdery" sediment with angular limestone cobbles; and Layer II, consisting of angular cobbles in a poorly sorted white (10YR 8/2) matrix grading to decomposing limestone bedrock (Weisler 2001:Figure 5.6).

The sparse artifacts included five pieces of worked *Trochus* and seven obsidian flakes. No bone was recovered, although 4.0 kg of mollusks were dominated by bivalves of *Tridacna*, *Anadara*, and *Hippopus*.

No radiocarbon dates were obtained. The sparse artifacts and weakly developed cultural layer point to only intermittent use of this shelter.

Mussau Island Rockshelters

(by Marshall I. Weisler)

During October and November 1986, two rockshelters were excavated by Marshall Weisler in the northwestern part of Mussau Island, in the vicinity of Tanaliu Village (see Figure 2.1). One objective in choosing these sites was the possibility that they might reveal a pre-Lapita settlement of the main island, as the Lapita Homeland Project had shown to be the case with rockshelters and caves in New Ireland, and was later demonstrated for Manus Island (Fredericksen et al. 1993). Unfortunately, these sites proved—for geomorphological reasons to be made clear below—not suited to the preservation of such a pre-Lapita record. They did, however, add considerably to our knowledge of the later Lapita period, especially site EKQ.

Site EKP, Eatulawana Rockshelter

About a 20-minute walk south of Pomanai village along the northwestern coast of Mussau Island, then 0.5 km inland following an unnamed stream that meanders through low-lying terrain with dense stands of sago (*Metroxylon* sp.) palm, is the limestone rockshelter of EKP at Eatulawana (UTM coordinates 783600E 9849400S). It is the largest of several shelters at the base of an uplifted limestone block that trends northeast–southwest for about 100 m. The block is 15–20 m high at its southwestern end, near the river. A scree slope fronts EKP for about 25 m and descends onto the broad swampy flat. The rockshelter measures 11 m wide at the entrance, 6 m deep, and the ceiling height is 5.4 m high at the dripline. The useable level floor area is 50 m^2 (Weisler 2001:Figure 5.7). Surface cultural material is limited to a few small undecorated sherds and marine shellfish. John Poli of Pomanai village related that his grandparents occupied the EKP site, having dug earth ovens in the northeastern corner of the shelter.

A baseline, oriented 314° MN and thus perpendicular to the dripline, was staked at 1 m intervals. Five 1 m^2 units of a discontinuous 7 m long trench were excavated in 10 cm arbitrary levels. All sediments from 2.25 m^3 were sieved through 5 mm mesh.

Layer I, a black silty organic-rich cultural layer (7.5YR 2/0 to 10YR 3/2), was uniform throughout the length of the trench, averaging 14 cm thick. Cobble-sized chunks of decomposing limestone were encountered toward the base of the layer. The matrix is plastic, of loose consistency with dense rootlets and few roots. An otherwise sterile-looking deposit, Layer II was stained from leaching of the upper dark cultural layer and represents a transition from Layer I to the C horizon. The sediment is very sticky, compact, silty clay which was difficult to excavate. There was virtually no cultural material and no roots. A yellowish-brown decomposing limestone bedrock is Layer III (see Weisler 2001:Figure 5.8 for a stratigraphic section).

Artifacts recovered from the excavations were limited to eight obsidian flakes with a total weight of 3.4 g, and 63 calcareous-tempered, plain body sherds weighing 107 g. In Unit 2, at 4–6 cm below surface, were 32 small clay nodules weighing 59 g. The clay was obviously imported to the site as it was different from the natural site matrix. Three volcanic manuports were also found.

Faunal material consisted of six pieces of medium mammal bone and one pig (*Sus scrofa*) tooth. Unidentified crustacea totaled seven pieces weighing 6.2 g. Some 3.175 kg of shellfish were recovered, with gastropods contributing 44% of the total weight, dominated by *Turbo* sp. and *Lambis lambis*. *Hippopus hippopus* and *Spondylus* sp. were the most prevalent bivalves.

Site EKP was probably not a primary habitation, as indicated by the limited quantity and restricted functional range of artifacts, low densities of food remains, lack of hearths and earth ovens, and a thin, weakly developed cultural deposit. The close proximity of sago palm stands near the stream below the site may have attracted short-term visitors to the area for harvesting and processing sago palm pith into flour. The EKP locale would have provided a convenient shelter for residing during such short periods of time.

Site EKQ, Epakapaka Rockshelter

Two km north along the coast from Pomanai village, then a five-minute walk inland on the south side of an unnamed drainage, is the Epakapaka rockshelter (UTM coordinates 783300E 9852300S), situated at the base of an upraised limestone block nearly 30 m high. The landowners are John Poli and Denny Epeli of Pomanai village. The shelter is 24 m wide (east–west) at the entrance, and 7.4 m deep, with a relatively level protected area of 88 m^2 (Figure 4.14). At the dripline, the ceiling height is 2.1 m, descending to 1.4 m at the rear of the shelter. The surface cultural deposit extends outside the shelter for about 100 m^2, marked by marine shellfish, potsherds, and other artifacts. Inside, at the west end of the shelter, is a low pavement, 1.5 m in diameter, consisting primarily of a single course of water-rounded, tabular coral and limestone cobbles. At the rear center of the shelter are the remains of three forked posts (12–15 cm in diameter) that previously supported a low sleeping platform, according to informants, who also related that villagers lived here during World War II. More recent site disturbance was evident from crab burrows, as well as digging for earth ovens and posts.

Site EKQ was excavated by Weisler and local assistants from November 16–22, 1986. After clearing the site area of shrubs and grasses, a 27 m long, east–west baseline was established roughly parallel to the dripline. Two 1 m^2 units were excavated, one on either side of the dripline, with a total of 4.8 m^3 of cultural and natural deposits sieved through 5 mm mesh. The dark, "greasy" layers were water-screened with sea water to facilitate recovery of obsidian flakes and charred bones that otherwise would have been difficult to identify within a black sediment matrix.

Stratigraphy and Depositional Sequence of EKQ. A description of the EKQ stratigraphy, as revealed in the southern profile of Unit 2, is presented below (see Figure 4.15):

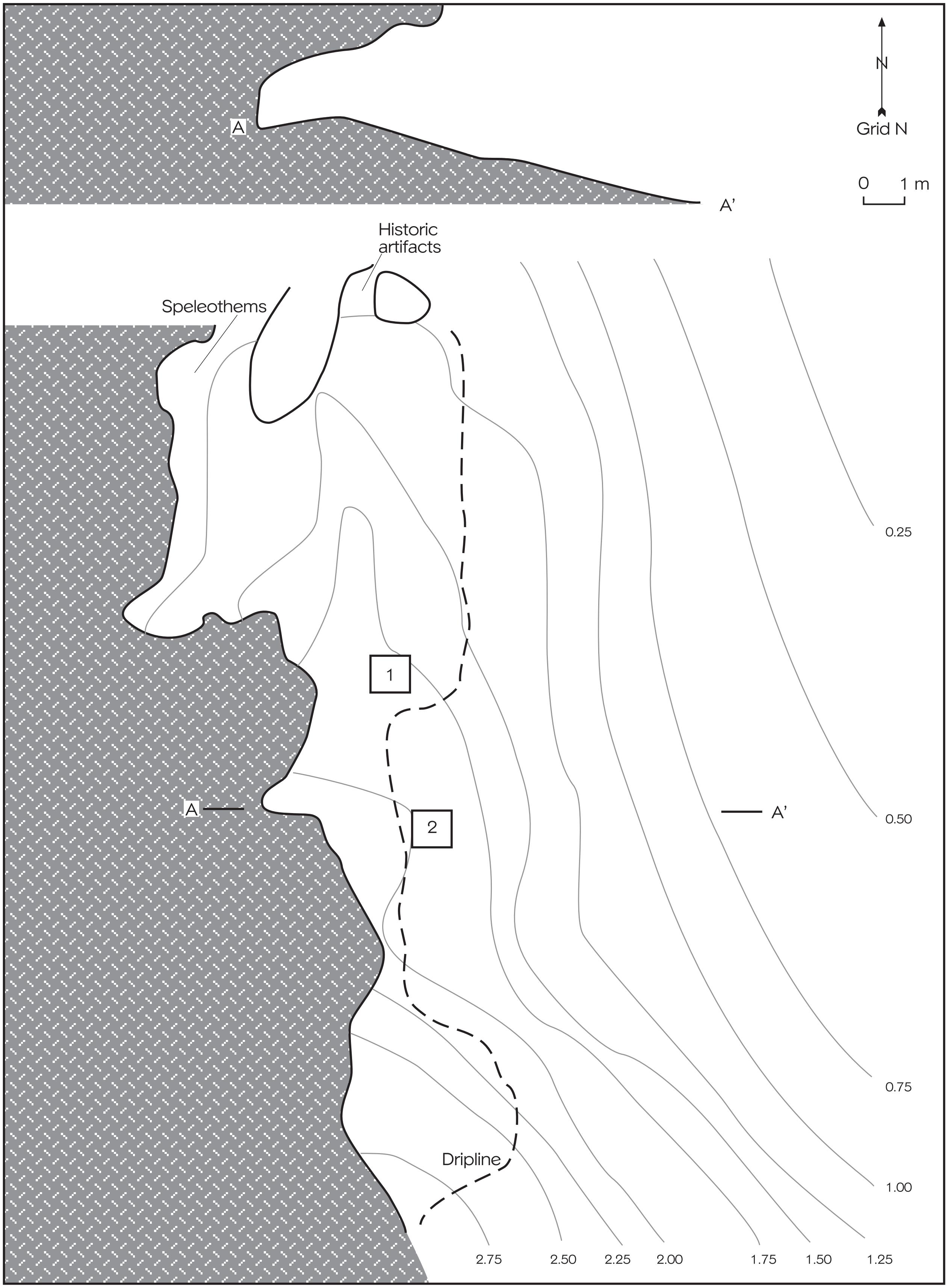


Figure 4.14. Plan of site EKQ, Epakapaka Rockshelter. (Plan by M. Weisler.)

Layer I: 0–7 cm below surface; probably post-occupation surface (after 1945) of relatively sterile, black (5YR 2.5/1) silt; structureless; consistency: loose, noncoherent (dry), slightly sticky (wet); slightly plastic; no roots, few rootlets; abrupt, smooth boundary.

Layer II: 1–46 cm below surface; fairly homogeneous cultural layer, no discrete features in profile, charcoal chunks, reworked ask pockets; very dark gray (10YR 3/1) sandy-silt, limestone pebbles and cobbles (probably reworked ceiling collapse), but very little coral; structureless; loose consistency, noncoherent (dry), slightly sticky (wet); slightly plastic; few roots and rootlets; few crab burrows; gradual, wavy boundary.

Layer III: 34–118 cm below surface; cultural layer, few discrete hearths, ash, charcoal chunks, fire-altered limestone, very dark gray (10YR 3/2) silt, few gravel-sized sediments; structureless; weakly coherent (dry), slightly sticky (wet); slightly plastic; few roots and rootlets; clear, wavy boundary.

Layer IV: 88–146 cm below surface; cultural layer, dense hearths, ash lenses, fire-altered limestone, black (5YR 2.5/1) sandy silt; structureless; weakly coherent (dry), sticky (wet); slightly plastic; few roots and rootlets; diffuse, smooth boundary defined by the increase of gravel toward boundary with Layer V.

Layer V: 134–180 cm below surface; cultural layer, charcoal chunks and flecks throughout; black (10YR 2/1) sandy gravel with many water-rounded coral pebbles and cobbles; structureless; slightly hard consistency (dry); non-sticky (wet); non-plastic; very few roots, no rootlets; sharp, smooth boundary; pocket of weakly cemented sand.

Layer VI: 173–198 cm below surface; sterile, very pale brown (10YR 7/3) beach sand; structureless; noncoherent (dry), non-sticky (wet); non-plastic; no roots or rootlets; abrupt, smooth boundary; area of weakly cemented sand.

Layer VII: 178–225 cm below surface; sterile, very pale brown (10YR 7/3) beach sand matrix within water-rounded coral gravel, pebbles, and cobbles; structureless; noncoherent (dry), non-sticky (wet); abrupt, wavy boundary; difficult to excavate due to rocky nature of layer; area of weakly cemented sand.

Layer VIII: 209–237 cm below surface; same description as Layer VI.

Layer IX: 220–260 cm below surface; same description as Layer VII.

In sum, nine layers were identified, five cultural and four natural. Layer I—a dark silt—was probably deposited during and after the 1940s. Layer II, thoroughly reworked, is homogeneous, a very dark gray loam with ash pockets and dispersed charcoal. The next cultural layer (III) is less disturbed, but still dark in color with charcoal and ash and few discrete hearths in a sandy matrix. Numerous scoop hearths and ovens define Layer IV. The basal cultural deposit, Layer V, consists of dark sediment with gravel- to cobble-sized material. Layers VI to IX are generally devoid of cultural material and represent separate beach-building episodes. Analysis of sediment samples from EKQ is presented by Weisler (2001:157, Table 5.2). Radiocarbon dating of the EKQ site is discussed in detail in Chapter 5.

Burial Feature. An extended, well-preserved human burial was encountered in excavation Unit 1, Layer III, from 49 to 55 cm below surface. A burial pit could not be identified. The lower half of the individual was exposed from the pelvis to the feet, while the remainder of the burial extended east into an unexcavated portion of the site. The burial was lying on its back, oriented east–west with the cranium at the eastern end. The metacarpals were positioned at the proximal ends of the femurs, indicating that the arms were laid parallel to the body. Fusion of the greater trochanter indicated an adult of uncertain age, and the narrow width of the sciatic notch suggested the individual was a male. No burial objects were encountered. A large, tabular stone (46 cm long) was positioned over the knees. The bones were removed to continue the excavation of the unit. At the request of the landowners, after excavation the pit was backfilled to the level of the intact portion of the burial, the human bones were replaced, and the unit was filled to ground level.

Cultural Content of EKQ. More than 13,000 artifacts were recovered from the excavations, with the majority of ceramics, obsidian, and bones coming from Layers III and IV (Figure 4.16). Some 12,463 mostly shell-tempered, plain body sherds were recovered, mostly very small, with a density of 3,463 sherds per m^3 of excavated deposit. Some 3.9%

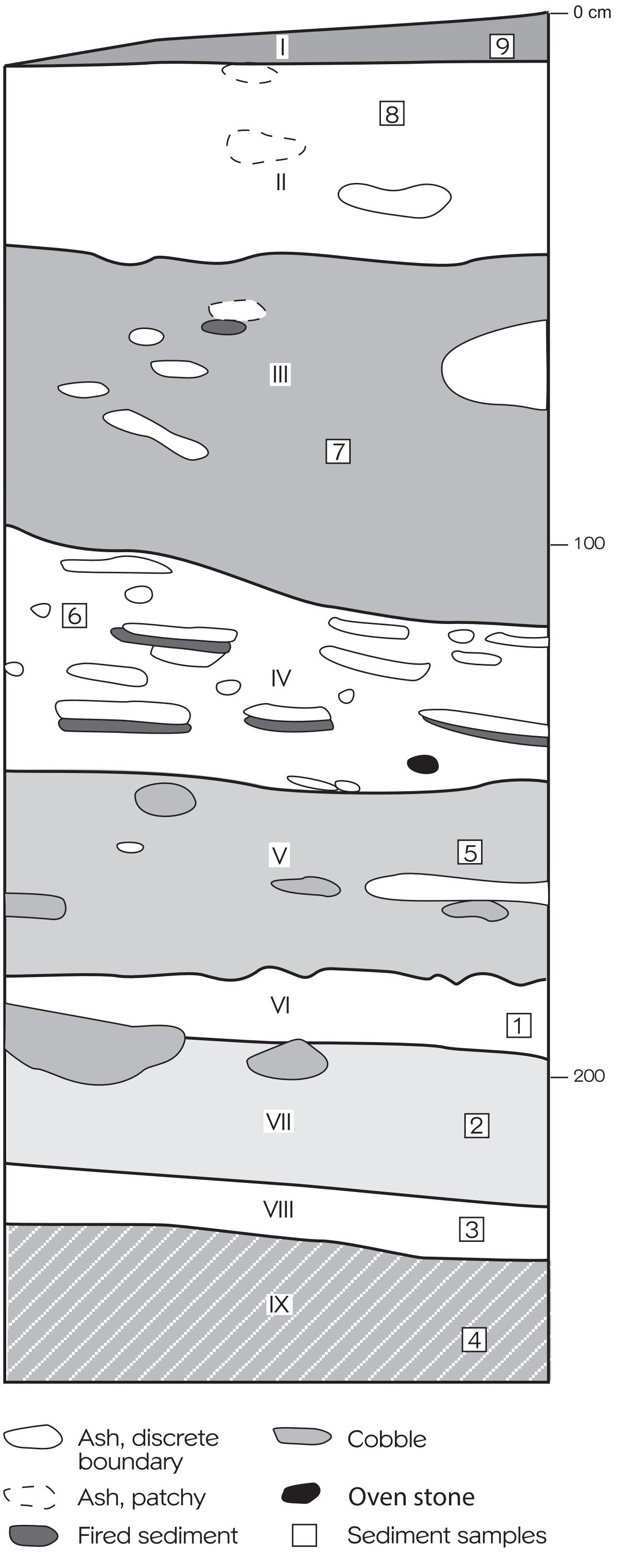


Figure 4.15. Stratigraphic profile of the S face of Unit 2, site EKQ. (Profile by M. Weisler.)

of the ceramic assemblage was decorated; decorated rims, both notched and tool-impressed, are present throughout the ceramic sequence. There are more dentate-stamped sherds in the lower portion of the deposit, decreasing toward the top. The ceramics from site EKQ are discussed further in Chapter 11.

Some 745 obsidian flakes were recovered from the surface (11 pieces) and from both excavation units. The distribution of obsidian from excavation Unit 1, by weight, is illustrated in Figure 4.17; putative sources were assigned by the heavy-liquid separation method. Although obsidian is present throughout the deposits, 90% of the material by weight was recovered from Layers III and IV.

EKQ has a substantial diversity of shell artifacts manufactured from *Anadara*, *Conus*, *Pinctada*, *Spondylus*, *Tridacna*, and *Trochus*. Two *Anadara* valves have rounded and polished distal margins consistent with use against relatively soft plant materials. Nine *Conus*-shell rings are separated here into narrow and wide groups, with mean widths of 7.0 and 14.1 mm, respectively. Two artifacts made from the black-lipped pearl shell (*Pinctada* sp.) included one cut piece, and one probable fragment of a vegetable peeler. A biconically drilled *Spondylus* bead measures 11.1 x 5.4 x 3.1 mm. The single *Tridacna* artifact is a small expanding flake.

Trochus-shell artifacts include one-piece angling fishhooks, trolling hooks, and manufacture debris from making such hooks, described in greater detail in Chapter 13. Most of the worked *Trochus* shell in the EKQ deposits appears to have been related to the manufacture of trolling hooks. Diagnostic debitage was formed by the removal of the basal whorl of the *Trochus niloticus* shell. These pieces, numbering about 65% of the debitage, are identified by thick, angular chunks of shell exhibiting portions of the flat base and side whorls. Other manufacturing debris, consisting of about 30% of the total, include *Trochus* shell fragments that contain only whorl portions higher up on the shell; other, nondescript fragments make up the remaining 5% of the assemblage. A small part of this worked shell assemblage might have resulted from opening shells for meat extraction, but experimental tests would be required to more accurately separate food from artifact debris.

More than 15 kg of marine shellfish were identified to 51 taxa. The average weight of individual pieces was 0.85

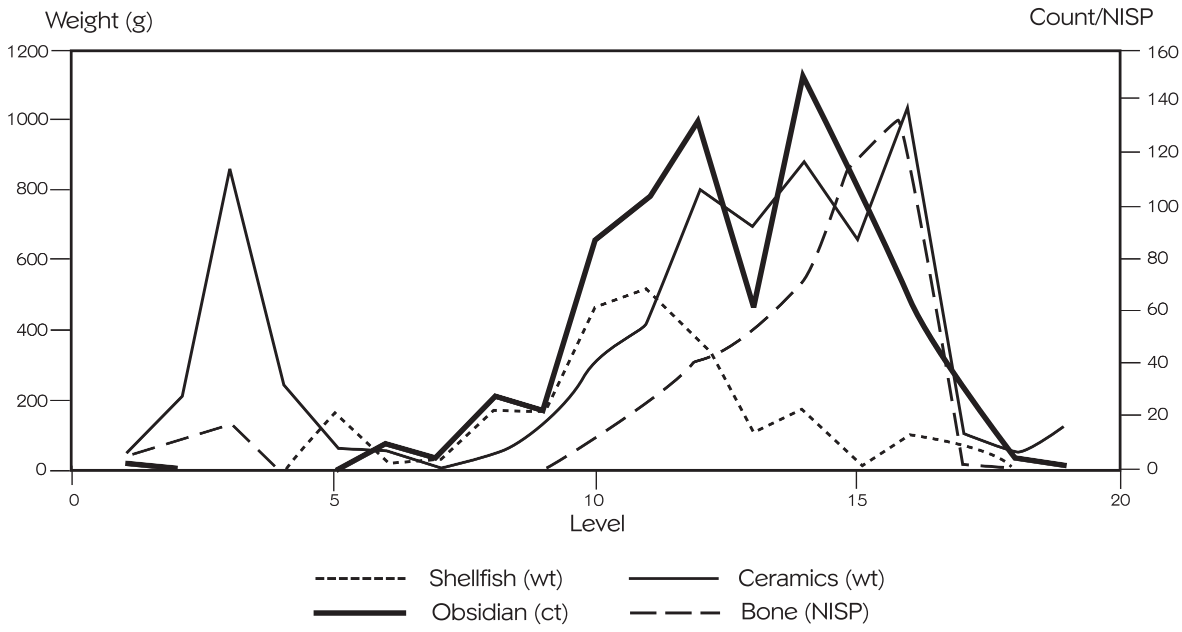


Figure 4.16. Stratigraphic distribution of cultural materials in site EKQ.

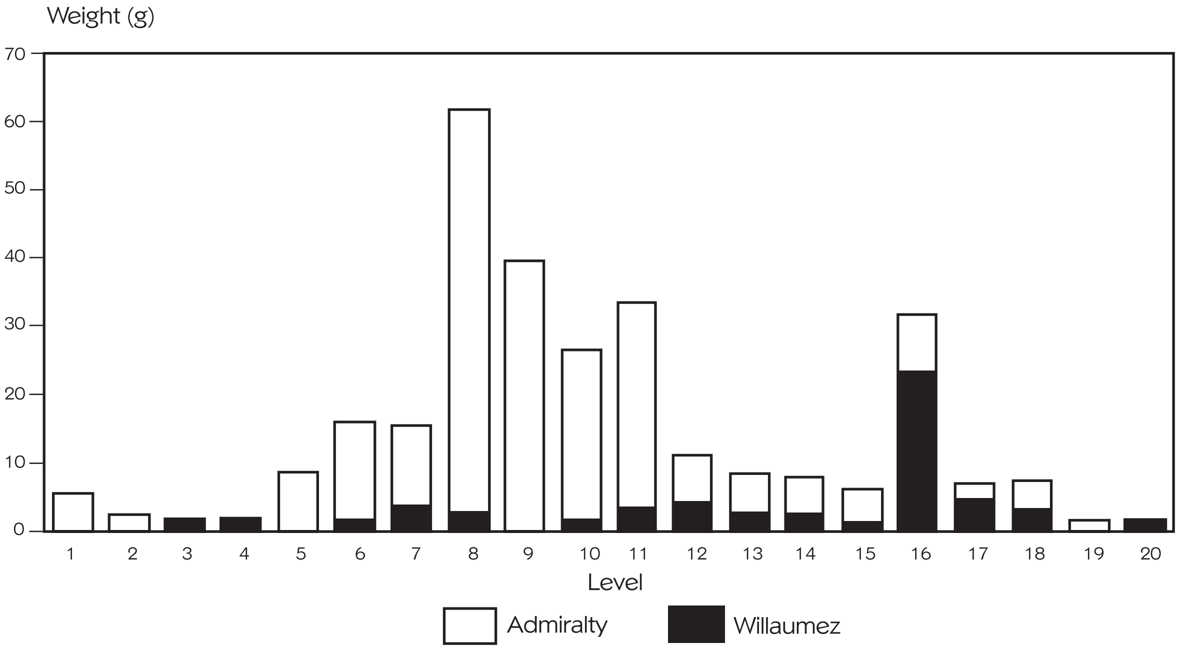


Figure 4.17. Stratigraphic distribution of obsidian in site EKQ.

g. Thirty-seven gastropod and 14 bivalve taxa were identified. Most bone recovered was of fish, with a relatively high number of pelagic species identified (see Chapter 7).

Although the Epakapaka rockshelter was occupied, presumably intermittently, over a 3,000-year period, intensive use—as evidenced by rapid accumulation of artifacts and midden, and presence of many hearths and earth ovens—was confined to layers III to V, a period dating to roughly 3050–2700 BP (see Chapter 5). The upper layers, occupied much later in the second millennium AD, are thoroughly mixed and homogeneous, are virtually devoid of pottery, and have much less obsidian and less bone midden. This undoubtedly reflects a change in site use, which may be related to island-wide settlement patterns.

Aceramic Midden Sites of Eloaua, Emussau, and Enusagila Islands (Sites EKS, EHK, and EKL)

The EKS Aceramic Midden on Emussau Island (by Marshall I. Weisler)

Emussau is a nearly circular island about 2 km east of Eloaua, and 1 km southeast of Boliu Island (Figure 4.18). The island's northwestern coast has a protected sand beach with excellent canoe access, while the remainder of the coastline is fronted by a fringing reef 100–300 m wide. The low-lying island (the highest point is just 4 m above sea level) is covered in a variety of economic trees. Emussau is not permanently inhabited today, although it is used periodically as a camp site for youth groups of the Seventh-Day Adventist church. Informants said that prior to the arrival of the mission, the island had a permanent settlement.

The EKS site (UTM coordinates 795700E 9828300S) is located immediately inland from the protected northwest coast and covers an area of at least 260 m north–south by 285 m east–west (74,100 m^2). Although the area is covered by a 2–3 cm lens of sterile white sand, small mounds (less than 50 cm across) had been heaped in rows for sweet potato cultivation over an 8,000 m^2 area. A dark midden sediment was revealed in this gardening zone, while a cultural layer was also visible in the walls of five wells toward the inland extent of the site, about 100 m from the shoreline. Numerous artifacts and large pieces of shellfish (especially *Lambis* sp.) were scattered over the surface. Other surface features include large mounds (ranging from 3.8 to 14.3 m in diameter) up to 1.3 m high, surrounded by level areas 20 by 30 m in size. Excavation of two of these mounds revealed dense concentrations of shellfish and bone midden, suggesting that they are prehistoric shell-midden dumping features, similar to those at the EKE site on Boliu Island.

Excavations. Beginning near the center of Emussau Island at an elevation of 4 m above sea level, a 400 m long transect was measured through the archaeological site to the shore (Figure 4.19), using a Lietz hand level, stadia rod, 50 m tape, and compass. Concentrations of shellfish and artifacts were noted as well as surface sediment type (sand, coral rubble, etc.), and plants were identified by local name and uses.

Four 1 m^2 units were excavated: two units into suspected refuse mounds, and two additional units in the adjacent, flat habitation areas. Natural stratigraphy was followed by excavating with trowel 20 cm arbitrary levels within strata. All excavated sediment was sieved through 5 mm (Unit 2) or 7 mm mesh (Units 1, 3, and 4), either

Figure 4.18. Aerial view of Emussau Island.

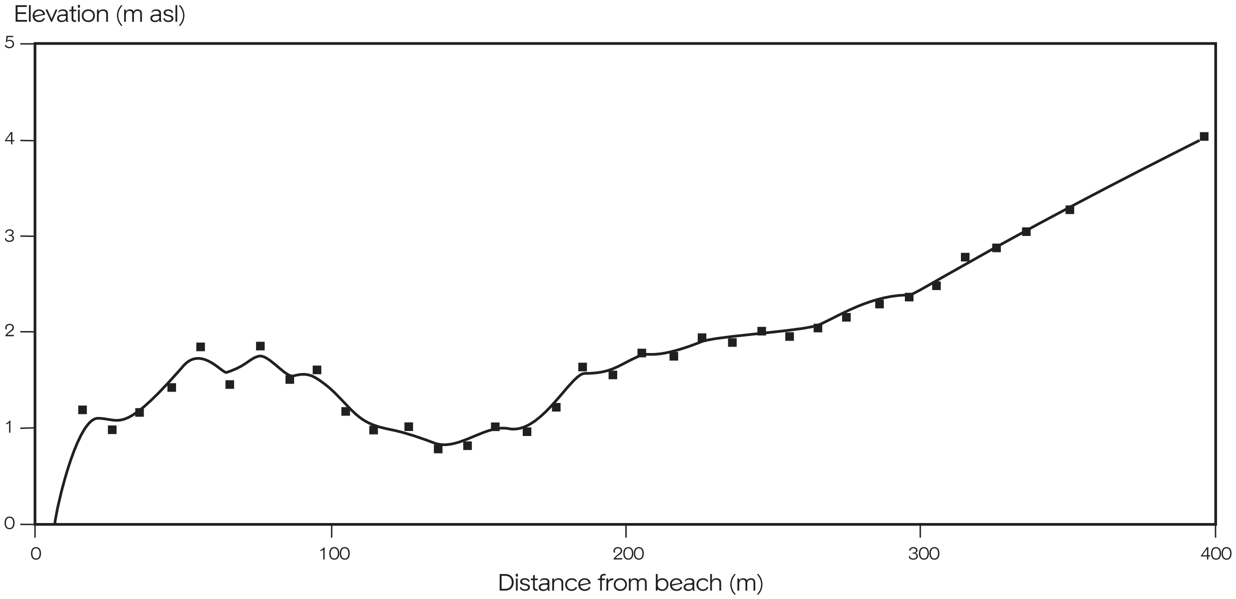


Figure 4.19. Elevation transect across the EKS site.

dry-screened (Unit 1) or, in the case of Units 2–4 with "greasy" black cultural deposits, wet-screened. A total of 4.9 m^3 was processed from the excavations.

All cultural material was field sorted into five classes: shell, bone, obsidian, charcoal, and artifacts. Bone and obsidian were weighed and counted and retained, while shellfish were tabulated by count (NISP), weighed, and discarded. Voucher specimens of all identified shellfish taxa, along with artifacts and charcoal, were retained.

Stratigraphy. The stratigraphy revealed in the excavated units in mounds was quite different from that in the flat areas. The discrete mounds were evidently formed from dumping shellfish, bone, and other food remains, with well-defined cultural layers incorporating dense midden concentrations. In contrast, the adjacent flat areas contained only minor amounts of midden and exhibited a weakly developed cultural layer. The stratigraphy of Unit 2 is as follows (the east profile is shown in Figure 4.20).

Layer I: Sterile, white (10 YR 8/1), loose sand that covers gardening area; 1–3 cm thick.

Layer IIA: Cultural, black (7.5 YR 2/0), sandy loam, few coral pebbles; structureless; noncoherent (dry), slightly sticky (wet); slightly plastic; dense roots in upper 15–20 cm; gradual, clear boundary.

Layer IIB: Cultural, black (7.5 YR 2/0), "greasy", sandy loam; dense, large shellfish (many *Lambis* sp.) made excavation difficult with trowel; structureless; noncoherent (dry), slightly sticky (wet); slightly plastic; more compact than Layer IIA; gradual, clear boundary.

Layer IIC: Cultural, very dark gray (7.5 YR 3/0), probably from leaching of upper layer into relatively sterile deposit; less shellfish, more coral pebbles; structureless; noncoherent (dry), non-sticky (wet), compact; gradual, wavy boundary. Radiocarbon sample Beta-20455 was taken from this layer at 80–100 cm below surface.

Layer IIIA: Sterile, gray (10 YR 5/1) sand, with few coral pebbles; structureless; noncoherent (dry), non-sticky (wet); non-plastic; abrupt, sharp boundary. Layers III to VIII represent beach-building events which are analogous to depositional features found on the shoreline. They all share sediment characteristics described for Layer IIIA.

Layer IIIB: Sterile, very pale brown (10 YR 8/3) sandy gravel with compact coral pebbles.

Layer IV: Sterile, very pale brown (10 YR 8/3) sand.

Layer V: Sterile, very pale brown (10 YR 8/3) gravelly sand with coral pebbles.

Layer VI: Sterile, very pale brown (10 YR 8/3) sand.

Layer VII: Sterile, very pale brown (10 YR 8/3) gravelly sand with coral pebbles.

Layer VI: Sterile, very pale brown (10 YR 8/3) compact sand. Water table at 196 cm.

The stratigraphy of Unit 4, situated in the flat area between the mounds, had the following simple stratigraphy:

Layer IA: Modern gardening zone, dark gray (10 YR 4/1) sandy loam, very little coral pebbles, loose consistency, non-plastic, non-sticky, few roots, rootlets common, sharp, wavy boundary. Low quantities of shellfish.

Layer IB: Transition to sterile subsoil, light brownish gray (10 YR 6/2) sand, very little coral, loose consistency, non-plastic, non-sticky, few roots, rootlets common, gradual, wavy boundary.

Layer II: Sterile subsoil, very pale brown (10 YR 8/2) sand, very little coral, loose consistency, non-plastic, non-sticky, few roots, rootlets common, gradual.

No subsurface features such as hearths, pits, or postmolds were encountered. One human adult burial was found already exposed in a well located near the south extent of the site. The bones were not collected, but appeared to be an adult based on size. Orientation could not be ascertained. Two *Trochus*-shell rings were present on the upper arm.

Radiocarbon Dating. A single radiocarbon age determination was obtained from 41.8 g of unidentified wood charcoal found dispersed throughout Unit 2, Level 5, yielding a conventional age of 350 ± 60 BP (Beta-20455).

Cultural Content of EKS. Three *Anadara* valves have irregular but quite pronounced wear along their margins, indicating that they were used for rough scraping tasks. The lip of a *Cassis* shell had been ground into a chisel, measuring 133.2 mm long. Two large *Cypraea* shell dorsa were each flaked into oblong shapes, presumably to be ground and used for vegetable scrapers. A marginal piece of *Pinctada*-shell valve may have been used for cutting purposes.

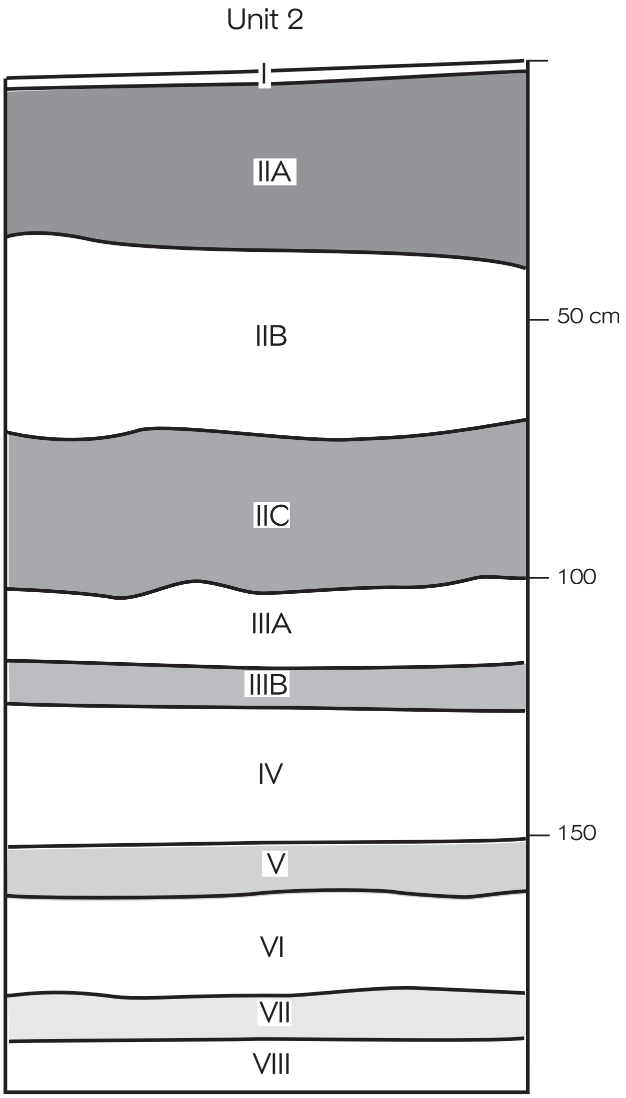


Figure 4.20. Stratigraphic profile of the east face of Unit 2, site EKS. (Profile by M. Weisler.)

Manufacture and use of *Terebra*-shell adzes at EKS is indicated by 21 specimens. Unfinished *Terebra*-shell adzes include nearly whole shells with the whorl removed by flaking, to more refined specimens that had been flaked into a plano-convex cross section. The five finished specimens have a mean length of 86.0 mm. Only the whorl end was shaped into the cutting edge. *Tridacna*-shell adzes made of both *Tridacna gigas* and *T. maxima* are also represented. The butt section of one *T. gigas* adze is slightly pointed, and is plano-convex in cross section (49.7 mm wide and 21.2 mm thick). A large flute section of *Tridacna* (81.8 mm wide), and an umbo section, both have battering along several edges suggesting use as hammerstones. Two possible adze blanks are made of *T. maxima*, while a third preform from the valve margin measures 87.7 mm long, 40.8 mm wide (at midsection), and 8.7 mm thick.

Trochus niloticus shell rings and manufacture detritus were also common at site EKS. Most of these were unfinished ring fragments from 54.2 mm long to half-rings with an exterior diameter of 83.7 mm. These unfinished rings exhibit flaking and partial grinding along the interior margins. The largest individual shell measured 110.4 mm at the base. It is significant that no "chunky" basal whorl fragments (typical of fishhook and trolling lure manufacture debris in Lapita contexts such as ECA and EKQ) were recovered at EKS, suggesting that the *Trochus* shells were being used exclusively for armbands. The mean width of nine whole and fragmentary finished (i.e., fully ground) shell rings is 5.5 mm. Two whole rings have maximum diameters of 57.0 and 61.7 mm.

Non-shell artifacts from site EKS included: an *Acropora* branch-coral abrader (133.3 mm long, 22.5 mm diameter); a plano-convex *Porites* coral block abrader (82.6 x 38.8 x 16.3 mm); a slate-pencil sea urchin (*Heterocentrotus* sp.) with wear facets on its distal end; a volcanic stone fragment with a flat worn surface (64.1 x 29.3 x 10.3 mm); a pumice nodule (39.0 mm maximum length) with a flat worn surface; a large pumice cobble (165 mm diameter) with sharpening grooves; a dense beachrock cobble with pecked holes, possibly finger grips; a basalt (?) adze front section, elliptical in cross section (48.2 mm wide and 28.8 mm thick) with battering, axe-like wear along the cutting edge; and nine small obsidian flakes.

A total of 83.51 kg of mollusks were recovered from the four excavation units. One mound unit contained 55.55 kg from 1 m^3, a particularly high density for any of the sites excavated in Mussau, suggesting that this feature was clearly a midden dump. Gastropods accounted for 48% of total weight and included predominantly whole or large pieces of *Strombus maculatus*, *Lambis lambis*, and Trochidae. Fifty-two percent by weight were bivalves, mostly *Anadara* sp., *Chama* sp., and *Tridacna maxima*. In striking contrast with the Lapita ceramic sites, pig bone (*Sus scrofa*) was abundant. A wide range of inshore fish species were also present in the bone midden (see Chapter 7).

Summary of Site EKS. Site EKS is a late prehistoric midden typified by a complete absence of ceramics, low quantities of obsidian, numerous *Trochus niloticus* shell rings, both *Tridacna*-shell and *Terebra*-shell adzes, and abundant pig bone. Unlike Lapita-age sites, this aceramic site is located close to the modern shoreline; discrete dumping mounds surround level habitation areas, much like the modern villages found throughout the Mussau group.

The Elunguai Site (EHK) on Eloaua Island (by Nick Araho)

The Elunguai site (designated EHK in the PNG National Museum site inventory) was first recorded during the 1984 reconnaissance by J. Allen and J. Specht (Allen et al. 1984:10–11). According to their report,

> running east from Elunguai hamlet on Eloaua is a site which spans the areas known as Elunguai, Talepakengi, Talewoko, Elosaurum and Eumua. This open site is about 1 to 1.5 m above high tide level and is 25–40 m wide. It is covered with gardens and regrowth, and coconuts. The site appears to be a series of discontinuous shell scatters, with obsidian and highly-fragmented pieces of pottery. None of the sherds is diagnostic of Lapita. Although the pottery seen is very small and poorly preserved, test excavations may produce diagnostic pieces and allow the site to be placed into a context relative to the Lapita sites [Allen et al. 1984:10–11].

Kirch reconnoitered EHK in 1985 and 1986, collecting a few shell artifacts from the surface of manioc gardens on the low beach terrace behind the mangroves. Although Kirch extensively searched the heavily gardened site for further evidence of the "very small and poorly preserved" pottery reported by Allen and others (1984), no further sherds were recovered, suggesting that pottery is an extremely rare item in the EHK site deposits. During the 1988 field season, Araho joined the Mussau Project as liaison officer for the PNG National Museum. After assisting Kirch with the final season of excavations at Talepakemalai (site ECA), Araho excavated five 1 m^2 test units at EHK. While the sample is limited, sufficient material was obtained to add to our understanding of the post-Lapita phase of prehistory in Eloaua Island.

Site EHK occupies two geomorphic terraces—separated by an escarpment of elevated coral limestone—immediately southeast of the small hamlet of Elunguai. The majority of the site is coterminous with a low beach terrace of unconsolidated calcareous sands (Figure 4.21).

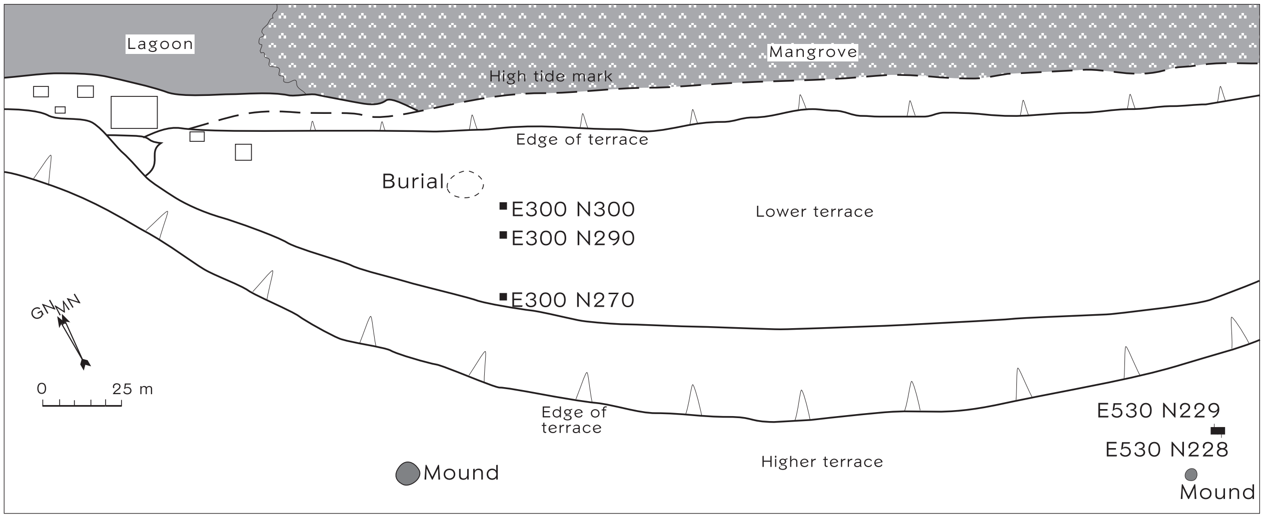


Figure 4.21. Map of the EHK site showing the location of excavated units.

This terrace, situated about 6 m asl, has a maximum width of about 70 m and a total length of 500 m. The seaward edge of the terrace is marked by an exposure of weathered coral, representing a former, uplifted reef edge, probably of late Pleistocene age. Seaward of this, the terrace drops abruptly down into a mangrove swamp. The inland edge of the lower terrace is defined by a steeply rising bank with numerous coral limestone outcrops, representing a yet older uplifted reef edge.

The lower terrace is covered with a dark gray-brown sandy loam, anthropogenically enriched through the additional of shell midden, charcoal, and other debris of human occupation. This lower terrace is cultivated by the inhabitants of the Eloaua hamlets, primarily for manioc (*Manihot esculenta*); coconut palms have been planted along the seaward margin of the terrace. This gardening had disturbed the upper 20–30 cm of the dense midden deposit, exposing a surface scatter of *Anadara* sp., *Chama* sp., and other mollusk species, as well as artifacts.

Five 1 m^2 test units were excavated at EHK, three on the lower terrace and two on the upper terrace. The three units on the lower terrace were oriented along a transect across the terrace on the E300 grid line, at N300, N290, and N270 (Figure 4.21). Units E300N300 and E300N290 were situated 10 m apart at the ends of a low mound feature which measured about 10 x 1.5 m. Unit E300N270 lay 20 m further west along the same transect, closer to the foot of the limestone escarpment. Elevations were taken along the E300 transect, and a profile across the lower terrace is shown in Figure 4.22. On the upper terrace, the two units were adjacent, forming a 1 x 2 m trench, at grid location E529-530N228.

Because the cultural deposit in the lower terrace test units was sticky and difficult to screen, it was wet-sieved using water obtained from a nearby well. Sediment from Unit E300N300 was sieved with 5 mm mesh, while that from all other units was sieved with a 7 mm mesh. Excavation proceeded in 20 cm levels, except where natural stratigraphy was encountered.

Stratigraphy. A fairly consistent stratigraphy was revealed in the three transect units, allowing the layers in each unit to be correlated with each other, as seen in Figure 4.23. The following layers were present:

> Layer I: Averaging 25–30 cm thick, this is a black, "greasy" textured loam with considerable clay content and much organic material, including a high density of shell midden. The black color clearly derives from a great deal of finely dispersed charcoal. This layer was present in Units E300N300 and E300N290, but in Unit E300N270 it was replaced by a light brown clay with a very low density of shell midden. This latter clay seems to represent material that has eroded from the upper terrace and escarpment slope and been deposited through slope wash.

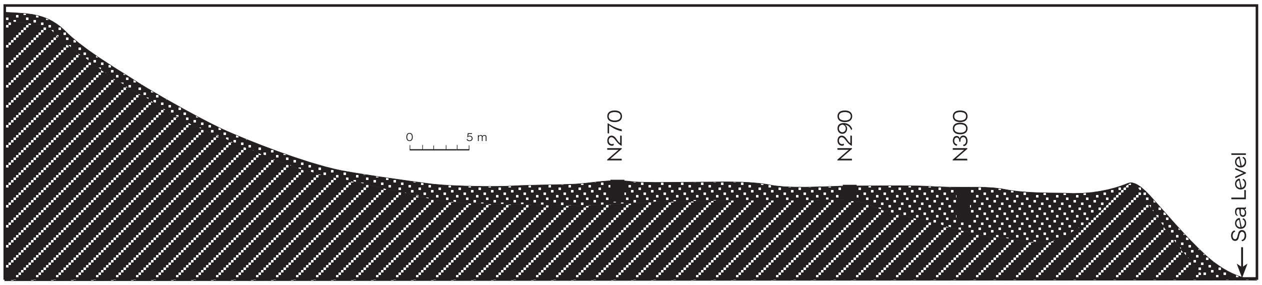


Figure 4.22. Elevation profile across the lower terrace of the EHK site, taken along the E300 transect line, and showing the location of test excavation units.

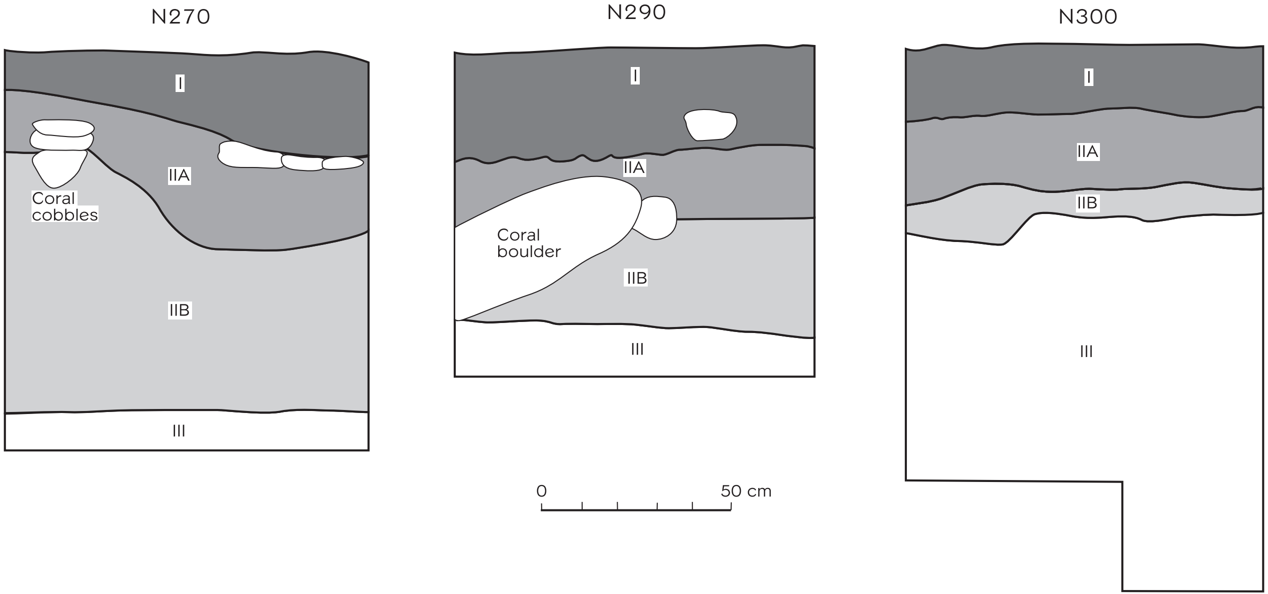


Figure 4.23. Stratigraphic sections of the E300 transect units at the EHK site.

Layer II: This is a light brown sandy loam, averaging about 20 cm thick, and also containing shell midden, especially in Unit E300N300 where the density of shells was quite high.

Layer III: Also extending across all units, Layer III consists of white, calcareous sand lacking shell midden and culturally sterile. This is therefore the original beach terrace formation upon which human habitation initially began. In E300N300 this sand deposit was excavated to a depth of 1.5 cm below surface, when a compact deposit of coarse sand and numerous *Acropora* branch coral fragments was exposed. In the other two (landward) units, bedrock consisting of weathered limestone was encountered underlying Layer III.

In short, there are two stratigraphically distinct occupation phases, represented by Layers I and II. Layer II, the earlier occupation, commenced on a coastal beach terrace and resulted in a shell midden accumulation, but without a heavy input of charcoal or other carbon-rich organic material. This was superseded by the Layer I occupation, which differs from Layer II in the higher shell midden density and in the enrichment of this deposit with carbonaceous material which has given the deposit its black color and "greasy" texture.

The only feature exposed during excavation was part of a human burial in E300N290, at 35 cm below surface. The feature continued into the south wall of the unit, and only a femur and a few other postcranial bones were exposed. At the request of the landowners, these skeletal fragments were reburied in the unit at the conclusion of the excavation.

The two continuous test units in the upper terrace revealed a shallow cultural deposit, with a dark gray to black garden soil (heavily reworked) containing shell midden, which graded rapidly into a brown clay at about 20 cm below surface. At about 40 cm below surface the weathered limestone bedrock was exposed. Although shell midden was present in relatively high density, this deposit has been extensively reworked, and no intact stratigraphy remains.

Radiocarbon Dating. Two samples of *Anadara antiquata* shell from Layers I and II of Unit E300N300 were submitted for radiocarbon dating, with details presented in Chapter 5. The dates suggest that the earlier occupation phase at EHK began in the middle of the first millennium AD, while the upper occupation dates to the beginning of the second millennium AD. There is every reason to think that occupation on the coastal terrace at EHK was continuous over this time span, although the location of individual dwellings and shell midden dumps could have shifted over time.

Cultural Content of Site EHK. In Unit E300N300 we discovered a *Terebra*-shell adze at the base of Layer II, associated with an *Anadara*-shell net sinker. This adze is significant, as it can be associated with a radiocarbon date calibrated to 1111–664 BP, and is the earliest *Terebra*-shell adze in the Mussau artifact assemblages. Another *Terebra*-shell adze was recovered from the surface, and a preform of a small *Tridacna*-shell adze was excavated from the top of Layer II in E300N300. From Layer I of E300N300 we also recovered a rough-out (not ground) of a *Trochus*-shell ring. In Unit E300N270, Layer I, we found a thick shell ring (broken) which may have been part of a *Tridacna*-shell ring preform. A number of *Anadara antiquata* shells that probably functioned as net weights were also found in both Layers I and II.

From Unit E520N228 in the upper terrace, we recovered a *Terebra*-shell adze at 10 cm below surface, and a possible shell fishhook preform at 20 cm below surface. A coral abrader was found in Unit E520N228. The two upper terrace units also yielded a total of 17 *Anadara antiquata* valves with rough perforations, which may have functioned as net weights.

Faunal Materials from Site EHK. Layer I on the lower terrace contains dense shell midden, especially in the vicinity of the low mound. Unit E300N300 had a Layer I shell density of 56.7 kg/m^3, and Unit E300N290 a density of 31.5 kg/m^3. The earlier Layer II deposit has a much lower shell midden density of 9.32 kg/m^3 in Unit E300N300, and of only 1.45 kg/m^3 in E300N290. In both layers, the dominant shell taxa were *Strombus luhuanus*, *Lambis lambis*, *Anadara antiquata*, and *Chama* sp., although many other taxa were also represented. The upper terrace shell midden had an even higher density of about 81.5 kg/m^3 as represented in Unit E530N228, one of the highest shell midden densities recorded for any of our Mussau sites. The same taxa dominated in this part of the site as on the lower terrace.

The vertebrate faunal sample from EHK totals 216 NISP, and is dominated by fishbones. However, there is also significant representation of pig (*Sus scrofa*), as well as small quantities of odontocete, bird, snake, and turtle; further details of the faunal assemblages will be presented in Volume II.

Summary of Site EHK. Excavations at the EHK site revealed the presence of intact stratification in a coastal habitation site with two main phases of occupation, spanning the late first and early second millennia AD. This site adds important data for the construction of a cultural sequence for Mussau in the post-Lapita period. Of particular note is the presence of a *Terebra*-shell adze in association with a calibrated radiocarbon age of 1111–664 BP, the earliest date for this diagnostic artifact type in Mussau. The Layer I assemblage on the lower terrace also contains a typical later prehistoric assemblage of *Terebra*-shell and *Tridacna*-shell adzes, and *Trochus*-shell rings in association with pig bone and high-density shell midden dumping; this assemblage shows close parallels with the upper stratigraphic deposits at sites EKE (Boliu Is.) and EKS (Emussau Is.).

The Enusagila Site (EKL) on Enusagila Island

Enusagila, smallest of the coral islets comprising the Eloaua-Emananus atoll, is situated between the two larger islands along the south edge of the lagoon (Figure 4.1). We reconnoitered the islet in 1986 and 1988, discovering a small shell midden eroding out of the eastern sand spit. The islet is low, with a maximum elevation of only about 1 m above sea level. The islet's interior is relatively flat and open, shaded with a canopy of large trees (*Pisonia grandis*) in which a population of frigate birds (*Fregata* sp.) roosts, resulting in a surface deposit of guano over the islet's interior. There are numerous coconut palms and, near the eastern end of the islet, some fruit trees (*Pangium edule*, *Terminalia catappa*). Some croton hedges in this area were said to mark a traditional burial ground ("ples matmat" in New Guinea pidgin).

Erosion of the seaward coast had exposed a shell midden deposit along the southeast tip of the islet (UTM coordinates 790900E 9826000S). The midden was dominated by large *Hyotissa hyotis* oysters, *Chama* sp., and *Tridacna* spp., much of the shell being burned. Volcanic oven stones were observed in the eroded midden bank. John Saupa of Emananus said that there had formerly been a small group of houses located here, suggesting there had formerly been a small hamlet, which might date to the late prehistoric to early post-contact periods. On September 30, Jason Tyler excavated a single 1 m^2 test excavation into the highest part of the eastern spit, near where the shell midden was actively eroding. Because the deposit was essentially uniform throughout, excavation was conducted in arbitrary 20 cm levels. The deposit consisted of a brown (10 YR 5/3) calcareous sand. The only artifact recovered was a single fragment of bottle glass, 30 cm below surface. No bone, pottery, or obsidian was present. The shell midden was densely concentrated, totaling 24.85 kg for the entire unit, and much of this showed evidence of having been burned, presumably through cooking the mollusks on open fires. Volcanic and burned coral oven stones were also present.

A complete valve of *Spondylus* sp. bivalve from Level 4 was submitted for radiocarbon dating, in order to assess the maximum age of the midden deposit. This shell yielded a conventional age of 330 ± 60 BP (Beta-30695), calibrated to 411–0 BP (2σ).

The EKL test excavation confirmed that this shell midden deposit is entirely of historic (post-European contact) age, and was probably just a small hamlet, possibly occupied by a single extended household. The dominant shell midden suggests that the site was occupied prior to the conversion of the Mussau islanders by the Seventh-Day Adventist mission in 1930, because shellfish eating was prohibited by the missionaries. The radiocarbon date and the single piece of historic glass would be consistent with an occupation date in the early colonial period, approximately 1900–1930.

The Sinakasae Site (EKU), Mussau Island

Sinakasae is the name of a small hamlet situated on an upraised limestone terrace on the southeastern end of Mussau Island, near the larger settlement of Lomakanauru (UTM coordinates 798600E 9831400S). The site largely corresponds to this hamlet, with a scatter of sherds, obsidian, shellfish midden, and *Tridacna*-shell and *Terebra*-shell adzes covering an area of about 2.1 ha. The site was brought to our attention by Mr. Aimalo Lavatea, who had collected a handful of potsherds on the surface.

The sherds were clearly not Lapita ware; moreover, they were in association with *Terebra*-shell adzes, which we had recovered only from sites of post-Lapita age. During the 1986 field season, Terry Hunt excavated five 1 m^2 test units along a single north–south transect positioned across the area with the greatest surface artifact density. Transect units were spaced at 10 m intervals. Stratigraphy was consistent across all transect units, and consisted merely of two layers:

> Layer I: 0–15/28 cm below surface. A black (5Y2.5/1), organically enriched loam (A horizon) and garden soil, with abundant shell midden and charcoal. The boundary with Layer II is diffuse.
>
> Layer II: 15/28 cm to base of excavation. A yellowish brown (10YR5/4) sandy loam with angular cobbles and outcrops of decomposing limestone; culturally sterile.

Layer I clearly represents an in situ occupation that has been somewhat mixed and reworked due to gardening. The shallow depth (average 25 cm) suggests that the occupation was not lengthy.

A combined sample of mammal bone (almost certainly *Sus scrofa*) from Units 2 and 5 was submitted to Beta Analytic for radiocarbon dating, yielding a conventional radiocarbon age of 740 70 BP (Beta-25930), with a calibrated age range of 796–551 BP (see Chapter 5). This confirms that site EKU postdates the Lapita period, indicating an early second millennium AD age for its occupation. This is consistent with evidence from the EKE (Boliu Is.) site for the use of *Terebra*-shell and *Tridacna*-shell adzes during this time period, along with small quantities of dark red pottery.

The ceramics from EKU are described in Chapter 11. They consist of sherds with a dark red paste and a black pyroxene temper. Decorations on some sherds consist of parallel rows of simple tool-impressed rectangular punctations. Aside from the *Tridacna*-shell and *Terebra*-shell adzes already noted, the site is noteworthy for considerable quantities of pig bone.

CHAPTER 5

Radiocarbon Dating and Chronology of the Mussau Sites

Patrick Vinton Kirch

At the commencement of the Lapita Homeland Project in 1985, the chronology of Lapita in the Bismarck Archipelago was an unresolved issue urgently requiring new data. The only Lapita site in the Bismarck Archipelago that had been radiocarbon dated was ECA on Eloaua Island, with two dates having been obtained by Brian Egloff from his limited test excavations (Bafmatuk et al. 1980). The fact that the two dates gave wildly different results of 3900 ± 260 and 3300 ± 180 BP (see Chapter 1)—even though the samples had been obtained from the same putative "coral oven"—clearly indicated that both could not be valid. Nonetheless, the older date was given substantial weight in arguments that the Lapita phenomenon had a long period of gestation in the Bismarck Archipelago (e.g., Allen 1984:194; Anson 1986:164). Consequently, a major objective of our work in Mussau in 1985 and subsequent field seasons was to obtain a series of stratigraphically well-contextualized samples that could be radiocarbon dated and provide a firm chronology both for the Mussau Lapita sites and for the post-Lapita sites that we also investigated.

By the conclusion of the 1988 field season, we had obtained and submitted for radiocarbon dating a total of 51 samples, 30 of these from Talepakemalai (Kirch 2000:Table 10.1). Because many of the Mussau sites lacked suitable charcoal for dating, especially ECA (due to its unique waterlogged nature), we had to depend extensively on the dating of marine shells, with fully 33 of the 51 dated samples being of shell. As these samples were dated prior to the development of accelerator mass spectrometry (AMS) radiocarbon dating, we were constrained by limitations on sample size, ruling out the dating of small samples of charcoal or nut shell. Moreover, in the late 1980s the precision of radiocarbon dating was at best on the order of ± 70 years (at 1σ), with many of the Mussau radiocarbon dates having 1σ standard errors on the order of ± 160 or even, in one case, of ± 230 years.

In spite of such limitations, the dates obtained for the Mussau sites led to a major advance in our understanding of Lapita chronology in the Bismarck Archipelago. The Mussau sites were, of course, not the only Bismarck

Archipelago Lapita assemblages to be investigated and dated during the Lapita Homeland Project; important suites of dates were obtained from excavations at Watom (Green and Anson 1987), the Arawe Islands of West New Britain (Gosden et al. 1989), and Lasigi on New Ireland (Gosden et al. 1989). Drawing upon the newly obtained radiocarbon dates from the 1985 excavations in Mussau, Kirch and Hunt (1988a) rejected Egloff's anomalous date of 3900 ± 260 from ECA, citing the new date of 3260 ± 90 BP (ANU-5080, uncalibrated) from Area B as the oldest accepted age for the ECA site (Kirch and Hunt 1988a:18, Table 1; see also Kirch and Hunt 1988b). Shortly thereafter, Spriggs (1990a) synthesized the emerging chronology for Lapita in the Bismarcks, incorporating newly available dates not only from Mussau but also from the Arawe and Watom sites, concluding that "Bismarcks Lapita sites certainly start by about 3450 BP (Mussau) and may well extend back as far as 3850 BP (Manus)" (1990a:20).

Specht and Gosden (1997), drawing in part upon dates obtained from Lapita sites in West New Britain (Arawe and others), exhaustively reviewed the by then fairly extensive suite of radiocarbon dates associated with Lapita in the Bismarck Archipelago. Although they lacked access to the complete set of dates from Mussau (or full details on many of the dated samples), Specht and Gosden questioned the validity of some of the Mussau shell dates, such as those from site EHB (1997:181–184).

> The accepted Lapita starting date of 3450–3550 B.P. is questioned by the results from New Britain. Lapita occupation of the New Britain sites may have begun no earlier than ca. 3300–3200 B.P., somewhat later than in the Mussau group. Given the similarities between the Mussau and Arawe pottery, however, we find this proposition unlikely. On the other hand, if our questioning of the oldest Mussau dates is accepted, Lapita throughout the Bismarcks may have begun about 200–300 years later than currently accepted [1997:187].

Specht and Gosden concluded: "The beginning of Lapita pottery in the Bismarck Archipelago thus cannot be placed reliably earlier than about 3300–3200 BP, certainly not as early as the 3550 BP date preferred by Kirch and Hunt" (1997:189). Summerhayes (2001b), analyzing a series of dates from the Arawe and Anir Lapita sites, concurred with Specht and Gosden's conclusions, arguing for "Early Lapita ranging from about 3350 BP to 3000/2900 BP" and for a "later Middle Lapita beginning from 2900 BP" (2001b:34-35).

In the 2001 Mussau site report, Kirch provided an exhaustive presentation of the 51 radiocarbon dates we had by then obtained, including all relevant details on the samples and their stratigraphic contexts (Kirch 2001b). These details addressed the critique of Specht and Gosden (1997), demonstrating that all of the marine shell samples showed clear indications of having been collected on the reef or in the lagoon while living, and were not the result of natural beach deposition (Kirch 2001b:197). After a thorough review of these dates, including the complex issues of calibration (especially of the shell dates), Kirch advanced several conclusions: (1) that the Lapita period in the Mussau Islands spans a period of at least 500 years; (2) that Lapita settlements had been emplaced on Eloaua by around 1400–1300 cal BC; (3) that the later ECA Area C and EKQ site assemblages dominated by incised ceramics dated to around 800 cal BC; and (4) that the post-Lapita, aceramic sites such as EHK, EKS, and EKU (and portions of EKE) dated to not earlier than AD 500 (Kirch 2001b:219).

Debate over the chronology of Lapita in the Bismarcks as well as the timing of its expansion into Remote Oceania has continued, with periodic reassessments, although relatively few additional dates have been obtained from the Bismarck region (but see Summerhayes et al. 2010 for new dates from the EQS site on Emirau Is.). The discussion has revolved around issues of calibration, such as the appropriate ocean reservoir offset value (ΔR) to be used for calibrating marine shell samples (Summerhayes 2007a; Petchy and Ulm 2012), and most recently around the application of Bayesian calibration methods (Denham et al. 2012; Rieth and Athens 2017). Applying Bayesian calibration to the radiocarbon dates available for Bismarck Archipelago Lapita sites, Denham and others (2012) concluded that: (1) "the earliest Lapita pottery in Mussau dates to *3470–3250 cal BP* (68.2%)"; (2) "the inception of Lapita pottery in the Bismarck Archipelago (excluding Mussau) is *3360–3240 cal BP* (68.2%)"; and (3) "the Mussau dates are suggestive of Lapita pottery being earlier there than elsewhere" in the Bismarcks, by a time factor of possibly as much as two centuries although probably shorter (2012:43–44). Specht and others (2014:95) in a review of the Lapita cultural complex accepted this 3470–3250 BP time frame for the inception of Lapita in Mussau.

More recently, Rieth and Athens (2017) also applied Bayesian calibration to the available dates from Mussau, using an updated version of the Oxcal calibration program and applying the revised ΔR value calculated by Petchy and Ulm (2012) to the marine shell dates.

> The Mussau Group has been recognized as having the earliest Lapita sites in the Bismarcks, designated ECA and ECB on Eloaua (Kirch 2001b). This assessment is supported by Denham et al.'s (2012) Bayesian analysis, which is based on charcoal and wood-derived radiocarbon determinations. We included charcoal and wood ages along with marine shell determinations from Kirch's (2001) excavations, as well as two determinations obtained more recently by Summerhayes et al. (2010) from Emirau. These ages (N = 26) were calibrated in a single-phase model for the island group. Shell dates were calibrated using Petchey and Ulm's (2012) ΔR of −293 ± 92. Our results indicate Lapita occupation began sometime during *3535–3234 (95% probability)* or likely *3453–3283 (68% probability)*. At 68%, our results are essentially the same as Denham et al.'s favored estimate (*3470–3250 cal BP, 68.2% probability*), while our 95% probability results remove over 100 years from their estimate (*3590–3110 cal BP, 95.4% probability*) [Rieth and Athens 2017:10–11].

In light of this continuing debate over the chronology of Lapita in the Bismarck Archipelago, it became apparent that renewed radiocarbon dating of Talepakemalai and other Mussau sites—using high-precision AMS dating and applying Bayesian calibration—was necessary. Drawing upon the curated collections from Mussau, 24 new samples, primarily from ECA but also from sites ECB, EHB, and EKQ, were selected for dating (Table 5.1). This chapter analyzes the full corpus of 75 radiocarbon dates now available for Mussau, including the 24 new AMS dates presented here for the first time, applying Bayesian calibration to subsets of this corpus in order to model and refine the chronology of Lapita and post-Lapita sites in Mussau.

Table 5.1. Radiocarbon age determinations from Mussau sites

Site	**Non-AMS Age Determinations**				**AMS Age Determinations**				**Total**
	Charcoal	**Wood**	**Marine Shell**	**Other**	**Charcoal**	***Canarium* or *Cocos* Nutshell**	**Wood**	**Marine Shell**	
ECA	6	8	15	1		13	5		48
ECB	1		2		2				5
EHB			2					1	3
EKQ			5					3	8
EKU				1					1
EKO			1						1
EKS	1								1
EHK			2						2
EKE			5						5
EKL			1						1
Total	8	8	33	2	2	13	5	4	75

The Mussau Radiocarbon Corpus

In selecting samples for dating in 1985–1988, priority was given to wood charcoal or to non-carbonized wood (such as the stilt-house post bases in Areas B and C of the Talepakemalai site) or other organic material (such as coconut endocarp) when these were available (in this pre-AMS era of the late 1980s, non-carbonized vegetative matter required large sample sizes, so the dating of small seeds or nuts was not feasible, as it later became with the advent of AMS dating). Unfortunately, however, charcoal or wood were not as common in the Mussau archaeological deposits as they are in some other Pacific islands contexts. At Talepakemalai and other Mussau Lapita sites, this partly reflects the nature of the Lapita occupation on stilt houses, where hearths, earth ovens, or similar combustion features are absent. As a result, only 17 of the initial suite of 51 dates from Mussau are on charcoal (8 samples), wood (8 samples), or coconut endocarp (1 sample). The other 34 samples are all of marine shell and, in one case (from the EKU site), mammal bone (presumed to be *Sus scrofa*).

The marine shells selected for radiocarbon dating are all of shallow-water bivalve and gastropod species that exhibited signs of having been collected for food and/or for industrial purposes by the ancient Mussau inhabitants. Species used in dating include the large bivalves *Tridacna* spp. (8 samples) and the closely related *Hippopus hippopus* (3 samples), *Hyotissa hyotis* (7 samples), *Spondylus* sp. (3 samples), *Anadara antiquata* (2 samples), *Chama* sp. (2 samples), and *Laevicardium* sp. (1 sample), along with the gastropods *Turbo* spp. (5 samples) and *Strombus luhuanus* (1 sample). While it might have been preferable to select only a single taxon of marine shell for dating at all sites, this was not possible as good specimens of midden shell or industrial detritus from a particular context that we wished to date did not always include a preferred species. Whenever possible, we chose the large bivalves *Tridacna* spp., *Hippopus hippopus*, or *Hyotissa hyotis*. All of these taxa were important food sources, and some (such as *Tridacna*, *Spondylus*, and *Turbo*) were also used as raw materials for manufacturing artifacts.

In selecting shell samples for dating, we rejected specimens exhibiting signs of water-rolling or weathering, which might have been a component of the natural beach or lagoon-floor environment. We are reasonably confident that all dated shell samples were originally *gathered while live* on the Mussau reefs, either for food or for raw material, and were *culturally deposited* in their respective sites. Consequently, these shell dates should not have any significant "in-built age" factor. That is to say, the dated age of the shell should closely approximate the time period at which the living mollusk was procured and taken from its marine habitat to an occupation site.

Laboratory methods, as reported by the ANU and Beta Analytic, Inc. labs respectively, were standard. The ANU lab reported that the 1985 charcoal samples were examined for rootlets, treated with hot 10% HCl, rinsed, and dried; shell samples were cleaned of their exterior surfaces with a dental drill and crushed before combustion. For the wooden posts from ECA Area B, the slightly degraded exterior surface of the wood was first scraped clean, followed by the removal of a piece of the outer 1–2 cm of solid wood; this was chopped into small fragments, washed with distilled water, and the cellulose extracted for dating. The Beta Analytic, Inc. laboratory, which dated samples from the 1986 and 1988 excavations, pretreated charcoal samples by first examining them for rootlets, followed by a hot acid wash to eliminate carbonates, rinsing to neutrality, with a subsequent hot alkali soaking to remove humic acids. After rinsing to neutrality, another acid wash was followed by another rinsing to neutrality. Shell samples were pretreated by etching away the outer layers with dilute acid; they were then attacked with further acid to produce carbon dioxide, which was used as the carbon source for dating. All benzene syntheses and counting proceeded normally.

Thirty non-AMS radiocarbon dates run between 1985 and 1988 on samples excavated from Talepakemalai are listed in Table 5.2, along with details on provenience and dated material. An additional 21 non-AMS dates from nine other sites are reported in Table 5.3, again with details of provenience and material.

In 2016, having decided that additional new AMS radiocarbon dates would be essential to resolve the issues regarding the chronology of Talepakemalai and other Mussau sites, I contacted Dr. John Southon at the Keck Carbon Cycle Facility at the University of California, Irvine, who agreed to undertake the analysis of the Mussau samples. For this new set of dates, priority was placed on short-lived

Table 5.2. Non-AMS radiocarbon dates from site ECA

Lab No.	Area	Unit	Level	Zone	Dated Material	δ^{13}C*	Conventional ^{14}C Age	±	Calibrated Age Range BP, 2σ (95.4%)**
ANU-5075	B	W200N149	7	C1	Finely dispersed charcoal	-24.0	2370	120	2742–2151
ANU-5076	B	W200N151	8	C1	Finely dispersed charcoal	-24.0	2430	230	3057–1928
ANU-5077	B	W201N151	9	C1	Finely dispersed charcoal	-24.0	2450	160	2868–2124
ANU-5078	B	W199N150	18	C2–3	Finely dispersed charcoal	-24.0	2600	160	3140–2325
ANU-5079	B	W200N150	12–13	C1	Finely dispersed charcoal	-24.0	2840	115	3323–2751
ANU-5080	Airfield	W400N72 (TP-9)	6		Wood charcoal	-24.0	3260	90	3702–3252
ANU-5081	B	W200N151	11	C3	*Tridacna gigas* shell	0.0	3010	80	3008–2606
ANU-5082	B	W201N149	12	C3	*Hyotissa hyotis* shell	0.0	2950	80	2915–2482
ANU-5083	B	W200N149	3	B1	*Hyotissa hyotis* shell	0.0	2810	80	2725–2345
ANU-5084	A	W228N102	3		*Tridacna gigas* shell	0.0	3190	80	3204–2780
ANU-5085	A	W229N100	9		*Hyotissa hyotis* shell	0.0	3130	80	3129–2743
ANU-5790	B	W200N150	Post 1		Wooden post, *Intsia bijuga*	-24.0	2950	80	3344–2885
ANU-5791	B	W199N151	Post 2		Wooden post, *Intsia bijuga*	-24.0	2930	80	3335–2869
Beta-20451	W200T	W200N120	9		Non-carbonized *Cocos nucifera*	-24.0	2950	70	3339–2892
Beta-20452	B	W198N145	Post 30	C3	Wooden post	-24.0	3050	70	3442–2885
Beta-30673	B-ext	W201N145	6	C1	*Spondylus* sp. shell	+0.6	3110	70	3077–2736
Beta-30674	C	W249N188	2		*Hippopus hippopus* shell	+1.0	3110	70	3077–2736
Beta-30675	C	W249N188	4		*Tridacna derasa* shell	+1.9	3110	80	3108–2730
Beta-30676	W250T	W250N90	2		*Turbo marmoratus* shell	+1.9	3590	110	3790–3225
Beta-30677	W250T	W250N100	2		*Spondylus* sp. shell	+1.2	3170	70	3155–2780
Beta-30678	W250T	W250N110	4		*Chama* sp.shell	+2.1	3190	80	3204–2780
Beta-30679	W250T	W250N100	15		*Tridacna gigas* shell	+2.3	3080	70	3041–2722
Beta-30680	W250T	W250N120	6		*Chama* sp.shell	+2.8	3320	80	3365–2942
Beta-30681	W250T	W250N120	9		Wooden post	-30.5	2860	60	3167–2844
Beta-30682	W250T	W250N140	6		Wooden post	-28.1	2970	50	3330–2971
Beta-30683	W250T	W250N150	7		*Hippopus hippopus* shell	+2.7	3140	80	3139–2748
Beta-30684	W250T	W250N170	3		Wooden stake	-28.6	3100	110	3563–3002
Beta-30685	C	W250N188	2		*Hyotissa hyotis* shell	+1.8	2770	70	2693–2332
Beta-30686	C	W250N188	Post 3		Wooden post, *Diospyros* sp.	-24.5	2850	70	3164–2793
Beta-30687	C	W250N191	Post 20		Wooden post, *Intsia bijuga*	-27.3	2600	60	2850–2490

* Values of 0.0 were estimated by the Australian National University laboratory.
** Calibrations for wood and nut shell based on IntCal13 calibration curve; calibrations for marine shell based on Marine13 calibration curve, with ΔR= -250 ± 92. All calibrations generated with Oxcal version 4.3.

Table 5.3. Non-AMS radiocarbon dates from other Mussau sites (ECB, EHB, EKQ, EKU, EKO, EKS, EHK, EKE, and EKL)

Lab No.	Site	Unit	Level	Dated Material	$\delta^{13}C$*	Conventional ^{14}C Age	±	Calibrated Age Range BP, 2σ (95.4%)**
ANU-5086	ECB	TP1	1	*Hyotissa hyotis* shell	0.0	3120	80	3515–2894
ANU-5087	ECB	TP1	2	*Hyotissa hyotis* shell	0.0	3150	80	3556–2936
Beta-20453	ECB	TP9	5	Unidentified wood charcoal	-24.0	3200	70	3610–3227
ANU-5088	EHB	TP1	9	*Tridacna gigas* shell	0.0	3470	90	3980–3339
ANU-5089	EHB	TP2	6	*Hyotissa hyotis* shell	0.0	3380	90	3867–3222
Beta-20454	EKQ	TP1	11	Unidentified marine shell	-0.49	3280	70	3709–3117
Beta-21789	EKQ	TP2	17	Marine shells	-0.1	3030	80	3391–2796
Beta-25036	EKQ	TP2	3	*Turbo setosus* shell	+1.9	740	70	787–377
Beta-25670	EKQ	TP2	9	*Turbo marmoratus* and *Tridacna maxima* shell	+2.0	3270	80	3706–3078
Beta-25671	EKQ	TP2	13	*Strombus luhuanus* shells (3)	+3.4	3190	90	3617–2960
Beta-25669	EKO	TP1	4	*Turbo marmoratus* shell	+2.3	3200	70	3601–3009
Beta-25930	EKU	TP2, 5	1	Medium mammal (*Sus scrofa*?) bone	-22.1	740	70	796–551
Beta-20455	EKS	TP2	5	Unidentified wood charcoal	-24.0	350	60	507–302
Beta-30688	EHK	E300N300	1	*Anadara antiquata* shell	+1.1	1080	60	1111–664
Beta-30689	EHK	E300N300	3	*Anadara antiquata* shell	+0.9	1560	70	1626–1122
Beta-30690	EKE	E200N175	1	*Tridacna maxima* shell	+2.2	910	70	927–524
Beta-30691	EKE	E200N175	3	*Tridacna maxima* shell	+2.1	870	60	894–512
Beta-30692	EKE	E200N175	6	*Tridacna gigas* shell	+2.5	1140	60	1174–705
Beta-30693	EKE	E200N175	9	*Hippopus hippopus* shell	+2.7	3420	70	3887–3318
Beta-30694	EKE	E200N200	5	*Laevicardium* shell	+2.7	540	70	629–149
Beta-30695	EKL	TP1	4	*Spondylus* shell	+1.5	330	60	411–0

* Values of 0.0 were not measured but only estimated by the Australian National University laboratory.
** Calibrations for wood and nut shell based on IntCal13 calibration curve; calibrations for marine shell based on Marine13 calibration curve, with ΔR= -250 ± 92. All calibrations generated with Oxcal version 4.3.

plant taxa, especially the hard endocarps (nut shells) of *Canarium indicum* (11 samples), endocarps of coconut (*Cocos nucifera*, 2 samples), and non-carbonized wood including two wooden post bases (Posts 3 and 30 from ECA, see Chapter 3). The advantage of dating *Canarium* nuts and coconut shell is that these are cultivated, annual fruits that should have zero in-built age. For site ECB, two samples of wood charcoal were dated, although lacking a reference collection for New Guinea region woods these could not be identified to taxon prior to dating; consequently, some in-built age may be associated with these dates. For the EHB and EKQ sites, only marine shell samples were available and were accordingly dated (4 samples); as with previously dated marine shell, these samples exhibited indications of cultural gathering and deposition. In all, 24 new samples were dated, all with standard errors of ± 15 years. The details of these AMS-dated samples are provided in Table 5.4. Laboratory protocols for the Keck Carbon Cycle Facility are provided on the Facility's website (https://sites.uci.edu/keckams/protocols/).

Table 5.4. High-precision AMS radiocarbon dates from sites ECA, ECB, EHB, and EKQ

Lab No. UCIAMS-	Site/Area	Unit	Level or Feature	Zone	Dated Material	$\delta^{13}C$	Conventional ^{14}C Age	±	Calibrated Age Range BP, 2σ (95.4%)*
176077	ECA	W200N120	11		*Canarium* nut shell	-28.8	3030	15	3329–3171
176078	ECA	W200N170	9		*Canarium* nut shell	-28.3	2580	15	2751–2722
176079	ECA, B-ext	W200N144	9	C3	*Canarium* nut shell	-29.5	2900	15	3136–2963
176080	ECA, B-ext	W200N145	9	C3	*Canarium* nut shell	-29.9	2990	15	3218–3079
176081	ECA, B-ext	W201N145	9	C3	*Canarium* nut shell	-27.5	2895	15	3073–2962
176082	ECA	W250N110	13		*Canarium* nut shell	-26.1	2975	15	3209–3076
176083	ECA	W250N130	13		*Canarium* nut shell	-26.4	3000	15	3233–3081
176084	ECA, C	W251N190	4		*Canarium* nut shell	-26.7	2660	15	2782–2750
176085	ECA, C	W251N190	7		*Canarium* nut shell	-28.0	2760	15	2919–2790
176086	ECA, C	W250N191	6		*Canarium* nut shell	-30.1	2720	15	2853–2775
185970	ECA	W250N110	Post 3		Wood	-29.5	2980	15	3211–3077
185971	ECA	W250N110	14		*Cocos nucifera*, non-carbonized	-24.2	2970	15	3206–3075
185972	ECA	W250N130	6		Twig-sized wood	-31.2	2935	15	3160–3005
185973	ECA	W250N130	9		*Cocos nucifera*, non-carbonized	-26.2	2980	15	3211–3077
185974	ECA	W250N130	10		*Canarium* nut shell	-27.0	2965	15	3205–3070
185975	ECA	W250N140	7		Non-carbonized wood	-25.7	2915	15	3144–2980
185976	ECA	W250N160	10		Tip of small wooden post	-28.0	2830	15	2975–2872
185977	ECB	TP9	3		Wood charcoal, species not identified	-26.2	3295	15	3570–3475
185978	ECB	TP10	4		Wood charcoal, species not identified	-25.8	3300	15	3570–3478
185995	EHB	TP1	7		*Trochus niloticus* shell	2.6	3445	15	3847–3382
185996	EKQ	TP1	5		*Turbo argyrostomus* shell	2.5	2945	15	3234–2762
185997	EKQ	TP1	8		*Turbo argyrostomus* shell	2.7	3090	15	3410–2929
185998	EKQ	TP1	17		*Tridacna crocea* shell	2.4	3265	15	3626–3161
207948	ECA, B		Post 30		Wood	-27.9	2945	15	3168–3036

* Calibrations for wood and nut shell based on IntCal13 calibration curve; calibrations for marine shell based on Marine13 calibration curve, with ΔR= -250 ± 92. All calibrations generated with Oxcal version 4.3.

Calibration Procedures and Bayesian Modeling

The calibration of wood, nut shell, and charcoal dates, as reported in Tables 5.2 to 5.4, was carried out with Oxcal version 4.3 (Bronk Ramsey 2009), using the IntCal13 atmospheric calibration curve (Reimer et al. 2013). As Mussau is situated barely 1° south of the equator, it was not appropriate to use the southern hemisphere correction.

The calibration of samples grown in a marine environment (such as mollusks) presents additional problems not present with wood or charcoal samples; this is because marine contexts are typically not in isotopic equilibrium with atmospheric ^{14}C (Stuiver and Braziunas 1993). The world's oceans are a sink for old carbon, creating a "reservoir effect" (Taylor 1987:126–132), in which marine samples typically yield ages that are somewhat older than their apparent true age. Unfortunately, this reservoir effect is not constant, varying historically over time as well as geographically over space. Oceanic reservoir effects are known to be especially salient along continental coastlines where there is significant upwelling of deep water. Whereas the "model surface ocean" (0–75 m depth) typically yields reservoir ages about 200–400 years older than the atmospheric age, the "model deep ocean" can yield reservoir ages of up to 1,800 years older (Stuiver and Braziunas 1993:Figure 5A).

Determining the specific reservoir effect for any particular marine environment is a complex problem, especially when one takes into account the probability of temporal variation. As Taylor (1987:127) suggests, "one approach to investigating the reservoir effect in marine shells [is] to examine the ^{14}C activity of contemporary samples to determine if the initial ^{14}C concentration in such materials could be significantly different from that of standard terrestrial organics." This requires the radiocarbon analysis of *pre-bomb* shell samples, collected before 1950, after which time the widespread testing of thermonuclear weapons injected large quantities of artificial ^{14}C in the atmosphere. Unfortunately, we are not aware of any such pre-bomb collections of marine shells from Mussau.

Lacking such a direct assessment of the local reservoir effect specific to Mussau, one may apply the generalized "model surface ocean" calibration for marine samples originally developed by Stuiver and colleagues (Stuiver et al. 1986; Stuiver and Braziunas 1993), the latest iteration of which is the Marine13 calibration curve (Reimer et al. 2013). In this model, the "surface ocean" is a zone 0–75 m deep, with the calibration curve being a smoothed version of the atmospheric curve offset by an average age of -373 years from the latter (Stuiver et al. 1986:982). In theory, the application of this marine calibration curve to conventional ^{14}C ages for mollusks or other marine samples grown in the "surface ocean" should bring these ages into line with those from contemporary true-age samples grown in a terrestrial environment. In practice, however, this "surface ocean" model is only a first-order approximation, with well-documented local variations. Where the specific local reservoir effect has been empirically determined through analysis of pre-bomb marine samples, the generalized model may be adjusted through the application of a ΔR correction factor, which either adds to or subtracts from the average -373 year offset of the model calibration curve.

In calibrating marine samples from Lapita and other Oceanic archaeological sites—virtually all of which are from localities where the specific local reservoir effect has not been empirically determined—different investigators have applied varying ΔR values. Kirch and Hunt (1988b:162) used a weighted average of the mid-ocean values from Hawai'i, Eniwetok, and the Society Islands (100 ± 24), while Spriggs (1990a) used a ΔR value of 0 ± 0. Specht and Gosden (1997:177) calibrated a series of ^{14}C ages from the Bismarck Archipelago not using the marine calibration curve at all, but rather the bidecadal atmospheric calibration curve offset by a standard -400 years. (Their method would have roughly the same effect as using the marine calibration curve with ΔR = 0.)

Initial calibration of the Mussau marine shell radiocarbon dates using the standard "model surface ocean" curve produced results that did not correspond well with the dates obtained on wood or charcoal from the same sites (Kirch 2001b). This led Kirch to compare two sets of paired marine and terrestrial samples—from the same stratigraphic contexts—that might enable a determination of the local Mussau ΔR correction. The most secure of these pairs, in that we can be reasonably confident that all samples derive from a tight cluster of behavioral events, consists of two wood and two shell samples from Zone C_3 of Area B, at site ECA (samples ANU-5790, -5791, -5081, -5082). The two wood samples are from posts that were part of the same stilt-house structure; they still retained their bark and had visible adzing marks cutting through the bark, and thus appear to have been cut fresh for construction purposes. The two shell samples (of *Tridacna gigas* and *Hyotissa hyotis* valves) represent culturally deposited midden that accumulated directly around the posts during the initial phase of stilt-house occupation. On archaeological and stratigraphic criteria these four samples represent events that occurred within a short time span, and hence should be of equivalent age. When these paired dates were calibrated on the "model surface ocean" curve with a ΔR value of 0, a very poor fit resulted, with a bimodal probability distribution (Kirch 2001b:Figure 10.1). Stuiver and Braziunas suggested that "with a pair of contemporaneous wood and shell samples from a single location, the reservoir deficiency may be calculated without a direct calibration to the calendar time scale" (1993:152–153), by converting a measured wood ^{14}C age "to a model marine ^{14}C age, which, when deducted from the measured shell ^{14}C age, yields ΔR" (1993:153). Following their method, the mean ^{14}C age of the two Area B wood posts is 2,940 years, which converts to a model marine ^{14}C age of approximately 3,300 years (as calculated on Stuiver and Braziunas' Figure 15B). Deducting this model age from the actual measured ^{14}C ages for the two shell samples, Kirch derived ΔR values of -290 (for ANU-5081) and -350 (for ANU-5082) respectively, or a mean ΔR of -320 years. Recalibrating the calibration of the four paired wood/shell samples from Area B using the atmospheric decadal curve for the wooden posts, and the marine curve with a ΔR value of -320 for the midden shells, a high degree of concordance was obtained between all four samples (Kirch 2001b:Figure 10.2).

A second test was run with a set of three samples from the ECB site, one of which consisted of wood charcoal (Beta-20453), and two of which are valves of the large mollusk *Hyotissa hyotis* (ANU-5086, -5087). In this case the three samples are not from the same excavation unit, but they are from the same stratigraphic context since the ECB site has only a single occupation component. Archaeological evidence (stratigraphic and artifactual) suggests that this small Lapita site was occupied for a relatively short period. As with the previous ECA Area B test pairs, calibration using the model surface ocean curve again produced widely divergent age ranges between the charcoal and marine shell samples. Again applying the method of Stuiver and Braziunas (1993) for the ECB paired samples, Kirch calculated ΔR values of -350 and -370 years, slightly more than those derived in the case of the ECA Area B paired samples (-320).

These two tests with matched sample pairs indicated that the ocean reservoir effect for Eloaua Island was relatively slight, with an offset from the atmospheric curve of perhaps only 50 years. Kirch concluded that applying a standard "model surface ocean" calibration curve was inappropriate, yielding ages that are considerably too young in comparison with wood and charcoal samples that—on independent archaeological/stratigraphic grounds—represent the same events. In the calibration of marine shell dates from Talepakemalai and other sites in the vicinity, Kirch therefore applied a ΔR value of -320 (Kirch 2001b).

The reason for this fairly substantial ΔR offset may have to do with local environmental conditions of the reefs and lagoon of Eloaua and Emananus islands. The "model surface ocean" represents a water body some 75 m thick, incorporating upwelling deep ocean waters which are continually mixed with the surface layer. The marine biological surveys of the Eloaua reefs carried out by C. Catterall (see Chapter 2) showed that the reef flats, seagrass beds, and other microhabitats for *Tridacna*, *Hyotissa*, and other mollusks are typically only about 1–3 m deep, and are frequently exposed or nearly exposed at low tide. Moreover, the tidal range itself is minimal (ca. 1 m), and the wave energy regime unusually low, resulting in a much slower rate of hydraulic exchange between open ocean and reef/lagoon water bodies than would be the case in a higher-energy environment. It seems likely that these biogeochemical conditions of the Eloaua and Emananus inshore environment create a situation in which there is substantial atmospheric isotopic exchange, so that the shallow-water reef organisms are more nearly in equilibrium with atmospheric ^{14}C levels. Of course, this is simply a hypothesis, but in the face of the paired sample tests discussed above, it offers the best available explanation.

While the empirically derived ΔR value of -320 resulted in calibration of marine samples that brought them into correspondence with associated wood, charcoal, and coconut shell samples from the same stratigraphic contexts, this was *not* the case with marine samples from the EKQ rockshelter site on Mussau Island's northwest coast.

Marine shell dates from EKQ exhibit their archaeological "best-fit" calibration—when judged by the criterion of similar ceramic assemblages—when these are calibrated using a value of $\Delta R = 0$. This most likely reflects differences between the kinds of reef environment surrounding Eloaua-Emananus, and those found along the coastal fringe of northwestern Mussau Island where site EKQ is situated. Unlike the broad, shallow, low-energy reef flats of Eloaua, the coastline in the vicinity of EKQ has a narrow fringing reef with a high-energy surge regime (in addition, the dated samples from EKQ were primarily surge-zone gastropods such as *Turbo* spp.). The lack of a barrier reef and lagoon along this coastline probably results in significant upwelling, with the result that this marine environment is more representative of a typical mixed "surface ocean" reservoir condition.

Petchy and Ulm (2012) investigated the issue of spatial and temporal variation in ΔR values across the Bismarcks region, in part through measurement of ^{14}C in known-age, pre-1955 (pre-bomb) marine shell samples, and through consideration of paired charcoal/shell samples from archaeological sites. Their results demonstrate that ΔR varies widely across the region, from as little as 18 ± 100 along the northern coast of New Guinea, to 314 ± 74 at the northern end of New Britain (2012:Figure 1). Petchy and Ulm (2012:Table 2) recalculated a Mussau-specific ΔR value of -293 ± 92, using the same matched pair of wood and shell samples from ECA that Kirch had used to calculate an approximate value of -320 (Kirch 2001b). Rieth and Athens (2017) used the Petchy and Ulm corrected ΔR value in their Bayesian modeling of Lapita appearance in the Bismarck Archipelago.

A slightly revised Mussau-specific ΔR value of -250 ± 92 has been applied for the calibration of marine shell dates in this chapter, based on the two wooden posts from ECA (dates ANU-5790 and -5791), but adding an additional marine shell date (Beta-30673) to the two marine shell dates (ANU-5081 and -5082) previously used to match the wooden post dates. The mean age of the three shell dates, 3023 ± 66 BP, when subtracted from the marine modeled age of the two wooden posts of 3273 ± 72 (as calculated by Petchy and Ulm [2012:Table 2]), yields a revised Mussau-specific ΔR value of -250 ± 92. As will be evident in the site-specific analyses to follow, this value yields calibrated age ranges for the marine shell samples from ECA and other southern Mussau sites that correspond well to the calibrated wood, nut shell, and charcoal age ranges derived from the same archaeological contexts. The exception is site EKQ, where application of the ΔR value of -250 ± 92 yields calibrated age ranges that are too old, when judged by comparison of the ceramic assemblage at EKQ with that from ECA (see Chapter 11). Consequently, for EKQ the marine shell dates have been calibrated with a ΔR of 0 ± 0, which yields results that are consistent with the archaeological ceramic correlations.

Bayesian modeling and calibration of radiocarbon dates has become standard practice in Pacific archaeology (e.g., Allen and Morrison 2013; Athens et al. 2014; Denham et al. 2012; Rieth and Athens 2017). The principal advantage gained through the application of a Bayesian approach is the incorporation of additional key information, especially stratigraphic relationships (Bronk Ramsey 2009; Buck et al. 1999; Hamilton and Krus 2018). Such information as the relative stratigraphic position of dated samples (referred to as *prior* probabilities) is combined in Bayesian modeling with the *likelihood* probabilities resulting from the actual ^{14}C measurements to produce *posterior* probabilities (referred to in Bayesian terminology as "highest posterior density [HPD] regions," see Buck et al. 1999).

The basic principles of a Bayesian calibration model can be summarized as follows. Given a stratum, k, within an archaeological depositional sequence that has one or more associated radiocarbon dates, the time period represented by stratum k can be stated mathematically as α_k minus β_k, where α (or the Alpha parameter) is the early bounding temporal estimate for stratum k, and β (or the Beta parameter) is the later bounding temporal estimate. Individual likelihood estimates are provided by the series of radiocarbon dates (the Theta parameters) associated with stratum k, designated $\theta k_{(1),}\ \theta k_{(2)} \ldots \theta k_{(n)}$, with the relationship between all three kinds of parameters being: $\alpha_k > \theta_{k(1\ldots n)} > \beta_k$. If stratum k directly overlies another stratum j, with abutting stratigraphic contacts and no indication of a hiatus in deposition, then the relationship between those two strata would be specified as:

$$\alpha_j > \theta_{j(1\ldots n)} > \beta_j = \alpha_k > \theta_{k(1\ldots n)} > \beta_k.$$

At site ECA, the application of a Bayesian model is made slightly more complex by the unusual depositional sequence of a temporally prograding shoreline. Rather than a vertically stacked succession of discrete stratigraphic units, such as found in a rockshelter (such as site EKQ), at ECA we have a horizontal progression over the span of approximately 100 m. Despite the absence of discrete strata separated by clear stratigraphic breaks, a Bayesian model is still appropriate and—as will be demonstrated below—results in statistically robust calibrations.

Bayesian modeling of radiocarbon dates from Mussau was conducted using the Oxcal program, version 4.3 (Bronk Ramsey 2009). For dates on terrestrial samples (wood, nut shell, charcoal), the IntCal13 calibration curve was used; for dates on marine shells the Marine13 curve was used, with $\Delta R = -250 \pm 92$, except in the case of site EKQ where no ΔR correction was applied. The process of Bayesian modeling was iterative, beginning with simple, single-phase models (initially keeping terrestrial and marine shell dates in separate models), using Oxcal's Sequence, Phase, and Boundary commands (Bronk Ramsey 2009). For site ECA with its longer and more complex chronology, these single-phase models were then combined into contiguous, multi-phase models for the two main excavation transects (the W200 and W250 transects). All models have agreement indices (A_{model}) greater than 60%. Boundary age ranges (the α and β parameters for each phase) are all reported at two standard deviations (2σ, 95.4% probability).

The Dating and Chronology of Site ECA

As the largest and most complex of the Mussau Lapita sites in Mussau, Talepakemalai (ECA) received the greatest attention in our radiocarbon dating program, with a total of 48 ^{14}C dates (30 initial non-AMS and 18 AMS dates). The dated samples were obtained primarily from the two main excavation transects: 19 dates from the W200 transect, which incorporates the larger excavation blocks of Area B and the Area B extension; and 26 dates from the W250 transect, which incorporates Area C. Two dated samples come from Area A, and one additional sample comes from the airfield excavation unit TP-9 (at W400N72). As discussed in Chapter 3, the W200 and W250 transects exhibit parallel depositional sequences, which are modeled separately below.

Dating of the W200 Transect and Area B, Area B extension

The dated portion of the W200 transect begins with Unit W200N120, proceeds northward to the Areas B and B-extension blocks between N144 and N151, and ends with Unit W200N170 (see Chapter 3). Available dates from the transect include three sets: (1) ten dates on wood or nut shell obtained from the waterlogged deposits (Zones C3-C1 in Area B); (2) four marine shell dates from Areas B and B-extension; and (3) five dates on finely dispersed charcoal recovered within Zone C1 in Area B.

An initial Bayesian model of the wood and nutshell dates was run with the ten dates divided into three phases: (1) the two dates from Unit N120; (2) the Area B and B-extension dates; and (3) the single date from N170. The resulting model has an A_{model} index of 86.9%. Although one date (Beta-20452) has an A value of 58.8%, this is not significantly below the cutoff of 60% and the date was not eliminated from subsequent models. The resulting Oxcal plot of the modeled wood and nutshell dates is shown in Figure 5.1. The earliest N120 phase has a starting boundary age range of 3451–3169 BP, the transitional boundary to the Area B/B-ext phase has a range of 3235–3089 BP, the transitional boundary to the N170 phase is 3070–2812 BP, and the end boundary for the sequence is 2751–2237 BP (all ranges are at 95.4% probability).

The four marine shell dates from Areas B and B-extension were then modeled as a single phase, as shown in Figure 5.2. The model has an A_{model} index of 109.5%. The starting and ending boundary ranges for these four dates are 3887–2839 and 3268–2199 BP respectively, with the modeled ages for individual dates ranging from 3430–2851 BP (Beta-30673) to 3241–2662 (ANU-5083), showing close agreement with the modeled age ranges for the wood and nutshell dates from Areas B/B-ext.

The third set, consisting of five charcoal dates from Zone C1, were modeled as a single phase, as shown in Figure 5.3; agreement was again good with an A_{model} index of 107.5%. The finely dispersed charcoal samples are regarded as having been deposited in Zone C1 at Area B after the stilt house was abandoned, consisting of charcoal that floated and washed in after the stilt-house village had shifted seaward. Thus it is expected that the age range for these charcoal samples should more closely correspond

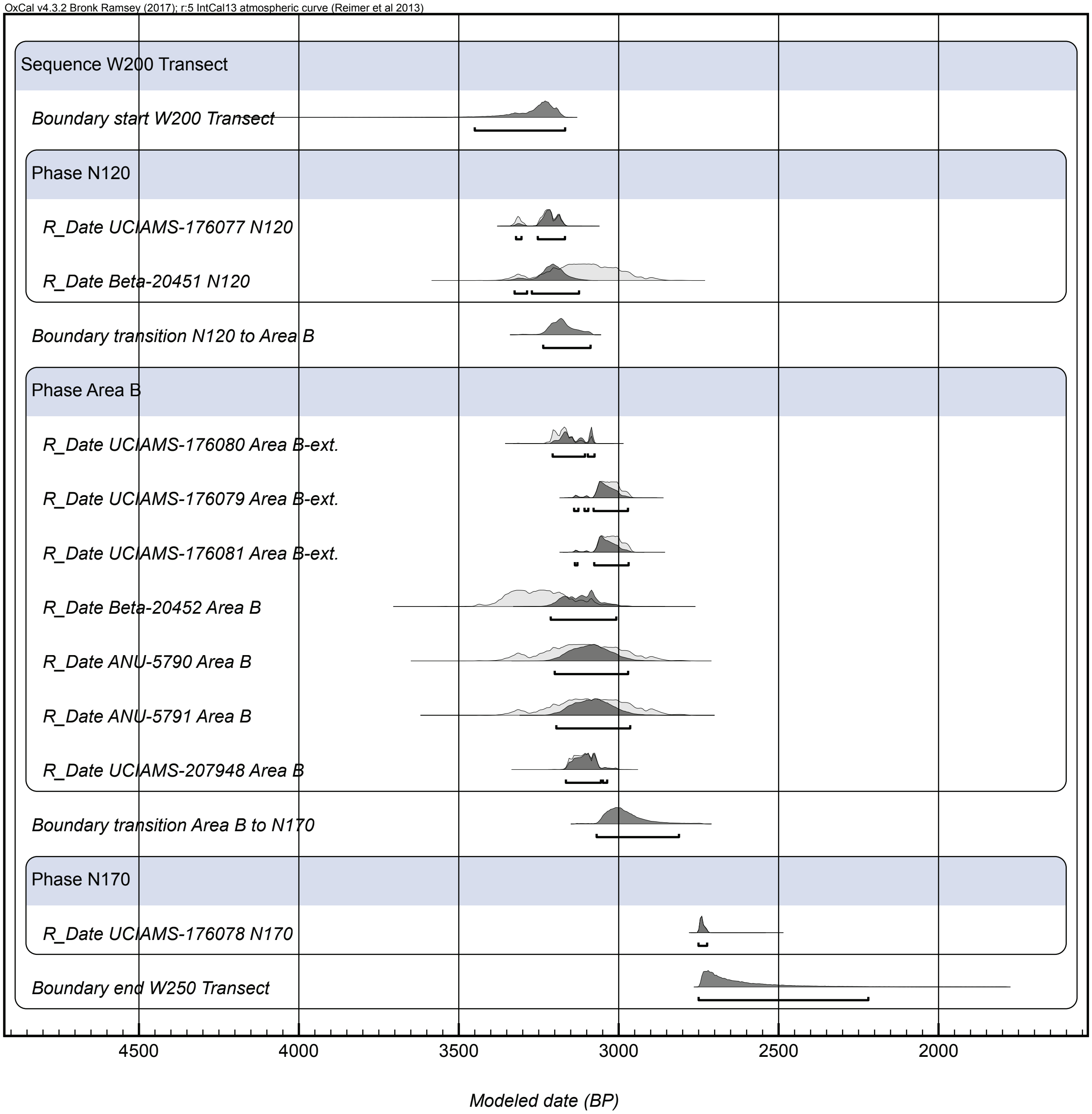


Figure 5.1. Oxcal plot of modeled radiocarbon dates on wood and nut shell from the W200 transect at site ECA.

to the date range for the N170 phase. The start boundary range for the five charcoal samples is 3588–2544 BP and the end boundary range is 2749–1737 BP, with individual modeled dates ranging from 3165–2505 BP (ANU-5079) to 2769–2205 BP (ANU-5075). These age ranges accord well with the modeled age for UCIAMS-176078 from Unit W200N170 of 2751–2724 BP.

The next step in the iterative process of Bayesian modeling was to combine the wood and nutshell three-phase model (Figure. 5.1) with the single-phase marine shell model (Figure 5.2), and with the modeled charcoal dates from Zone C1 (Figure 5.3), to produce an integrated model of the entire W200 transect; the resulting Oxcal plot shown in Figure 5.4. The integrated model groups

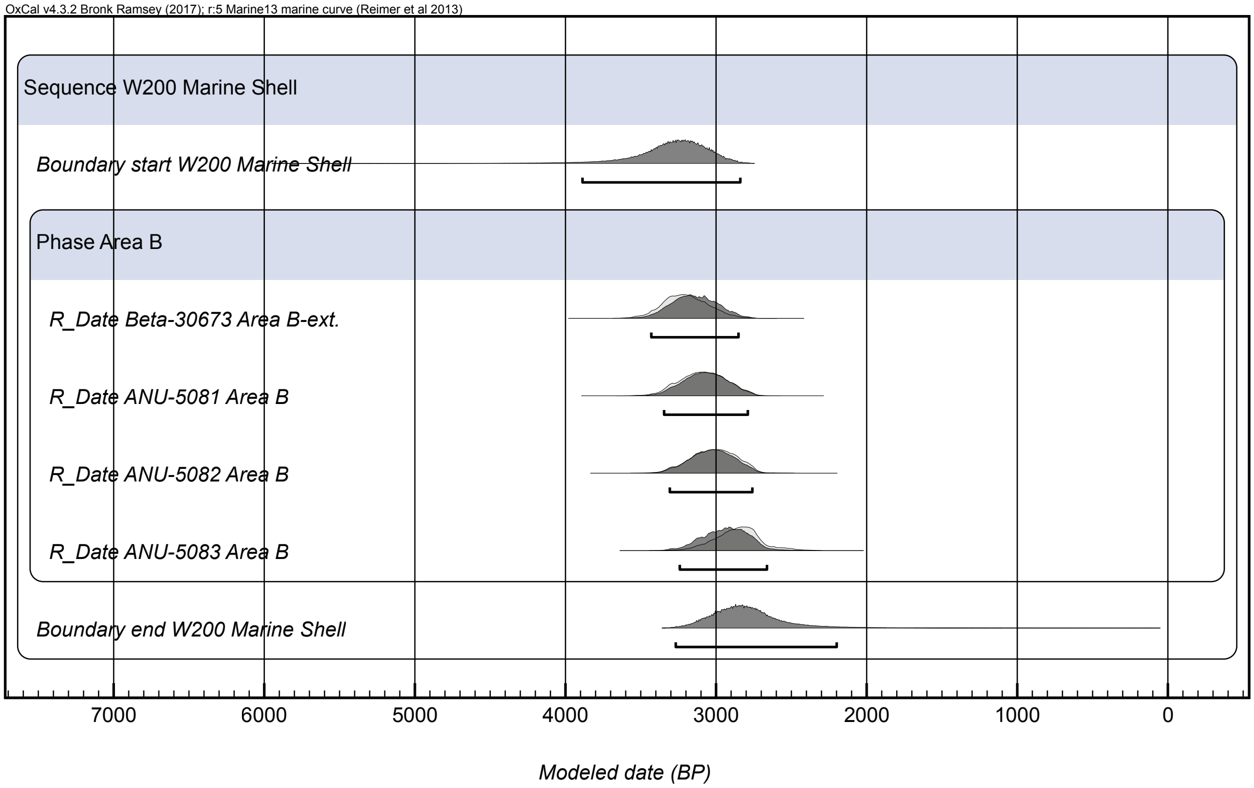


Figure 5.2. Oxcal plot of modeled marine shell radiocarbon dates from Area B at site ECA.

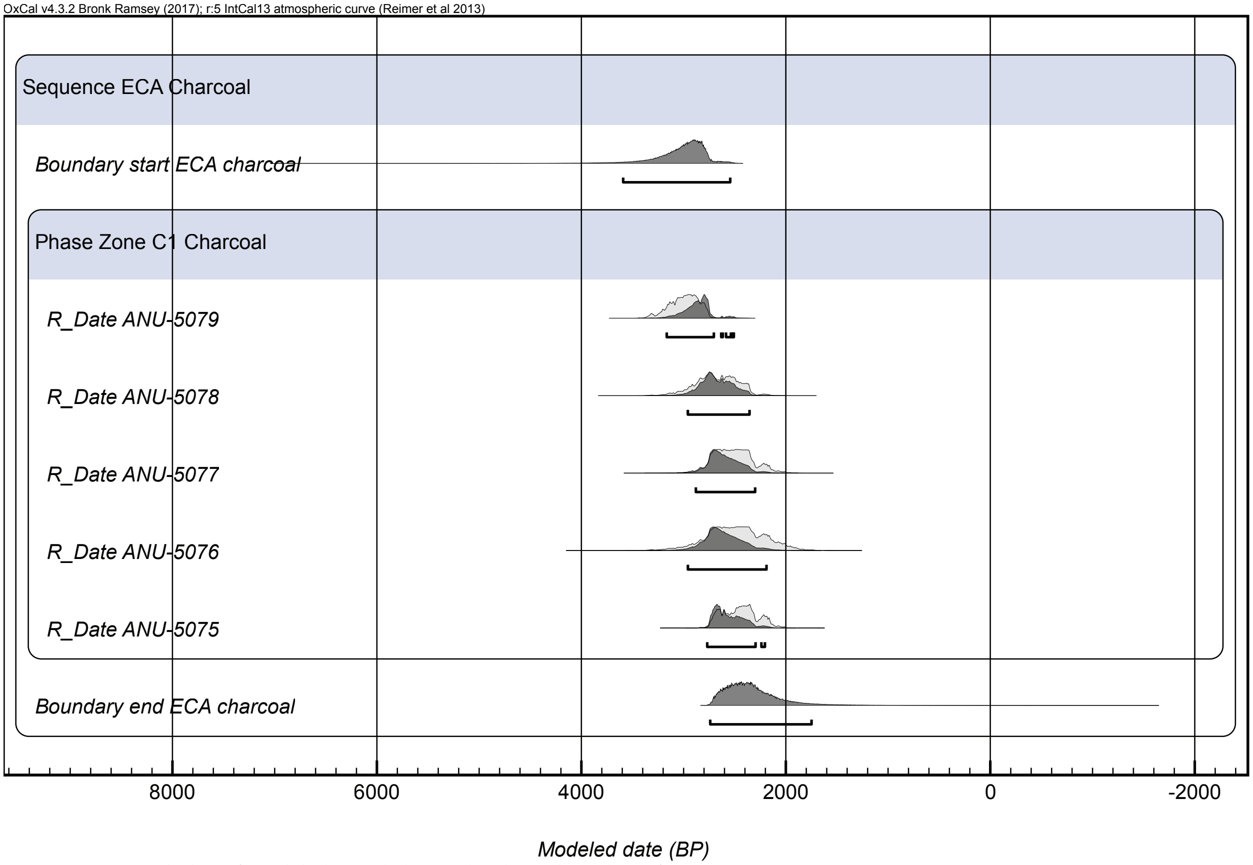


Figure 5.3. Oxcal plot of modeled wood charcoal radiocarbon dates from Area B, Zone C1 at site ECA.

the dates from the W200 transect into five phases: (1) the two dates from the W200N120 unit; (2) the wooden posts of the Area B and B-extension stilt houses, along with one *Canarium* nutshell date (UCIAMS-176080); (3) *Canarium* nutshell and marine shells that accumulated as midden around the stilt-house posts; (4) the Zone C1 charcoal dates; and (5) the *Canarium* nutshell date from W200N170. A first run of this integrated model showed two of the charcoal samples from Zone C1 (ANU-5075 and -5077) as having poor agreement indices (< 60%), so these were eliminated from the model. Marine shell sample ANU-5083 from Zone B1 was also eliminated as it also did not show good agreement. Otherwise, the 16 remaining terrestrial and marine samples were successfully incorporated into the model, with an A_{model} index of 90.6%. The start boundary for the W200 transect sequence is 3375–3169 BP, followed by the transition boundary between W200N120 and Area B posts of 3234–3089 BP, the transition boundary between the Area B posts and the Area B midden accumulation (Zones C3-C2) of 3155–3020 BP, the transition boundary between the Area B midden and Zone C1 of 3061–2836 BP, the transition boundary between Zone C1 and the W200N170 unit of 2919–2724, and finally the end boundary for the W200 sequence of 2753–2521 BP.

Dating of the W250 Transect and Area C

The W250 transect begins at N70 and extends to N200, with radiocarbon dates available from N110 to N191; the transect incorporates Area C with its two blocks spanning the transect from N187 to N191. Twenty-six dates are available from the W250 transect and Area C: (1) 17 dates on wood (primarily wooden posts) and *Canarium* or *Cocos* nutshell; and (2) nine marine shell dates.

A Bayesian model of the wood and nutshell dates was first constructed with two phases: (1) an earlier phase incorporating twelve dates between N110 and N170; and (2) a later phase with six dates from Area C. The resulting Oxcal plot is shown in Figure 5.5. Within the N110-N140 phase the dates are ordered by their position along the W250 transect, from south to north, the direction along which the shoreline gradually prograded. All dates exhibit good agreement, and the model has an A_{model} index of 87.5%. The start boundary for the first phase (N110-N170) is 3302–3150 BP, the transition boundary to Area C is 2993–2834 BP, and the end boundary for Area C is 2791–2543 BP.

A second model was run for the eight marine shell dates, dividing the model into three phases: (1) an earliest phase with one date (Beta-30676) from Unit W250N90; (2) a second phase incorporating dates from N100 to N150; and (3) a late phase with three Area C marine shell dates. Dates within the N100-N150 phase were again ordered from south to north. The model has an A_{model} index of 120.5%; the resulting Oxcal plot is shown in Figure 5.6. For this marine shell dates model, the starting boundary range is 5058–3334 BP, the transition from N90 to the N110-N150 group is 3746–3200 BP, the transition from the N110-N150 phase to Area C has a range of 3478-3017 BP, and the end boundary for Area C is 3218-2092 BP. These broad age ranges reflect the greater standard errors associated with the marine shell dates.

The separate nutshell and wood, and marine shell models for the W250 transect (Figures 5.5 and 5.6) were then integrated into a single three-phase model, the final version of which is shown in Figure 5.7. Construction of this integrated model required several iterations, as initial runs revealed poor agreement between some dates, especially with several of the marine shell dates. To achieve the model shown in Figure 5.7, which has an A_{model} index of 83.7%, it was necessary to remove the following dates: Beta-30674, -30675, -30680, -30683, and -30684, as these all exhibited A values well below the 60% threshold. In addition, UCIAMS-185976, although it is positioned slightly south of Area C (at N160), was shifted to the Area C phase. The integrated Bayesian model for the W250 transect has the following age ranges: start boundary for the transect of 5432–3189 BP; transition boundary from N90 to N100-N140 of 3262–3087 BP; transition from N100-N140 to Area C of 3154–2970 BP; and end boundary for Area C of 2778–2492 BP.

Dating of Area A and the Paleobeach Ridge

Three additional radiocarbon dates are available for site ECA, all from the paleobeach ridge situated south of the Lapita-era shoreline (see Chapter 3). One date (ANU-5080) was on a sample of unidentified wood charcoal excavated in TP-9, one of the initial test pits excavated along the airfield (situated at W400N72). The sample came from the top of Layer II, and is associated with nine potsherds.

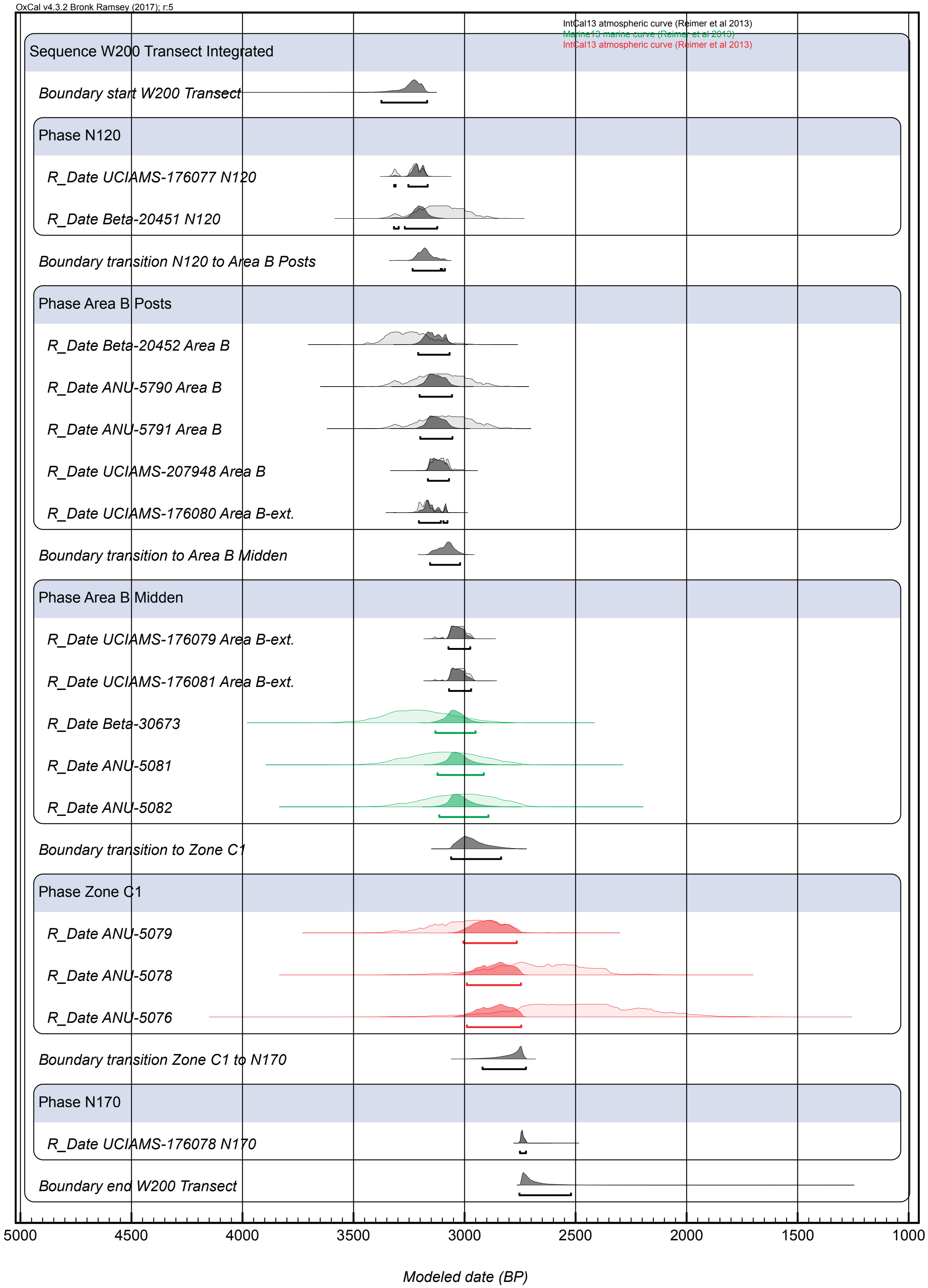


Figure 5.4. Oxcal plot of modeled integrated wood, nutshell, marine shell, and charcoal radiocarbon dates from the W200 transect at site ECA.

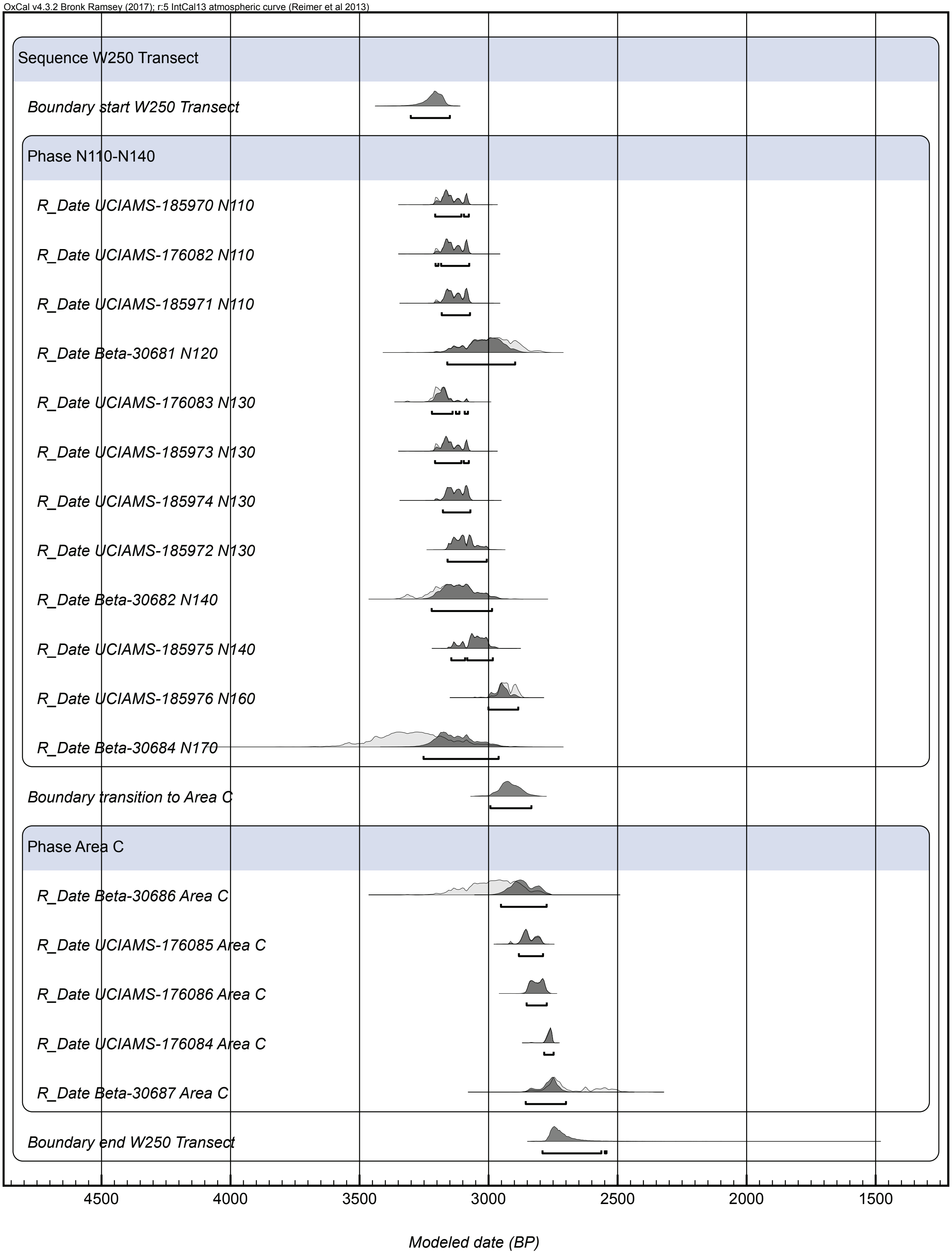


Figure 5.5. Oxcal plot of modeled wood and nutshell radiocarbon dates from the W250 transect at site ECA.

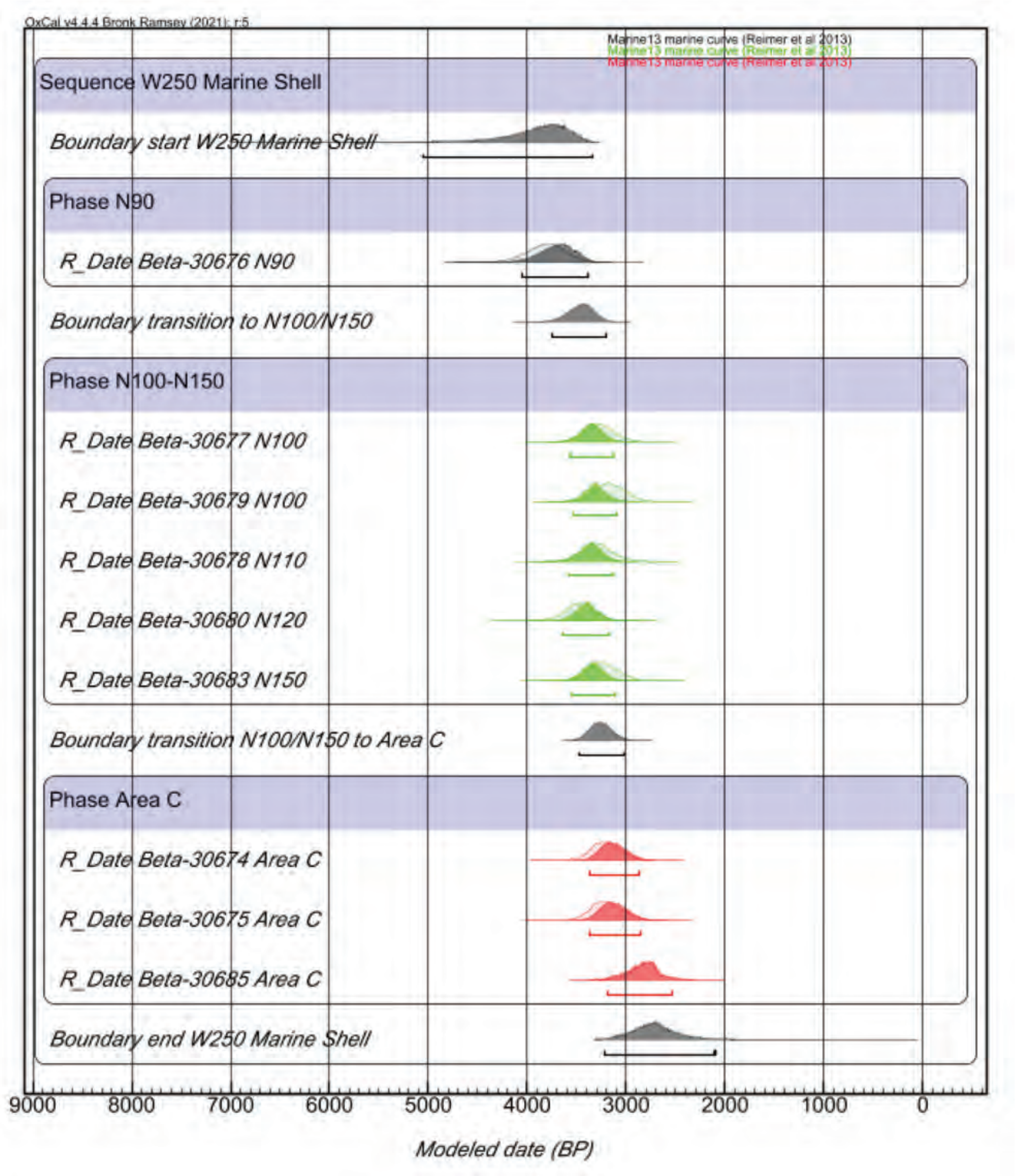


Figure 5.6. Oxcal plot of modeled marine shell radiocarbon dates from the W250 transect at site ECA.

The other two dates are both of marine shells (ANU-5084 and -5085) from the Area A excavation (situated at W228-229/N100-102). As described in Chapter 11, Area A contained almost exclusively reddish plainware sherds from restricted-orifice jars with everted rims, although two sherds with dentate stamping were also recovered. Area A also yielded a substantial number of *Conus*-shell rings (see Chapter 13).

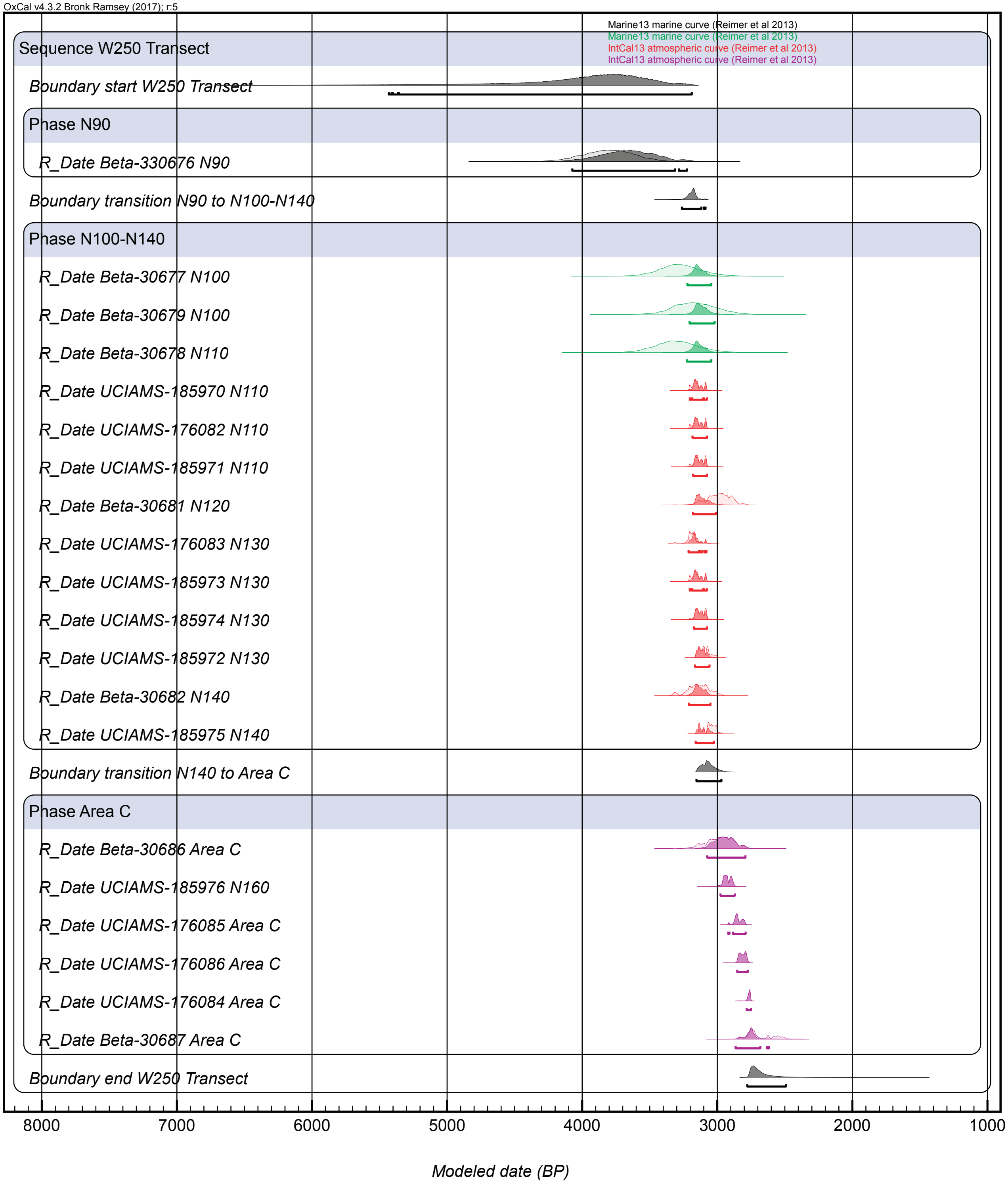


Figure 5.7. Oxcal plot of modeled integrated wood, nutshell, and marine-shell radiocarbon dates from the W250 transect at site ECA.

Although Area A and TP-9 are 172 m apart on an east–west orientation, they are situated on the same geomorphological feature, the paleobeach ridge. Given this depositional context and the fact that the conventional ^{14}C ages from the three samples from Area A and TP-9 are similar, it seemed reasonable to combine them in a single Bayesian model, as portrayed in Figure 5.8. The model has an A_{model} index of 101%. The start boundary range for the three dates is 4407–3218 BP and the end boundary is 3560–2319 BP. For the Area A dates, the modeled ranges are 3601–3105 BP (ANU-5084) and 3577–3052 (ANU-5085). Unfortunately, the large standard errors associated with these dates result in these quite broad age ranges; however, we can infer from the modeled dates that Area A is penecontemporaneous with the earlier part of the ECA sequence, probably overlapping with Zone C3 at Area B. This is an important conclusion, because it indicates that the dominance of plainware sherds at Area A requires a functional—rather than temporal—explanation.

Chronology of the ECA Site

Modeled boundary age ranges (Bayesian α and β parameters) for key components of the ECA site are summarized in Table 5.5. The oldest components of the site are the paleobeach ridge and adjacent waterlogged deposits immediately north of the former shoreline (what we refer to as the "muck zone" in Chapter 3), at N120 on the W200 transect and at N90 on the W250 transect. This is followed by the emplacement of the stilt-house posts at Area B; at the same time other structures were constructed along the middle section of the W250 transect as represented by other posts exposed in the units between N100 and N140. The final phase at ECA is represented by Area C on the W250 transect and by the deposits in the vicinity of N170 on the W200 transect.

The time spans represented by the various phases along the W200 and W250 transects can be estimated by applying the Difference command in Oxcal. For the W200 transect, the time span from the emplacement of the stilt-house posts at Area B to the end of occupation at N170 is modeled at 352–677 years duration. The time span from the emplacement of the Area B posts to the end of midden accumulation in Zones C3-C2 is estimated to have a duration of 83–366 years, while the span from the emplacement of the Area B posts to the end of Zone C1 has a span of

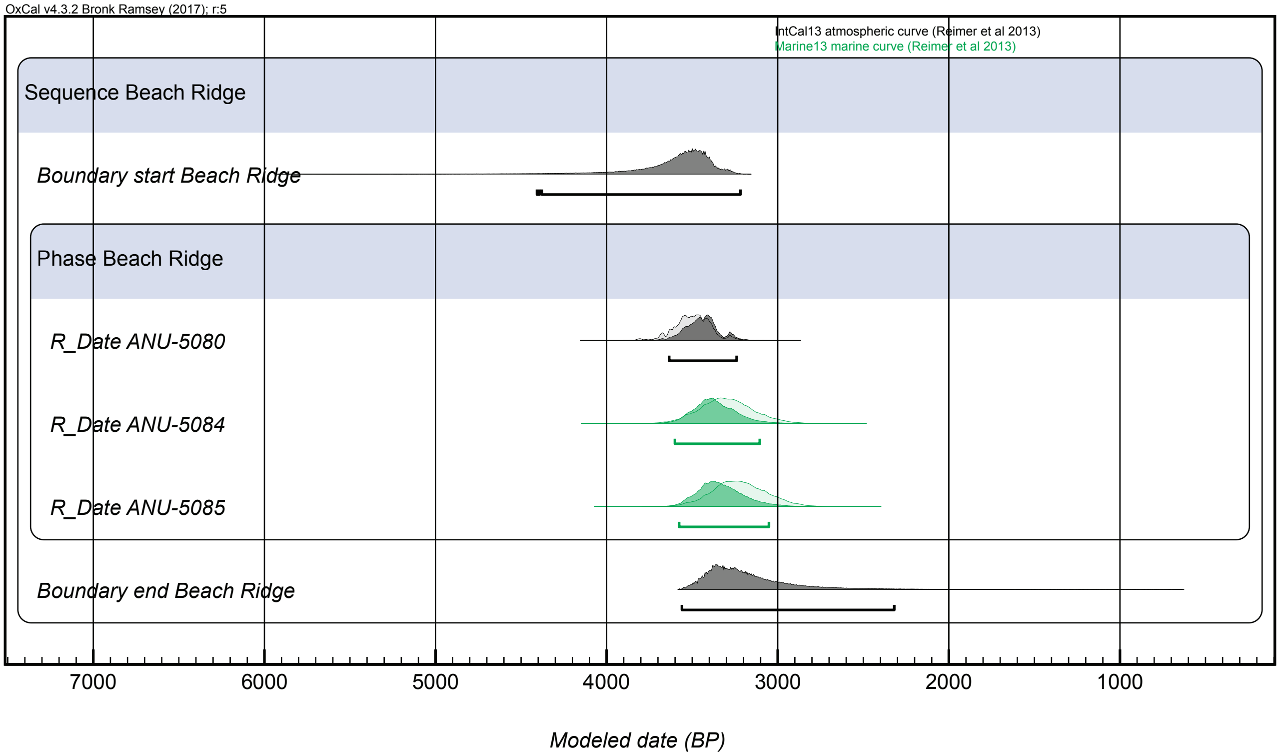


Figure 5.8. Oxcal plot of modeled charcoal and marine-shell radiocarbon dates from the paleobeach ridge at site ECA.

Table 5.5. Modeled age ranges (α, β, and θ parameters) for ECA site components (all ranges cal BP at 2σ, 95.4% probability)

Site Component	Start (α) BP	Modeled Dates (θ) BP	End (β) BP
Paleobeach ridge	4407–3218	3635–3240 (ANU-5080) 3601–3105 (ANU-5084) 3577–3052 (ANU-5085)	3560–2319
W200 phase N120	3375–3169	3317–3166 (UCIAMS-176077) 3318–3123 (Beta-20451)	3234–3089
Area B posts (Zone C3)	3234–3089	3209–3068 (Beta-20452) 3203–3057 (ANU-5790) 3200–3055 (ANU-5791) 3165–3070 (UCIAMS-207948) 3206–3077 (UCIAMS-176080)	3155–3020
Area B midden (Zone C3-C2)	3155–3020	3073–2975 (UCIAMS-176079) 3070–2971 (UCIAMS-176081) 3131–2951 (Beta-30673) 3122–2914 (ANU-5081) 3114–2893 (ANU-5082)	3061–2836
Area B zone C1	3061–2836	3005–2765 (ANU-5079) 2990–2746 (ANU-5078) 2990–2745 (ANU-5076)	2919–2724
W200 phase N170	2919–2724	2751–2724 (UCIAMS-176078)	2753–2521
W250 phase N90	5432–3189	4073–3225 (Beta-330676)	3262–3087
W250 phase N100-N140	3262–3087	3221–3044 (Beta-30677) 3205–3020 (Beta-30679) 3224–3044 (Beta-30678) 3203–3077 (UCIAMS-185970) 3184–3076 (UCIAMS-176082) 3179–3076 (UCIAMS-185971) 3180–3010 (Beta-30681) 3213–3080 (UCIAMS-176083) 3204–3077 (UCIAMS-185973) 3174–3076 (UCIAMS-185974) 3165–3058 (UCIAMS-185972) 3210–3051 (Beta-30682) 3160–3025 (UCIAMS-185975)	3154–2970
W250 Area C	3154–2970	3075–2792 (Beta-30686) 2976–2871 (UCIAMS-185976) 2919–2790 (UCIAMS-176085) 2853–2775 (UCIAMS-176086) 2783–2750 (UCIAMS-176084) 2865–2618 (Beta-30687)	2778–2492

234–489 years. For the W250 transect, the modeled time span for the deposition bracketed between the end of the N90 phase and the end of Area C is 365–715 years; the span for the phase spanning N100 through N140 (with numerous stilt-house structures indicated by wooden posts) is 3–251 years; and, the occupation north of N140 and incorporating Area C has a model duration of 199–611 years.

Dating of Lapita Sites ECB and EHB

The small Lapita site of ECB has two marine shell and three charcoal radiocarbon dates; two of the shell dates and one charcoal date were run as part of the initial set of non-AMS dates; two additional charcoal samples were dated more recently by the AMS method (Tables 5.3 and 5.4). None of the charcoal samples was identified

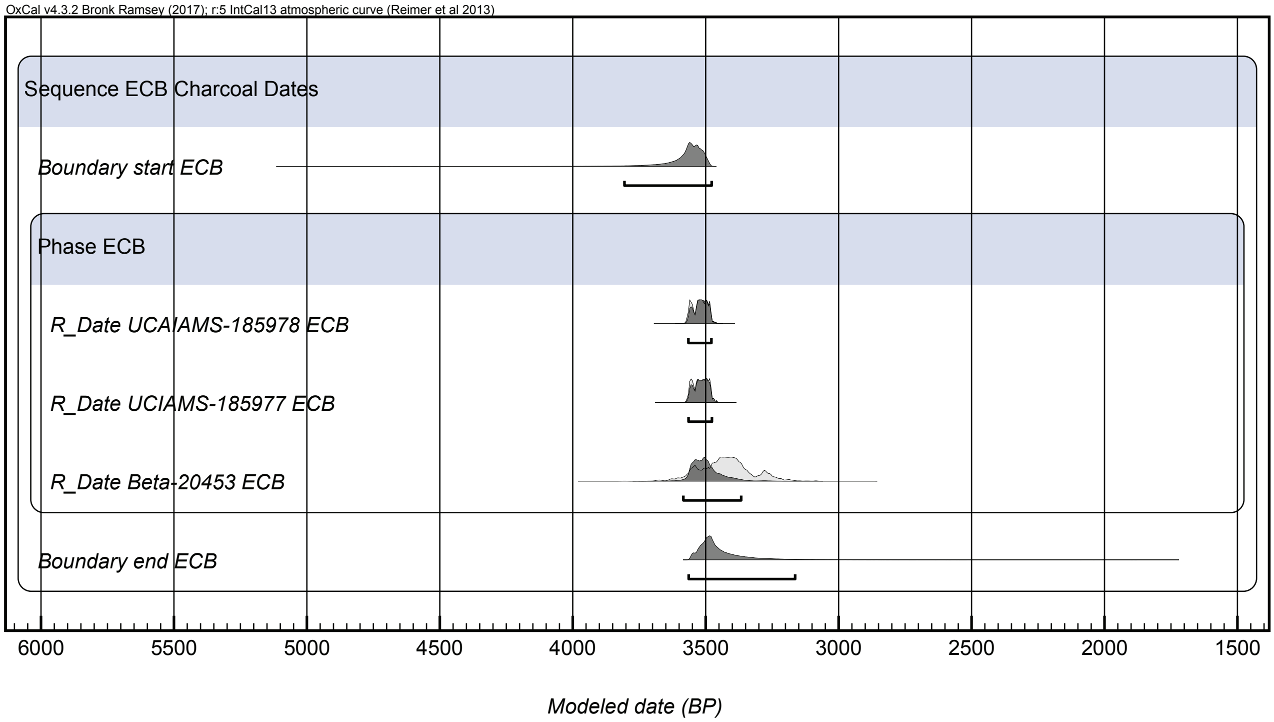


Figure 5.9. Oxcal plot of modeled wood charcoal radiocarbon dates from site ECB.

to taxon, and an unknown amount of in-built age may be inherent in the resulting dates. Figure 5.9 shows the modeled ECB charcoal dates, and the modeled ages are reported in Table 5.6. The model for ECB charcoal dates has an A_{model} index of 96.9%. The starting boundary (α parameter) for the ECB charcoal dates is 3806–3478 BP, and the ending boundary (β parameter) is 3564–3164 BP. The modeled charcoal dates (θ parameters) for ECB, at 2σ, are indicative of an occupation age between roughly 3560 and 3400 BP. Even allowing for a certain amount of in-built age, this would suggest that the occupation of ECB overlaps with the earlier part of the sequence at ECA (Area B on the W200 transect), which is consistent with our ceramic seriation (see Chapter 11).

The two marine shell dates from ECB, when modeled with a ΔR value of -250 ± 92, give results very similar to the charcoal dates, although with broader age ranges due to the larger standard errors associated with those dates (Figure 5.10). The A_{model} index is 115%. The starting boundary for the ECB shell dates is 5818–2952 BP, and the ending boundary is 3502–638 BP (Table 5.6). An integrated model for ECB combining both charcoal and marine shell dates gave an A_{model} index of 61.7%, barely above the acceptable threshold, and was therefore excluded from further consideration.

The small EHB Lapita site situated on Emananus Island is noteworthy for the high frequency of very fine dentate-stamped sherds. Our seriation of pottery motifs (see Chapter 11) puts the EHB site at the base of the Mussau Lapita sequence, as the earliest site. Unfortunately, no charcoal, wood, or nut shell was recovered from the excavations at EHB; however, two marine shell samples were dated in the initial non-AMS series, and an additional shell sample was AMS dated more recently (Tables 5.3 and 5.4). Figure 5.11 is a plot of the modeled marine shell dates from the EHB site (ΔR = -250 ± 92); the model has an A_{model} index of 123.6%. At 2σ (95.4% probability) the start boundary for the EHB phase is 4413–3366 BP, and the ending boundary is 3877–2826 BP. Given the large standard errors associated with these dates, it is worth also considering the 1σ (68.2% probability) boundary parameters, which are 3881–3525 BP and 3691–3335 BP respectively. The modeled shell dates (θ parameters) from EHB indicate that this site was occupied not later than about 3350 BP, making it earlier in age than Area B at site ECA, although possibly overlapping in time with the paleobeach ridge deposits there. These ranges concur with our ceramic seriation in placing EHB as the earliest of the Lapita sites in Mussau, predating Zone C3 at Area B (see Chapter 11).

Dating of Rockshelter Sites EKQ and EKO

The EKQ rockshelter located in northwestern Mussau Island has a cultural deposit extending to a depth of 2.6 m, of which the upper 0.4 m is aceramic, with the lower 2.2 m containing pottery dominated by incised motifs similar to those recovered from Area C at site ECA. Only a few sherds with dentate stamping were found at the bottom of the cultural deposit. Two 1 m^2 test pits were excavated in the EKQ site, and four radiocarbon dates were obtained from each of these units (Tables 5.3 and 5.4). All dates are on marine shell samples. The four dates from Unit 2 are all non-AMS dates run with the initial Mussau series, while the four dates from Unit 1 include three new AMS dates. Of the eight radiocarbon dates, seven are from the deeper ceramic-bearing deposits, while one (Beta-25036) is associated with the upper, aceramic deposits.

The four radiocarbon dates from EKQ Unit 1, spanning excavation levels 17 through 5 and all associated with incised ceramics, were modeled with the Sequence command in Oxcal (but not grouped into a Phase), as shown in Figure 5.12. For reasons discussed earlier, no ΔR correction was applied to this model. Agreement of all dates is good, with an A_{model} index of 97.1%. As is evident in the Oxcal plot, the modeled age ranges match the stratigraphic order of the samples. The starting boundary (α parameter) for the series is 3745–2997 BP, and the ending boundary (β parameter) is 2773–2097 BP (Table 5.6). These age ranges accord quite well with those for Area C at ECA, which corresponds to our expectations given the similarities in the ceramic assemblages from EKQ and Area C at ECA.

The three dates associated with incised ceramics from EKQ Unit 2, spanning excavation levels 17 to 9, were similarly modeled using the Oxcal Sequence command, with the dates ordered stratigraphically, and with ΔR = 0. Unlike the situation for Unit 1, the resulting Oxcal plot (Figure 5.13) does not show a progressive temporal sequence matching the stratigraphic order, and indeed the A_{model} index is only 32.5%, well below the accepted threshold value. The probable explanation for this result is that the deposits in the lower part of Unit 2 have undergone some mixing or perturbation, so that the samples are not in pristine stratigraphic context. The starting and ending boundaries for the Unit 2 sequence are 3413–2809 BP and 3110–2527 BP respectively.

One additional radiocarbon date was obtained from EKQ, from level 3 of Unit 2, within the upper aceramic

Table 5.6. Modeled age ranges (α, β, and θ parameters) for Lapita components at sites ECB, EHB, and EKQ (all ranges cal BP at 2σ, 95.4% probability)

Site Component	Start (α) BP	Modeled Dates (θ) BP	End (β) BP
ECB charcoal dates	3806–3478	3565–3479 (UCIAMS-185978) 3565–3477 (UCIAMS-185977) 3584–3367 (Beta-20453)	3564–3164
ECB shell dates	5818–2952	3534–2944 (ANU-5087) 3510–2915 (ANU-5086)	3502–638
EHB shell dates	4413–3366	3901–3361 (ANU-5088) 3865–3325 (ANU-5089) 3847–3385 (UCIAMS-185995)	3877–2826
EKQ Unit 1	3745–2997	3167–3007 (UCIAMS-185998) 3132–2898 (Beta-20454) 2926–2780 (UCIAMS-185997) 2765–2690 (UCIAMS-185996)	2773–2097

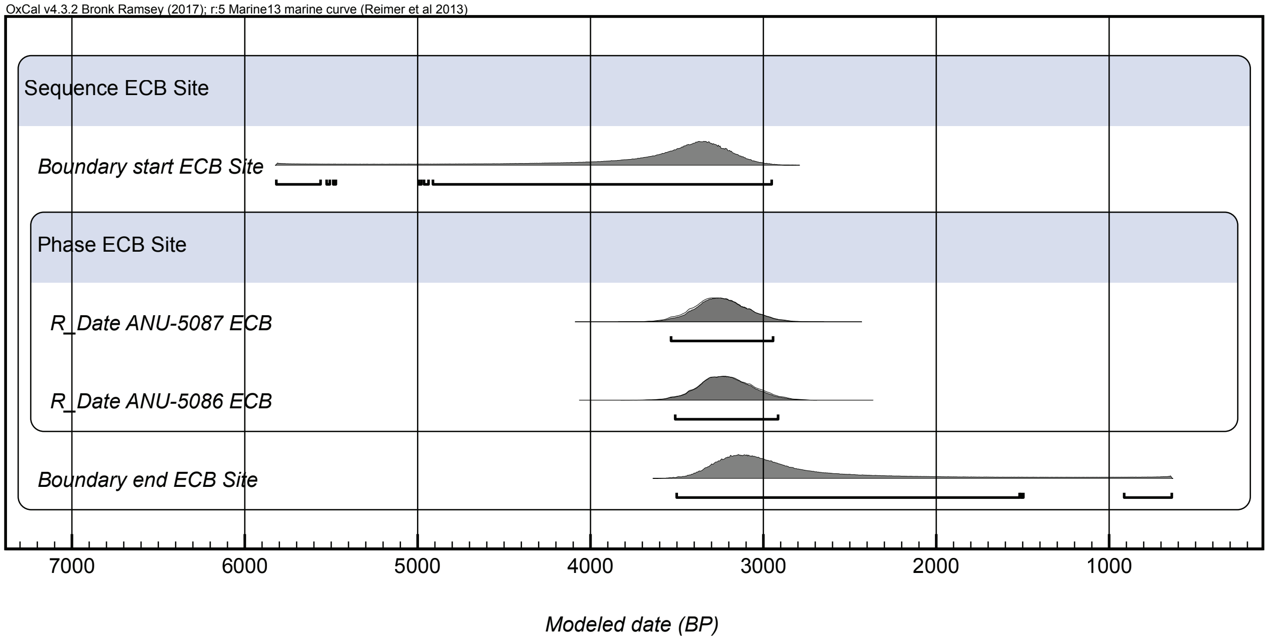


Figure 5.10. Oxcal plot of modeled marine-shell radiocarbon dates from site ECB.

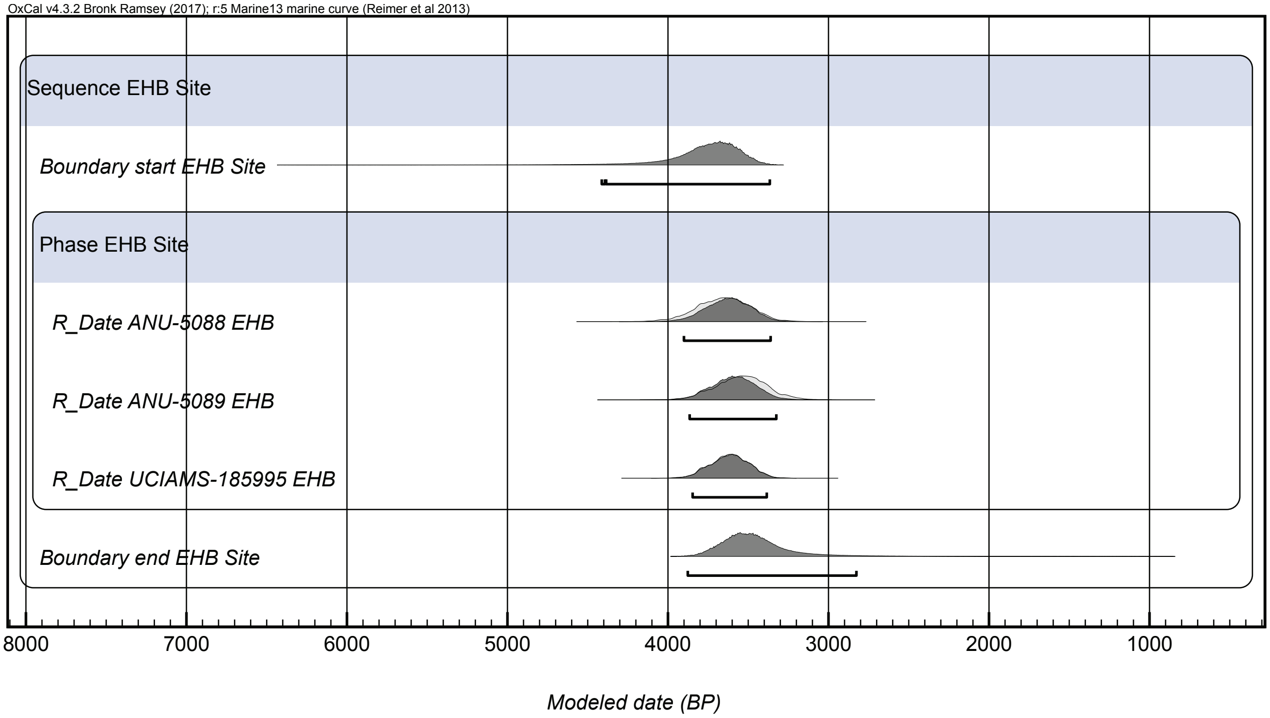


Figure 5.11. Oxcal plot of modeled marine-shell radiocarbon dates from site EHB.

part of the sequence. This sample (Beta-25036) yielded a calibrated age of 787–377 BP. The large gap between this age and the ages of the underlying samples associated with incised ceramics indicates that there must have been a considerable hiatus in the use of the EKQ rockshelter between the end of the phase of incised ceramics in the

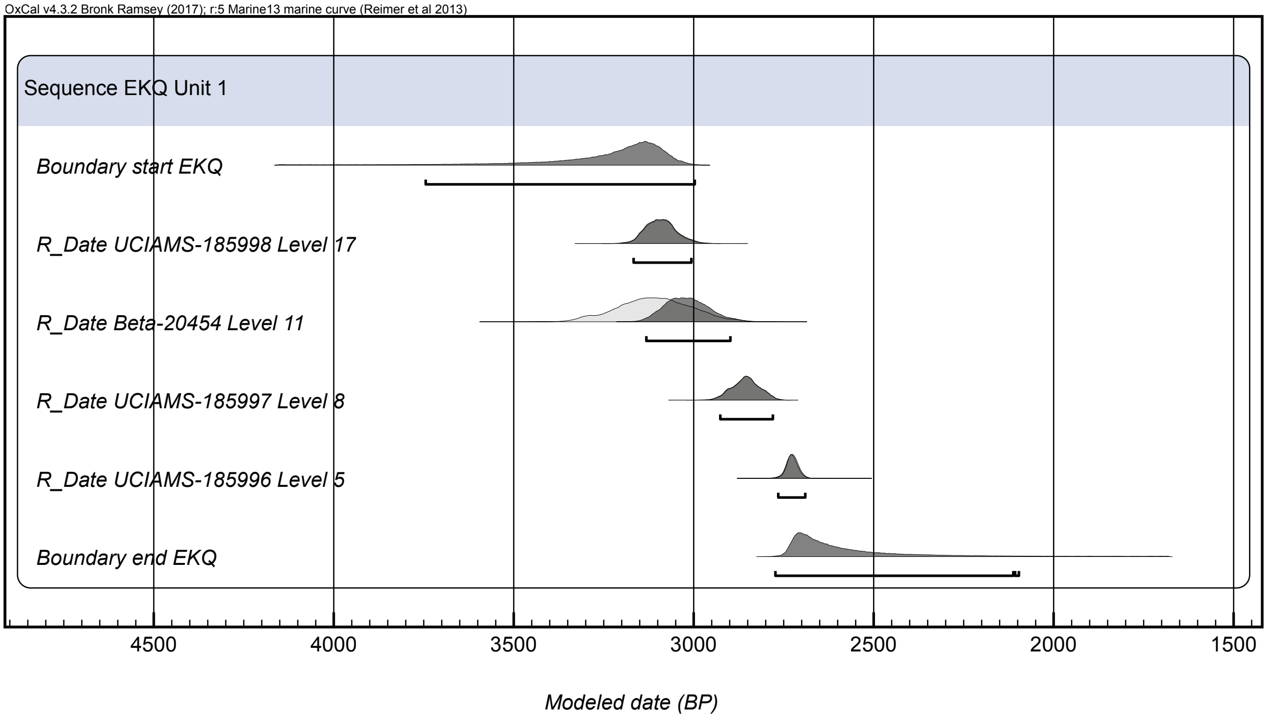


Figure 5.12. Oxcal plot of modeled marine-shell radiocarbon dates from the lower, late Lapita component in Unit 1 at site EKQ.

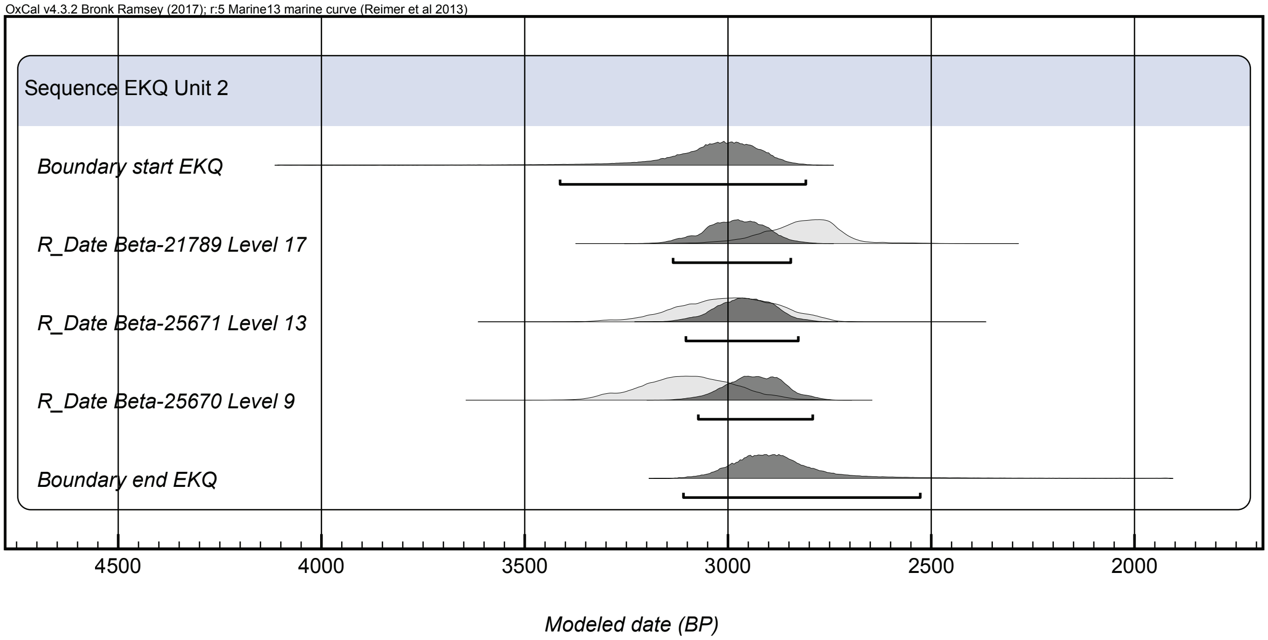


Figure 5.13. Oxcal plot of modeled marine-shell radiocarbon dates from the lower, late Lapita component in Unit 2 at site EKQ.

mid-first millennium BC and the later reoccupation of the rockshelter.

The EKO rockshelter on Eloaua Island, which yielded a small assemblage of largely plain, calcareous-sand tempered pottery, has a single marine shell radiocarbon date of 3200 ± 70 BP (Beta-25669, Table 5.3). When calibrated with a ΔR value of -250 ± 92, which is appropriate given its location on Eloaua Island, the date yields a 2σ age range of 3601–3009 BP.

Dating of Site EKE

The EKE site on Boliu Island has an early Lapita component evidenced primarily by reddish, calcareous-sand tempered plainware (similar to that at Area A of site ECA), overlain by aceramic deposits that appear to be much later in time, hence indicating a long hiatus between the two components.

Only a single radiocarbon date (Beta-30693, Table 5.3) was run on marine shell associated with the Lapita plainware ceramics, from the base of Unit E200N175 (level 9). When calibrated with a ΔR value of -250 ± 92, this date has a 2σ age range of 3887–3318 BP, and a 1σ age range of 3725–3434 BP. This date suggests that the Lapita activity on Boliu occurred quite early during the Mussau sequence, probably penecontemporaneous with Area A at site ECA, which has very similar ceramics.

The upper, aceramic deposit in Unit E200N175 of site EKE was dated by three shell samples taken from levels 6 to 1 (Table 5.3). Figure 5.14 is an Oxcal plot of these dates as modeled using the Sequence command, with a ΔR value of -250 ± 92; the dates are in correct stratigraphic order, and the model has an A_{model} index of 102.1%. The starting boundary for this aceramic deposit is 2058–663 BP and the ending boundary is 918–389 BP. The individual modeled ages (Bayesian θ parameters) for the three radiocarbon dates are 1148–678, 926–561, and 885–519 BP, making it evident that the aceramic component at site EKE does not span much more than the last one thousand years. One additional marine shell date was run from Unit E200N200 at site EKE, also from an aceramic context (Beta-30694), yielding a calibrated age of 629–149 BP at 2σ.

Dating of Post-Lapita Sites (EKU, EKS, EHK, and EKL)

Four other sites with aceramic midden deposits belonging to the post-Lapita period in Mussau were also dated. Site EHK on Eloaua Island is an extensive aceramic midden (see Chapter 4); two samples of *Anadara antiquata* shell from Unit E300N300 were dated (Table 5.3). Figure 5.15 is an Oxcal plot of the modeled dates using the Sequence command, with the two samples in stratigraphic order; the model has an A_{model} index of 99.7%. The start boundary for the EHK midden deposit is 1273–955 BP, and the end boundary is 1064–0 BP, indicating that the deposit probably accumulated during the last millennium.

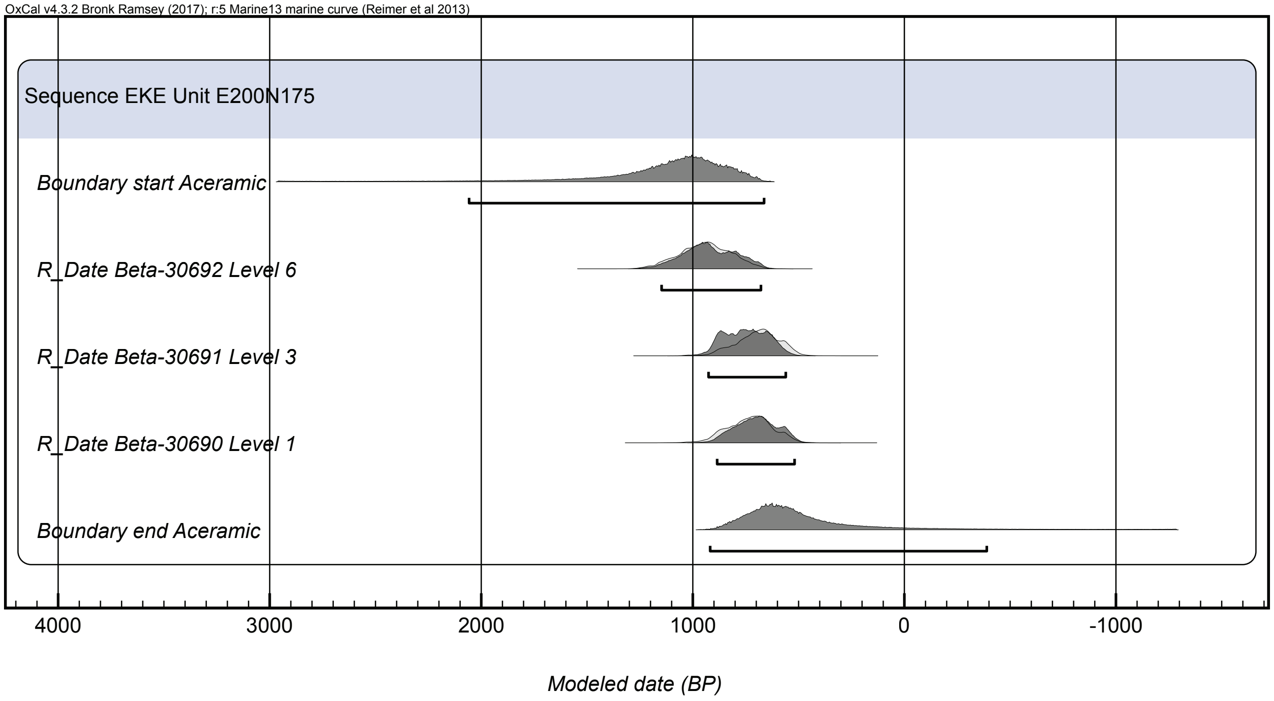


Figure 5.14. Oxcal plot of modeled marine-shell radiocarbon dates from the upper, post-Lapita component in Unit E200N175 at site EKE.

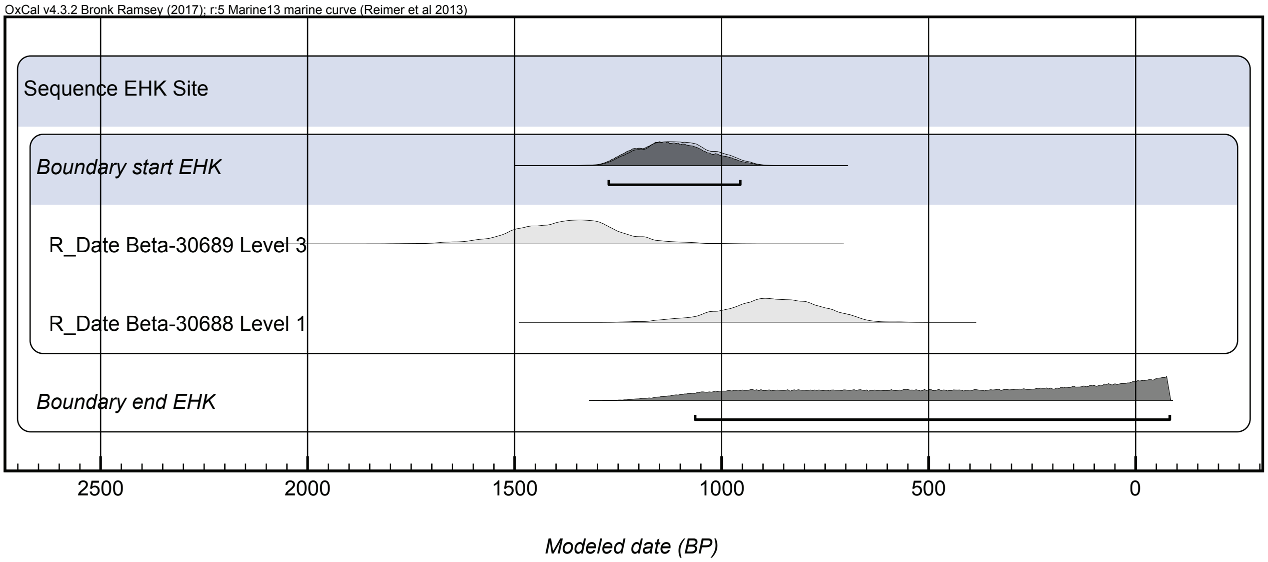


Figure 5.15. Oxcal plot of modeled marine-shell radiocarbon dates from the EHK site.

Site EKS is an aceramic midden on Emussau Island, across the Malle Channel from Eloaua Island (see Chapter 4). A single sample of unidentified wood charcoal from level 5 of Unit 2 was radiocarbon dated, with a calibrated age range of 507–302 BP, placing the site occupation in the late pre-contact period.

Site EKL is a midden on the small islet of Enusagila (see Chapter 4). A *Spondylus* sp. marine shell from level 4 of the single test pit excavated into this midden was radiocarbon dated, with a resulting age range (using ΔR = -250 ± 92) of 411–0 BP. This age range is consistent with the presence of historic bottle glass in the midden, indicating that the midden deposit dates to the post-contact period.

The final post-Lapita site to have been dated is Sinakasae or EKU, situated on an upraised limestone terrace at the southern end of Mussau Island (see Chapter 4). The site is of some interest because in addition to adzes of *Tridacna* and *Terebra* shell, it also yielded a number of sherds of a dark red pottery with pyroxene temper, some decorated with end-tool impressions. The pottery is clearly not Lapita, and was probably imported to Mussau, possibly from Manus. A sample of mammal bone, almost certainly of pig (*Sus scrofa*), was radiocarbon dated, yielding a calibrated age range of 796–551 BP, putting the occupation of the site within the same range as the EHK midden on Eloaua Island, and the upper deposits at EKE on Boliu Island.

Summary and Conclusions

The extensive dating program described above, combined with Bayesian modeling of the various site sequences that incorporates stratigraphic relationships, allows for a more refined chronology of the Lapita and post-Lapita phases in Mussau than was previously available (Kirch 2001b:Figure 10.16). The earliest Lapita site in Mussau—both on the basis of the radiocarbon chronology and on the evidence of ceramic seriation (see Chapter 11)—is EHB on Emananus Island, which was established sometime between about 3750 and 3450 BP. Only slightly later or overlapping in time with EHB, however, are the largely plainware assemblages of the ECA paleobeach ridge (including Area A), EKE on Boliu Island, and the small EKO rockshelter. The fact that EHB—with its highly decorated pottery—and these plainware assemblages are penecontemporaneous is of considerable interest, as it suggests that EHB may have been a functionally specialized site. This is a point I will return to in the concluding chapter.

Following these earlier assemblages, cultural deposition along the parallel W200 and W250 transects at ECA began around 3300–3200 BP. The main stilt-house occupations at Area B (and Area B extension) and in the zone between N100 and N140 on the W250 transect span a time range from about 3200 to 2950 BP. Although the charcoal dates from the small ECB site would place the occupation there at around 3550–3475 BP, it is likely that there is some in-built age in these dates on unidentified (and likely old) wood. The calibrated shell dates from ECB give a wider age range, from about 3500 to 3050 BP, suggesting that ECB may be penecontemporaneous with the main stilt-house occupations at ECA; this interpretation is consistent with the ceramic evidence (see Chapter 13).

The late Lapita phase in Mussau—marked by ceramic assemblages characterized almost exclusively by incised decoration—is represented by the deposits at the northern ends of the W200 and W250 transects, especially by Area C at ECA. The transition from dentate-stamped to incised Lapita thus occurs around 3000–2900 BP, although this clearly was a process that took some time, and not a single event. The EKQ rockshelter is penecontemporaneous with Area C at ECA, and in both cases the occupations seem to have ceased by around 2750–2700 BP.

The abandonment of the ECA and EKQ late Lapita sites, by 2700 BP, is followed by a long—and currently unexplained—hiatus in the Mussau archaeological record. In spite of our efforts to test several midden sites on Eloaua, Emananus, Boliu, and Emussau islands, no sites dating to the long interval between 2700 and 1200 BP were discovered. It seems a distinct possibility that these and other smaller offshore islands were not occupied during this long interval.

At around 1200 BP, possibly slightly earlier, the archaeological record on the offshore islands again becomes evident, with the aceramic middens such as EHK on Eloaua and EKE on Boliu, and slightly later with the upper deposit in EKQ and the open site of EKU on Mussau Island. These sites generally lack pottery (EKU being the exception in containing small quantities of non-Lapita ceramics), but contain distinctive *Terebra*-shell and *Tridacna*-shell adzes, as well as *Trochus*-shell rings. The midden on Emussau Island, EKS, dates to just prior to European contact, while the small EKL midden on Enusagila Island postdates European contact.

CHAPTER 6

Vertebrate Fauna from the Mussau Sites: Reptiles, Birds, and Mammals

Patrick Vinton Kirch

A major goal of the Mussau Project, as related in Chapter 1, was to shed light on the nature of the Lapita economy, through the evidence of both faunal and floral remains. Fortunately, the calcareous depositional environments of most of our sites, and in particular of Talepakemalai, are highly conducive to the preservation of bone and shell. In the course of our excavations, we recovered more than 56,000 animal bones. Although the majority of these are of fish, a wide range of taxa including reptiles, birds, and mammals is represented. This chapter deals with the non-fish vertebrate assemblages, while Chapter 7, following, treats the fishbone. Invertebrate fauna is the subject of Chapters 8 and 9.

Material and Methods

Vertebrate faunal remains retained in our sieves were systematically collected from all excavation units and levels of Mussau sites in all three field seasons. As described in Chapter 3, most sediment was screened through 5 mm mesh sieves, although we also screened some units and levels with 3 mm mesh; comparative tests did not reveal any bias from the use of the 5 mm mesh. Over the course of the three field seasons, a total of 56,034 NISP (number of identified specimens) of vertebrate fauna was recovered, of which 49,848 (88.9%) were of fish (Table 6.1). The fishbones, treated in Chapter 7, will not be further discussed here.

Of the total of 6,186 NISP of non-fish vertebrate remains, the largest sample by far comes from site ECA (4,753 NISP); reasonably large samples were also obtained from sites EKE and EKQ, and somewhat smaller samples from sites ECB, EHB, and EKS (Table 6.1). Table 6.2 shows the distribution of non-fish vertebrate fauna within the ECA site; here the largest samples are from the extensive Area B excavation and from the various transect units (W200 and W250 transects).

Initial sorting of bone into major categories of fish and non-fish bone was carried out in the Oceanic Archaeology Laboratory (then located at the University of Washington), while the non-fish bone was sent to the late Dr. Alan

Table 6.1. Distribution of vertebrate fauna (NISP) from the Mussau site excavations

Taxonomic Group	ECA	ECB	EHB	EHK	EHM	EKE	EKQ	EKS	EKU	Totals
Fish	44167	446	415	256	1	2069	1518	935	41	49848
Turtles	1360	40	38	2		146	2	4	3	1595
Lizards and snakes	13		1	1		1	1			17
Crocodile	1									1
Birds	92	4		1			5	1		103
Marsupials	1						2		1	4
Fruit bats	26					2	2			30
Rodents	5						2			7
Porpoises	227	1	1			22		2	1	254
Canis familiaris (dog)	6					24		2	4	36
Sus scrofa (pig)	73	3	7	15		62	5	32	32	229
Homo sapiens	33				2	161	5		1	202
Small to medium mammal	15					3	1			19
Medium mammal	76		6	34	19	133	19	46		333
Small vertebrate	19	1				1	4	1		26
Medium vertebrate	2803	92	85	18	19	144	29	83	52	3325
Large vertebrate	3	1				1				5
Totals	48920	588	553	327	41	2769	1595	1106	135	56034

Ziegler, who served as the project's consulting zooarchaeologist. Ziegler, formerly the Vertebrate Zoologist at the Bernice P. Bishop Museum in Honolulu, was a specialist in mammology with extensive experience working on the fauna of the New Guinea region, as well as considerable expertise in zooarchaeology (Ziegler 1973). In identifying the Mussau non-fish vertebrate materials, Ziegler utilized the zoology collections of the Bishop Museum for reference.

Of the 6,186 non-fish vertebrate specimens Ziegler was able to assign 2,478, or 40% of the material, to a taxonomic category such as order, family, genus, or species. The remaining 60% of this material was too fragmentary to be identified below the following general categories: (1) small-to-medium mammal, indeterminate order and family, in the general size range of phalanger or larger pteropodid; (2) medium mammal, indeterminate order and family, in the general size range of larger phalanger, porpoise, large dog, or pig; (3) small vertebrate, highly fragmented bone of indeterminate class, order, and family, with an estimated head-to-body length less than 0.3 m; (4) medium vertebrate, highly fragmented bone of indeterminate class, order, and family, with an estimated head-to-body length from about 0.3 m to roughly 2.0 m; and (5) large vertebrate, highly fragmented bone of indeterminate class, order, and family, with an estimated head-to-body length of more than about 2 m.

In reporting the vertebrate faunal remains from Mussau we use Number of Identified Specimens (NISP) as the primary means of quantification, rather than the Minimum Number of Individuals (MNI). This reflects the high degree of fragmentation of many of the specimens, which renders determination of MNI problematic. However, as Grayson (1984) demonstrated, MNI and NISP are in general highly correlated, especially when sample sizes are robust.

Table 6.2. Distribution of non-fish vertebrate fauna (NISP) within site ECA

Taxonomic Category	Area A	Area B	Area C	Transect Units	Airfield Test Units	Totals
Turtles	92	457	27	750	34	1360
Lizards and snakes		2	2	7	2	13
Crocodile			1			1
Birds		17	9	62	1	89
Phalangers		1				1
Fruit Bats		9	1	16		26
Rodents		2	2	1		5
Porpoises	3	66		158		227
Canis familiaris (dog)		2		4		6
Sus scrofa (pig)	1	18	5	31	18	73
Homo sapiens		21	3	9		33
Small to medium mammal		1		14		15
Medium mammal	3	43	5	22	3	76
Small vertebrate	4	7	1	6	1	19
Medium vertebrate	62	1441	47	992	261	2803
Large vertebrate		2		1		3
Totals	165	2089	103	2073	320	4750

Reptiles

Turtles

By far the most frequently represented non-fish vertebrate across the Mussau assemblages is that of turtle, constituting 26% of all of the non-fish, and fully 64% of the specimens identified to other than the most general categories (Figure 6.1). Indeed, a large amount of the material assigned to the "medium vertebrate" category undoubtedly consists of turtle bone, Ziegler preferring to err on the side of caution in his identifications.

Virtually all of the turtle bones are presumed to derive from marine species, the most likely being *Chelonia mydas* (green sea turtle) and *Eretmochelys imbricata* (hawksbill turtle), both of which would be consistent with the fragmentary limb material as well as the plastron and carapace bone fragments. *Dermochelys coriacea* (leatherback turtle) may also be represented by some of the limb material. Ziegler opined that individuals ranging from about 0.3 m up to 1.0 m in carapace length seem to be represented by the Mussau material.

While all three species may well be present in these assemblages, there is reason to think that the majority of the material is of *Chelonia mydas*, as this species is especially susceptible to capture when the females return to the beaches where they lay their eggs. As Loveridge writes, in some areas of the Pacific humans take advantage of this annual reproductive event "to capture breeding females by the thousand" (1946:23). The extensive sandy beaches of Eloaua, Emananus, Boliu, and other islets of southern Mussau would have been ideal egg-laying sites for *Chelonia* turtles. Loveridge further observes that while the loggerhead and green sea turtles are "superficially similar," "differences are immediately apparent when steaks of both are served at table," with the flesh of the latter being much more

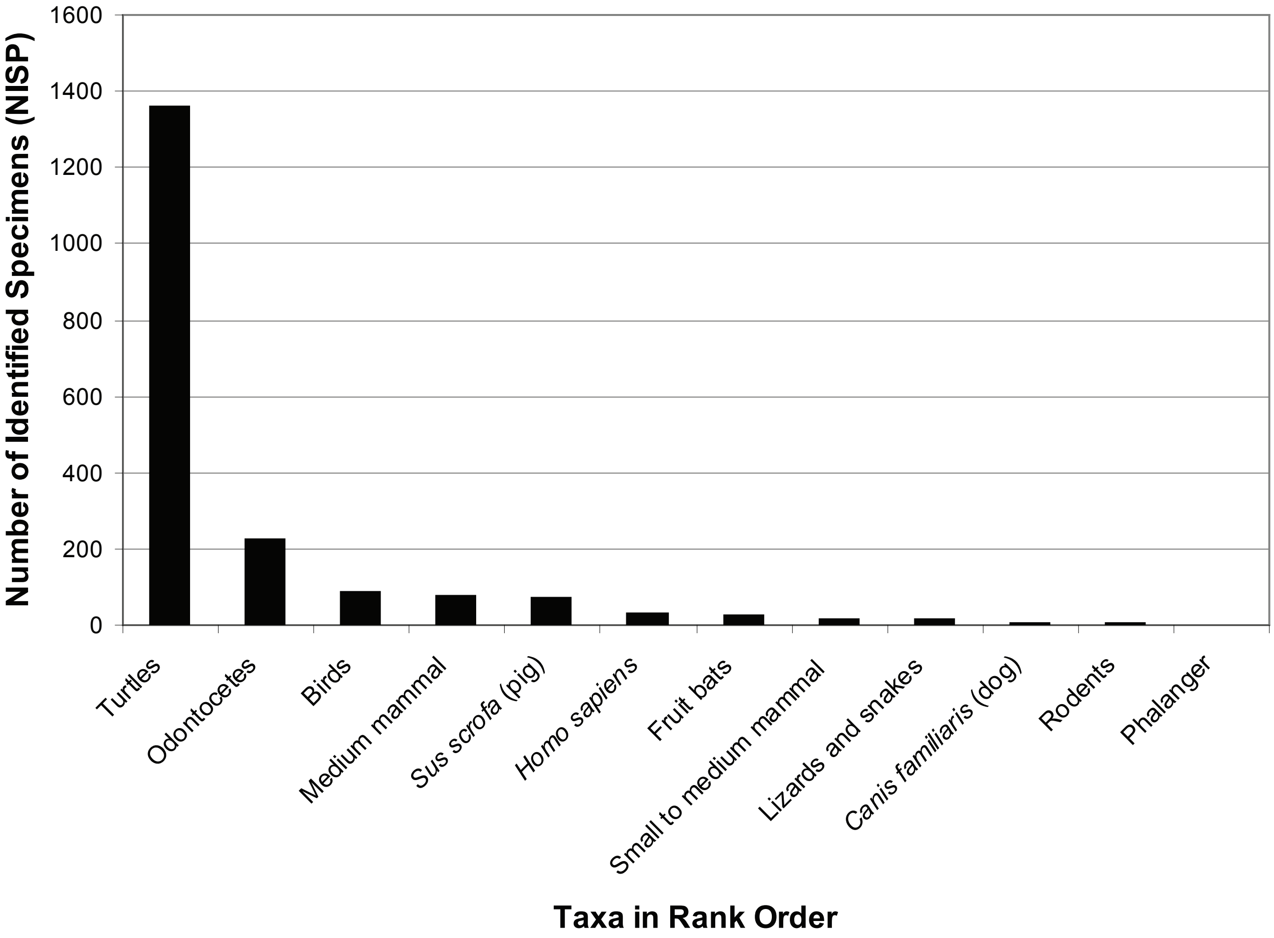


Figure 6.1. Rank-ordered frequency histogram of non-fish vertebrate faunal remains from site ECA.

succulent (1946:21). Indeed, the title "green" is derived from the color of the fatty tissues "so long associated with aldermanic banquets."

It is noteworthy that most of the turtle remains were derived from the three main Lapita sites ECA, ECB, and EHB, and from the earlier stratigraphic contexts at EKE (Table 6.1), with only a few bones from the later, post-Lapita sites of EHK, EKS, or EKU. (The limited number of turtles bones at EKQ may be related to the absence of good sandy beach nesting sites along this exposed windward coast of Mussau Is.) Thus it would appear that turtles were extensively exploited during the Lapita period, but much less so in later prehistory, possibly due to cumulative reductions in the regional breeding populations. The stratigraphic distribution of turtle bones within Area B at site ECA likewise is indicative of a reduction over time in the numbers of turtles being taken (Table 6.3).

Lizards and Snakes (Squamata)

Ziegler assigned 17 specimens to the order Squamata, breaking these down further into categories of (1) small lizard, snout-to-vent length of less than 10 cm, 2 specimens; (2) medium lizard, snout-to-vent length of 10–50 cm, 3 specimens; and (3) medium snake, with a total length of 1.0–2.0 m, 12 specimens. In an effort to refine these identifications further, I sent the material to Gregory K. Pregill, Curator of Herpetology at the San Diego Natural History Museum. Unfortunately, Pregill responded that because this material all consisted of postcranial elements, which "are so generalized structurally that generic and species-level identifications are hazardous at best," he was not able to refine the identifications (Pregill, personal communication, January 29, 1990). Of the "small lizards," Pregill did venture that these were likely to be either gecko or skink, whereas the "medium lizards" were definitely larger than gecko or skink.

Table 6.3. Distribution by stratigraphic zone of non-fish vertebrate fauna (NISP) in Area B, Site ECA

Taxonomic Category	C3	C2	C1	B2	B1	A1	Totals
Turtles	33	115	199	80	24	3	454
Lizards and snakes		1		1			2
Crocodiles							
Birds	9	1	3	3	1	1	18
Phalangers			1				1
Fruit bats		4	3	2			9
Rodents				1	1		2
Odontocetes	3	6	34	10	13		66
Canis familiaris (dog)	1				1		2
Sus scrofa (pig)		2	6	6	2	2	18
Homo sapiens	1	5	14	1			21
Small to medium mammal	1						1
Medium mammal			11	22	5	5	43
Small vertebrate	1	1	4	1			7
Medium vertebrate	112	318	582	304	113	12	1441
Large vertebrate		1			1		2
Totals	161	454	857	431	161	23	2087

Crocodile (*Crocodylus* sp.)

A single vertebra from a species of *Crocodylus* was recovered from Area C at ECA (in Unit W251N191, level 6). Ziegler estimated that the specimen came from an animal with a snout-to-vent length of at least 1 m, or an overall head-to-tail length of approximately 2 m. It is also conceivable that some of the fragments in the "larger vertebrate" category (see Tables 6.1 and 6.2) are of crocodile, as there is little else possible in this size range.

Crocodylus porosus, the salt-water or estuarine crocodile, is quite abundant in the mangrove swamps of Mussau, and the single *Crocodylus* specimen almost certainly comes from this species. Of *C. porosus*, Loveridge writes that "once it has found how defenseless is the average man or woman when taken unawares, the estuarine crocodile becomes as confirmed a man-eater as the most persistent man-killing tiger" (1946:46). Our Mussau informants expressed a healthy respect for these formidable creatures. It is not surprising, therefore, that they were never extensively hunted for food.

Birds

Ziegler identified 103 NISP as being some form of bird, referring most of the material to either "small" or "medium" size categories, although he was able to further identify some specimens into more specific categories such as "small larid," "medium galliform," or "medium columbid." Fortunately, David W. Steadman was later able to examine the Mussau bird material, and more precisely identify 58 specimens from sites ECA, ECB, and EKQ, referring these to some 17 species. These results were subsequently published by Steadman and Kirch (1998), and the following paragraphs are based on that publication. The bird bones from sites ECA, ECB, and EKQ are enumerated in Table 6.4.

Seabirds

Thirty bones from seven seabird species make up slightly more than half of the bird bones from the Mussau sites. Most frequent are the two larid species *Anous stolidus*, the brown noddy, and *Anous minutus*, the black noddy. Also within the Laridae family are *Sterna fuscata*, the sooty tern, and *Sterna hirundo*, the common tern. All of these larids are relatively common species throughout Oceania. An indeterminate species of *Pterodroma*, or petrel, is represented by two specimens. Steadman noted that the size of the two elements would be consistent with *Pterodroma arminjoniana*, a widespread tropical petrel. Finally, there are seven NISP of *Sula leucogaster*, the brown booby, a species common in the entire New Guinea area.

Landbirds

Aside from the domestic chicken (see below), ten species of landbirds are represented in the Mussau faunal assemblage. One specimen of the osprey, *Pandion haliaetus*, came from site ECA. The golden plover, *Pluvialis dominica*, a common migratory shorebird throughout the Pacific, is represented by two specimens, one each from ECA and EKQ. An indeterminate species of *Numenius*, or curlew, was recovered at site ECB. In the fruit-dove family Columbidae, there are

Table 6.4. Distribution of bird bones (NISP) from Mussau excavated sites

Taxonomic Category	ECA	ECB	EKQ	Totals
Seabirds				
Pterodroma sp.	2			2
Sula leucogaster	6	1		7
Sterna fuscata	3			3
Sterna hirundo	1			1
Anous stolidus	6		4	10
Anous minutus	5	1		6
Sterninae sp.	1			1
Landbirds				
Pandion haliaetus	1			1
Gallus gallus	10	2		12
Pluvialis dominica	1		1	2
Numenius sp.		1		1
Ptilinopus sp. 1	1			1
Ptilinopus sp. 2	1			1
Ducula sp.	1			1
Caloenas nicobarica	2			2
C. nicobarica or *Ducula* sp.	2			2
Cf. *Cacatua* sp.	1			1
Tyto sp.	1			1
Aplonis metallica	3			3
Totals	48	5	5	58

two different but both indeterminate species in the genus *Ptilinopus*, both from site ECA, as well as an unknown species of imperial pigeon, *Ducula* sp., again from ECA. Of particular interest are two specimens of the Nicobar pigeon, *Caloenas nicobarica*, and two other specimens that are either this species or a *Ducula*. Nicobar pigeons are raised in a semi-domestic manner on tiny Tench Island, and exchanged with the Mussau people when Tench islanders periodically visit. In 1985, a group of Tench people visited Mussau, and I was able to procure a basket of seven of these pigeons, which my Mussau hosts gratefully accepted as a contribution to our farewell feast. The remaining landbirds in the assemblage are an unknown species of cockatoo, *Cacatus* sp., an indeterminate barn owl, *Tyto* sp., represented by one specimen each, and three specimens of the glossy starling, *Aplonis metallica*.

Jungle Fowl or Chicken (*Gallus gallus*)

Bones of the domestic chicken or jungle fowl, *Gallus gallus*, were present at both sites ECA and ECB, confirming the presence of this animal in the Lapita phase (Figure 6.2). Nevermann (1933) does not mention chicken being present in Mussau ethnographically, nor were chicken bones present in later prehistoric assemblages such as EKS or EKU. It seems never to have been important in the Mussau subsistence economy.

Mammals

Marsupials: Cuscus (Phalangeridae)

Four bones were assigned by Ziegler to the marsupial genus *Phalanger*, and he regarded these as "quite probably all *P. maculatus* (Spotted Phalanger)" (Ziegler, personal communication, May 7, 1987). Only one bone comes from Area B at site ECA, with two specimens from EKQ and one from EKU. Now assigned to a new separate genus, *Spilocuscus maculatus* is the only species of cuscus known to be present in Mussau (Whitmore 2015), and there is little doubt that this is the species represented. Tim Flannery of The Australian Museum kindly examined a humerus specimen and confirmed that it was most likely from *S. maculatus* (T. Flannery, personal communication, January 20, 1987). It has been argued by Flannery and White (1991) that the cuscus and probably several other marsupials were purposively introduced by humans from New Guinea into the islands of the Bismarck Archipelago during the late Holocene, as food sources. It seems very likely that *S. maculatus* was such an instance of "animal translocation" to Mussau.

Fruit Bat (Pteropodidae)

Thirty bones were identified as coming from the family Pteropodidae, of which there are various species in the Bismarck Archipelago. Ziegler separated this material into three size classes: (1) small pteropodid, in the size range of the genera *Rousettus*, smaller *Dobsonia*, or very small *Pteropus* such as *P. woodfordi*, with 4 specimens; (2) medium pteropodid, in the size range of larger *Dobsonia* or medium-sized *Pteropus* such as *P. nitendiensis*, with 22 specimens; and (3)

Figure 6.2. Femora of *Gallus gallus* from sites ECA and ECB: *a*, ECA-63-2-3; *b*, ECA-60-7-3; *c*, ECB-16-3-1.

large pteropodid, in the size range of *Pteralopex atrata* or large *Pteropus* such as *P. tonganus*, 4 specimens. With the exception of two bones each from sites EKE and EKQ all of the fruit bat bones are from site ECA, where they come mostly from Area B and the transect excavation units (Tables 6.1 and 6.2). This material indicates that the Lapita occupants of Talepakemalai occasionally hunted fruit bats, presumably for food, but they certainly were not a major component of the diet.

Rodent (*Rattus* sp.)

The extremely limited numbers of rodent bones—just five from ECA and two from EKQ—was quite unexpected, given that the bones of the commensal Pacific rat, *Rattus exulans*, had been very abundant in the author's excavations in such islands as Tikopia, Ofu (Samoa), or Mangareva. Ziegler did not identify these five bones to species, although he noted that they are in the size range of *R. exulans*, and it seems probable that they are from this widespread species.

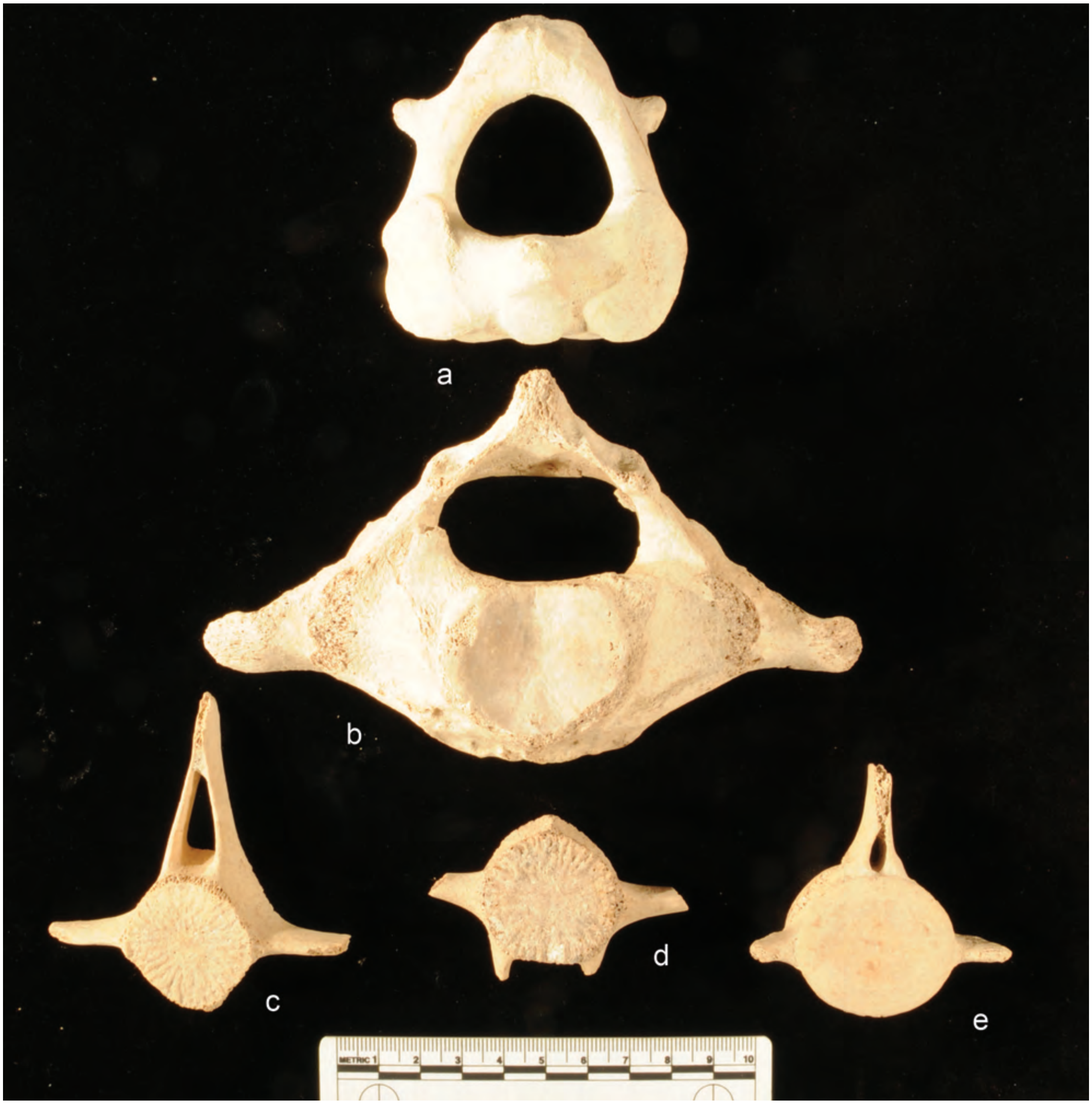


Figure 6.3. Odontocete bones from site ECA: *a*, ECA-50-5-5; *b*, ECA-18-8-21; *c*, *d*, *e*, ECA-55-9-6.

Why rat bones are not more abundant, however, remains an interesting question. It is certainly not due to sampling bias in terms of sieve size, as similar mesh sizes were used in the author's other excavations. One conceivable explanation is that in the islands of Near Oceania, such as Mussau, there are numerous potential predators on small rats, especially snakes, which are lacking in the islands of Remote Oceania. This is a topic that might bear further research.

Porpoise (Delphinidae)

The bones of one or more species of smaller odontocetes (in the overall size range of about 3 m) are the second most frequent taxonomic group in the Mussau faunal assemblage, making up 10% of the identified material (Figure 6.3). (Some of the "medium mammal" material doubtless also comes from porpoises.) Most of the material comes from site ECA, with a significant number also from EKE, and a handful of bones from other sites (Table 6.1). At ECA, the porpoise bones come mostly from Area B and the transect units (Table 6.2). Within the Area B excavation, porpoise bones occur in all analytical zones from C3 to B1, but are most plentiful in zone C1 (Table 6.3).

In an effort to obtain more precise identifications on these cetaceans, six teeth and a lumbar vertebra were sent to James Mead, Curator of Marine Mammals at the U. S. National Museum of Natural History (Smithsonian Institution). Mead replied that the vertebra could be of the monospecific genus *Peponocephala* (*Peponocephala electra*, the melon-headed dolphin, or many-toothed blackfish), but was definitely too small to be of the genus *Tursiops* (bottlenose dolphins). Of the teeth, one was identified as *Peponocephala*, one as either *Peponocephala* or *Tursiops*, and two as possibly *Grampus*, of which there is the single species *G. griseus* (Risso's dolphin) (J. Mead, personal communication, October 15, 1986). Although this is not definitive, it seems likely that both *Peponocephala electra* and *Grampus griseus* are represented in the Mussau archaeological material. Based on my own field experience, dolphins of one or more species are abundant in the channels between Eloaua, Boliu, and the other offshore islands. On more than one occasion when driving my inflatable Metzler boat between islands, large pods of up to one hundred dolphins surrounded me and played in my wake, coming so close that I could reach out and touch their backs.

How these fast and agile marine mammals may have been hunted is unclear. It seems that spears or large nets might have been employed for this purpose. Nevermann reports that "dolphins" were eaten on Emirau ("Emir"), adding that they "are driven ashore with canoes . . . at two suitable spots on the coast" (1933:69).

Dog (*Canis familiaris*)

The domestic dog is relatively sparsely represented in the Mussau faunal assemblages, with the greatest number (24 NISP) coming from post-Lapita contexts at the EKE site; four specimens also come from the later prehistoric sites EKS and EKU (Table 6.1). At Talepakemalai, there are just six specimens, from Area B and transect units. One specimen, however, is from analytical zone C3 in Area B, the earliest phase, indicating that the Lapita people in Mussau did possess dogs (Table 6.3). Nevermann commented that "on St Matthias . . . the natives kept dogs, which looked as though they had been poorly looked after" (1933:69). He opined that dogs might have been "introduced only recently to the islands," but clearly was mistaken in this view, based on our archaeological evidence.

Pig (*Sus scrofa*)

Bones and teeth of pigs are the third most frequently represented taxonomic category in the Mussau sites, the 229 NISP making up 9% of the remains identified to some taxonomic level. A significant percentage of the 333 "medium mammal" bones also are likely to be of pigs. Pig bones or teeth are represented at every site except EHM, and are especially prevalent at the late prehistoric sites of EKS and EKQ, where they dominate the non-fish fauna. This is not surprising, given Nevermann's report that "originally, the only domestic animal on St Matthias and Emir was the pig (*mosu*), which resembles the pigs kept on other islands in the Bismarck Archipelago but without their long snout, and rather resembling the wild pig in appearance" (1933:68). Nevermann further notes that "tame pigs are recognizable by having their ears slit artificially," and were fed to keep them from foraging in the bush.

While pigs were clearly important in the post-Lapita, late prehistoric subsistence economy of Mussau, they were also present throughout the Lapita phase, albeit in lower frequency. In Area B at Talepakemalai, pig bones or teeth are represented in all analytical zones except C3. Drilled pig incisors, presumably used as pendants or some other form of ornament, are also present in the Area B assemblage (see Chapter 13). A nearly complete pig humerus from Zone C1 of Area B (Unit W196N151) is illustrated in Figure 6.4. Thus there is no doubt that pigs were a component of Lapita subsistence, but their contribution to the diet was minor in comparison to such marine protein sources as mollusks, fish, turtles, and even porpoises.

Three pig teeth from Unit TP2 of site EKQ were sent to Greger Larson at Oxford University for extraction of DNA and genetic sequencing (Larson et al. 2007:Table S3). Unfortunately, aDNA was lacking in the deeper samples from levels 12 and 16, but was extracted and sequenced from the sample from level 3, dated to the late prehistoric phase. This sample yielded haplotype BX, one of the haplotypes making up the "Pacific Clade" of pigs. According to

Figure 6.4. Pig humerus from site ECA, Area B, Zone C1 (ECA-45-5-1).

Larson and others, the Pacific Clade originated in East Asia, and "Lapita and later Polynesian dispersals into Oceania appear to be exclusively associated with Pacific Clade pigs" (Larson et al. 2007:4838).

Human (*Homo sapiens*)

A total of 202 NISP of human bones and teeth are included in the Mussau faunal assemblage (Table 6.1). The greatest amount of material comes from site EKE, where it was concentrated in the uppermost deposits of three units, possibly representing shallow burials that had been previously disturbed either by gardening activity or by pig rooting. EKQ had 5 NISP human, EHM 2 NISP, and EKU 1 NISP. The remaining 33 NISP come from site ECA, with 21 of those specimens from Area B (Table 6.2).

A morphometric analysis of 24 of human skeletal and dental remains excavated during the 1985 and 1986 field seasons at sites ECA, ECB, EHB, EKQ, and EHM was published by Kirch and others (1989). Swindler ([1990]) analyzed an additional 12 teeth recovered from the 1988 excavation at ECA. Based on patterns of dental morphology and metrics, Kirch and others ventured the following opinion: "On the whole, an extremely tentative affinity assessment would be that the Mussau Lapita people were slightly more like Indonesians than like Melanesians on the basis of dental morphology" (Kirch et al. 1989:74–75).

Two attempts were made, at different times, to obtain aDNA from the Talepakemalai human material. The first, by Erika Hagelberg (1997), failed to obtain any DNA. A second, more recent attempt by Lisa Matisoo-Smith at the University of Otago, using the greatly improved so-called "next-generation" sequencing methods, also failed to produce any results. It seems that the waterlogged, calcareous depositional environment of the ECA site, while it appears to preserve bone very well, also leaches out collagen and DNA.

Summary and Conclusions

The Lapita Phase

The non-fish vertebrate fauna from the three main Lapita sites (ECA, ECB, EHB), along with materials from the older deposits at EKQ and EKE, provide important insights into Lapita subsistence economy. First, however, it must be emphasized that both fish and mollusks vastly outnumber any of the non-fish vertebrates, and clearly dominated in terms of the protein component of Lapita diet in Mussau. These components of the Mussau faunal assemblages are the subject of the following two chapters.

With respect to the triumvirate of domestic animals widely associated with Austronesian-speaking peoples across Oceania—the pig, dog, and chicken—all three were undoubtedly present in Mussau during the Lapita phase. The best attested of these is the pig, but limited numbers of dog and chicken are also represented in firm stratigraphic contexts. None of these animals, however, appears to have been very important economically. Pig tusks were used as ornaments, and there is sufficient pig bone in the Lapita deposits at site ECA to suggest that it was consumed, but not in larger numbers.

Far more important than the domestic animals was the exploitation of two large marine vertebrates—sea turtles and porpoises. Turtles, especially, apparently contributed significant quantities of meat. Most of these were probably the green sea turtle, *Chelonia mydas*, readily taken when the females came ashore to lay their eggs, but quite likely also hunted as they grazed on the Mussau reefs and seagrass beds. Porpoises also provided large, high-quality meat packages. Exactly how these were obtained remains unclear, but the numbers are such as to indicate active predation by humans, rather than just occasional exploitation of stranded individuals.

With respect to wild terrestrial fauna, the pattern is one of low-intensity taking of a variety of common seabirds and some landbirds (such as fruit doves), fruit bats, and the occasional cuscus, snake, or lizard. The birds may have been sought as much for their feathers, and cuscus for its fur, as for food.

One unexpected result was the very low frequency of rat bones. The Pacific rat, *Rattus exulans*, with an origin in the island Southeast Asian region, is thought to have been dispersed with Austronesian-speaking peoples into the Pacific (Tate 1951). This commensal species appears in often high frequency in early settlement sites across Remote Oceania. That it is not abundant in the Mussau Lapita sites suggests that some form of predation, possibly by a variety of snakes, was suppressing the rat population in Mussau.

Later Prehistoric Trends

The taking of both turtles and porpoises continued into the post-Lapita phase in Mussau, although the numbers suggest an overall decline, possibly related to centuries of exploitation of these animals. Turtle populations, especially, are likely to have been susceptible to repeated taking of breeding females. Occasional hunting of birds, fruit bats, snakes, and lizards is also evidenced for the later sites.

The greatest difference between the Lapita and post-Lapita phases in terms of the non-fish vertebrate assemblages is in the much higher densities of pig bone in the late prehistoric sites. At Area B in ECA, the Lapita deposits have a pig bone density of just 0.64 NISP/m^2, whereas in the later sites the densities are 3 for EHK, 6.4 for EKU, and 8 for EKS. These much higher densities of pig bone correspond with the ethnographic description by Nevermann (1933) of substantial pig herds in the Mussau villages.

CHAPTER 7

Fish Remains from the Mussau Islands Sites

Virginia L. Butler

There has been much interest in understanding aspects of Lapita fisheries and their role in subsistence and overall lifeways since the cultural complex became the focus of attention in the 1950s (e.g., Green 1986; Groube 1971; Kirch and Dye 1979; Poulsen 1968). However, in a 1988 synthesis of fishbone records from Lapita sites excavated before 1984, Butler (1988) found that direct evidence for Lapita fisheries from bones themselves was quite limited. She found that of the 42 sites excavated before 1984, fish remains were documented as present from just 64%. Explicit methods of recovery and analysis were only available for eight of these, but three sites reported fewer than 30 identified specimens. Such a paucity of data certainly limited scholars' ability to *identify* patterning in Lapita resource use, much less *explain* such patterns. Fortunately, since the 1980s, there has been a huge increase in attention to fishbone study throughout Oceania (e.g., Allen 1992a; Fitzpatrick and Kataoka 2005; Giovas et al., 2016; Lambrides and Weisler 2016; Leach and Davidson 2000; Nagaoka 1994; O'Connor et al. 2011), including for Lapita records (e.g., Bouffandeau et al. 2018; Butler 1994; Cannon et al. 2019; Clark and Szabó 2009; Nunn et al. 2007). This work has explored a range of questions related to human-fish relationships, including the extent to which past people focused on nearshore vs. offshore resources, the nature of fishing methods and how they might vary across habitats and through time, the extent fisheries were intensified due to population growth and other factors; and whether communities were able to sustainably use fishery resources.

This chapter represents an example of such a focused study on Lapita fisheries. It summarizes the results from analysis of fish remains from the Mussau Islands, Papua New Guinea (PNG) that were recovered from large-scale excavation led by Patrick V. Kirch between 1985 and 1988 as part of the Lapita Homeland Project (see Chapter 1). Analysis mainly took place between 1987 and 1991. Most sites reflect Lapita-era occupation, including early and late contexts. As well, several contexts were sampled that postdate Lapita, allowing the opportunity to consider temporal change in fish use. Analysis was guided by several basic questions: 1) What fish taxa were used and how did fisheries change over time and vary across environmental settings? 2) Are there any trends in fish body size over time and space that can be related to fishing intensity or other cultural factors? 3) What can the fish remains tell us about fishing strategies used, such as habitats exploited or fishing methods? Recent work by scholars has characterized Lapita fisheries as "opportunistic" (Cannon et al. 2019); this study added the goal of addressing the extent to which the Mussau fish record was consistent with this picture. The project also provided an opportunity to examine methodological issues regarding how the selection of counting units, screen size, and skeletal elements recorded affect results of fish faunal analysis in this region, issues of limited concern in Oceania when the original work was carried out.

Methods and Materials

The fish remains included in this study are from eight sites, sampled at varying intensities (Table 7.1). Site ECA, composed of four main loci, received the most attention by far. Because of the large number of faunal remains from this site (44,167 NISP vertebrate faunal remains from ECA were identified as fish), and time constraints, not all of them could be analyzed. Considering project contexts, Butler and Kirch devised a strategy for subsampling fish remains from site ECA. In the block of units of Area B representing 29 1 m^2 grid units, remains were sampled in a checkerboard fashion, with materials from every alternate 1 m^2 unit receiving intensive analysis. All fish remains from ECA Area A and Area C were analyzed. All the fish remains from the remaining seven sites were included in analysis. The complete database of analyzed archaeological fishbones is available in the online Supplementary Materials. Please see www.dig.ucla.edu/talepakemalai.

Comparative Skeletons and Taxonomic Identification

An early step in analysis involved creating a list of fish taxa that could be present in the Mussau assemblages based on several fishery studies of the Indo-Pacific and waters around New Guinea (Kailola 1987a, b; Masuda 1975; Munro 1967). Skeletons from as many of the fish families from local marine waters as possible were obtained for comparative analysis. Greatly assisting the faunal project was the capture of 61 fish representing 19 families from the Mussau Islands, by John Aini of the Kavieng Fisheries Research Lab under the supervision of Dr. Andrew Wright (Dept. of Fisheries, Marine Resources, PNG), Kavieng, New Ireland in the 1980s. Kirch's team in Mussau prepared the skeletons, which were incorporated into the collection of the Oceanic Archaeology Laboratory. An additional 45 skeletons from 14 families were borrowed from the B. P. Bishop Museum. Overall, I had access to skeletons from 25 families, with multiple genera and species for several families; a complete list of the reference skeletons used in this analysis is available online in the Supplementary Materials. Datasets associated with this book are available at www.dig.ucla.edu/talepakemalai.

I began analysis by sorting the fish remains from the Mussau sites (including selected units from ECA-B) to skeletal element. After completing this exercise across all site assemblages, I went through all the original bags a second time, to pull remains that were inadvertently excluded in the first sort. For each element group (e.g., articulars, quadrates, hyomandibulae), I then developed criteria to distinguish specimens by fish family. I attempted to distinguish vertebrae from all fish. Those from Scombridae (tunas) and elasmobranchs (shark and ray) were easy to distinguish, but I was not able to define criteria to distinguish other families (see Lambrides and Weisler 2015 for more on this topic).

Given the tremendous number of genera and species comprising Indo-Pacific region fish families and the limited number of these taxa among the comparative skeletons, obtaining family-level identifications was the goal. Subfamily assignments were obtained in some cases. I sent remains from several fish groups (e.g., teeth from sharks and rays, eels [Anguilliformes], Perciformes pharyngeals that did not match reference materials) to ichthyologists who specialized in that group for close study. In other cases, subfamily assignments were based on the systematic literature that included osteological characters diagnostic of particular taxa.

I created additional analytic categories to address possible identification bias or to address limitations with the comparative collections. The remains of Scaridae and Lethrinidae tend to dominate previously studied Lapita

Table 7.1. Background information on Mussau sites with analyzed fish remains

Site	N Excavation Units (1 x 1 m)	Mesh Size (mm)	Age	Identified Fish NISP
ECA, transects	16	3, 5, 7	Lapita	1,773
ECA, Area A	6	5, 7	Lapita	87
ECA, Area B	14	3, 5, 7	Lapita	1,087
ECA, Area C	7	5	Lapita	254
ECB	19	5, 7	Lapita	134
EHB	9	7	Lapita	108
EKQ	2	5	Lapita/Post-Lapita	335
EKE	19	5	Lapita/Post-Lapita	514
EKU	5	7	Post-Lapita	21
EHK	5	5	Post-Lapita	98
EKS	4	5, 7	Post-Lapita	261

assemblages (Butler 1988:Table 4). The skeletal morphology of these families is also extremely distinctive, suggesting the possibility that ease of identification has artificially inflated their abundance. To address this possibility, elements which were clearly *not* scarid or lethrinid, but which could not be assigned securely to another family, were recorded as "nonScaridae/nonLethrinidae." I also created the category "Serranidae/Lutjanidae" (seabasses/snappers) for specimens that were clearly from one of these two families, but which could not be placed in a single family. I created the "Scombridae/Sphraenidae" category (tunas, mackerels/barracuda) for the same reason.

Counting Units

Because of potential concerns that counting unit used may affect quantification of taxonomic representation (Grayson 1984; Reitz and Wing 2008), I carried out a study comparing results based on two of the most commonly used measures: number of identified specimens (NISP) and minimum number of individuals (MNI). Both measures have been criticized on several grounds (Grayson 1984). The main problem with MNI is that it highly depends on how the faunal material is aggregated; the major problem with NISP is potential interdependence of the specimens being counted (Grayson 1984).

Several investigators have shown that for mammal faunas, MNI and NISP are highly correlated (Grayson 1984; Lyman 2008), and given the simplicity in calculation, Grayson (1984) suggests that NISP provides sufficient information for many faunal interpretations. Given that the impact of quantification on fish faunal analysis had not been much studied when the original analysis took place, I examined the relationship for Mussau to establish a basis for analytic decisions.

MNIs were calculated using White's method (1953) and involved summing the left, right, and unpaired elements of each taxon; the most abundant of this triad represents the MNI for a given taxon. A number of taxa were identified using scales, vertebrae, or teeth exclusively (Elasmobranchs, Ostraciidae). The number of specimens never exceeded the number present in an individual fish and MNI for these taxa was counted as one. The MNI for scombrid was based on caudal vertebrae (the four with prominent lateral struts); the total number of caudal vertebrae was divided by four to obtain MNI. For NISP, I tallied each element of an articulated set of remains (e.g., fused hyomandibula/quadrate from Muraenidae [moray eel]).

To explore the relationship in counting units, I performed regression analysis on the largest sample from the Mussau sites: ECA. MNI values were calculated with the whole site treated as an aggregate. A plot showing the relationship between MNI and NISP for the aggregate ECA assemblage shows that the two variables are highly and significantly correlated ($r = 0.935$, $p < 0.001$), when the variables are transformed by log10 (Figure 7.1). The following equation characterizes the relationship between NISP and MNI:

$$MNI = a(NISP)^b \qquad (1)$$

where a and b are constants empirically derived for each faunal assemblage (Casteel 1976/1977; Grayson 1984; Lyman 2008). A plot of standardized residuals against log NISP of the ECA sample shows a random scatter (Figure 7.2), indicating the exponential model is appropriate.

MNI and NISP have been shown to relate to one another in a predictable fashion for the ECA Mussau fish assemblage (see Nagaoka [1994], who demonstrated the correlation for the Cook Islands). Given the aggregation problems with use of MNI and the fact the two measures are highly correlated, I use NISP to examine patterning in the fish record at Mussau.

Effects of Mesh Size

The Lapita Homeland Project began in the mid-1980s before the impact of mesh size on faunal recovery was fully appreciated by archaeologists working in Oceania (Butler 1988; Gordon 1993; Nagaoka 1994, 2005). As has been shown in numerous archaeological contexts, the problem boils down to this: "small" specimens (from small fish, or small elements from large fish, or fragmentary remains from any size fish) are less likely to be recovered from "large" mesh screens than "small" mesh screens (e.g., Casteel 1972; Wheeler and Jones 1989). Mesh size also affects absolute number of specimens recovered, with smaller mesh screens resulting in much larger numbers of specimens as well. While "large" and "small" can be variously defined, given excavation conventions, typically large mesh are 6.4 mm (0.251 in) and larger, while small mesh refer to 3.2 mm (0.126 in) mesh and smaller. A key concern is that reliance on large mesh screens can bias recovery and representation of small fish taxa. A second concern arises if mesh size *varies* across contexts that one is comparing. Differences in fish representation

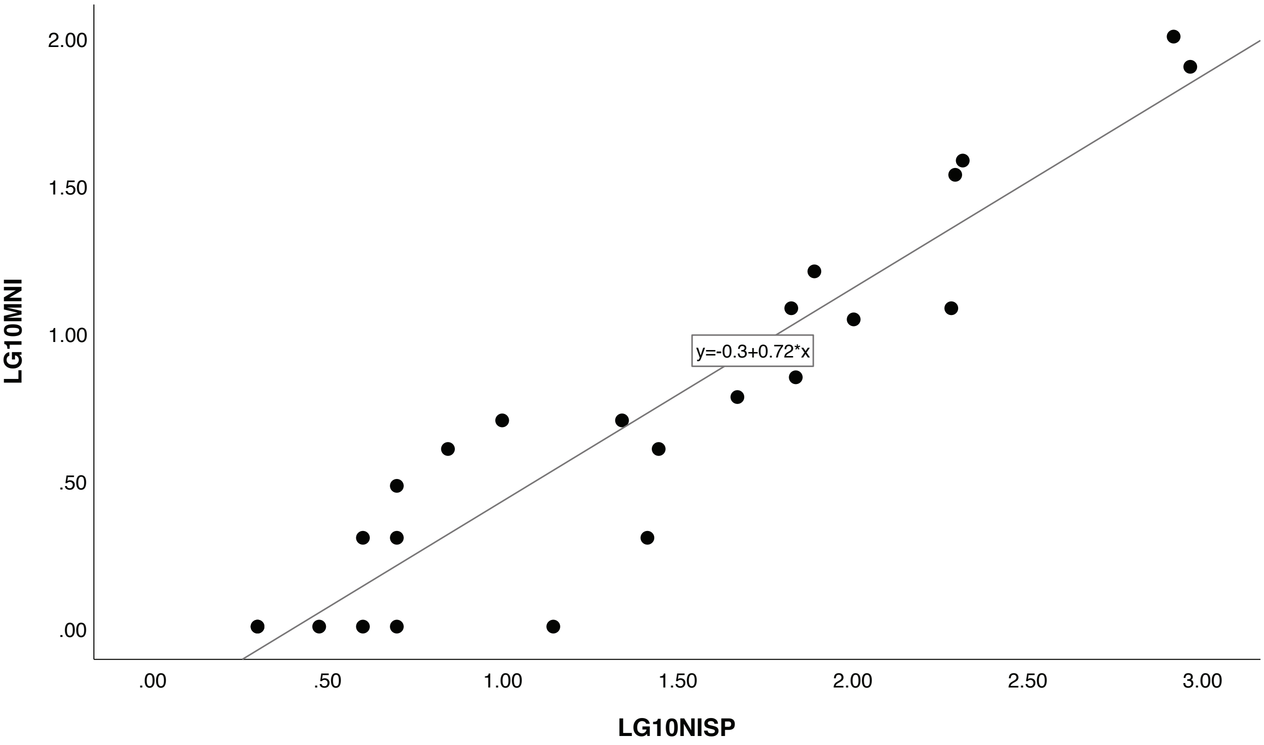


Figure 7.1. Relationship between log10 NISP and log10 MNI based on fishbone analysis at Mussau site ECA. (Diagram by V. Butler.)

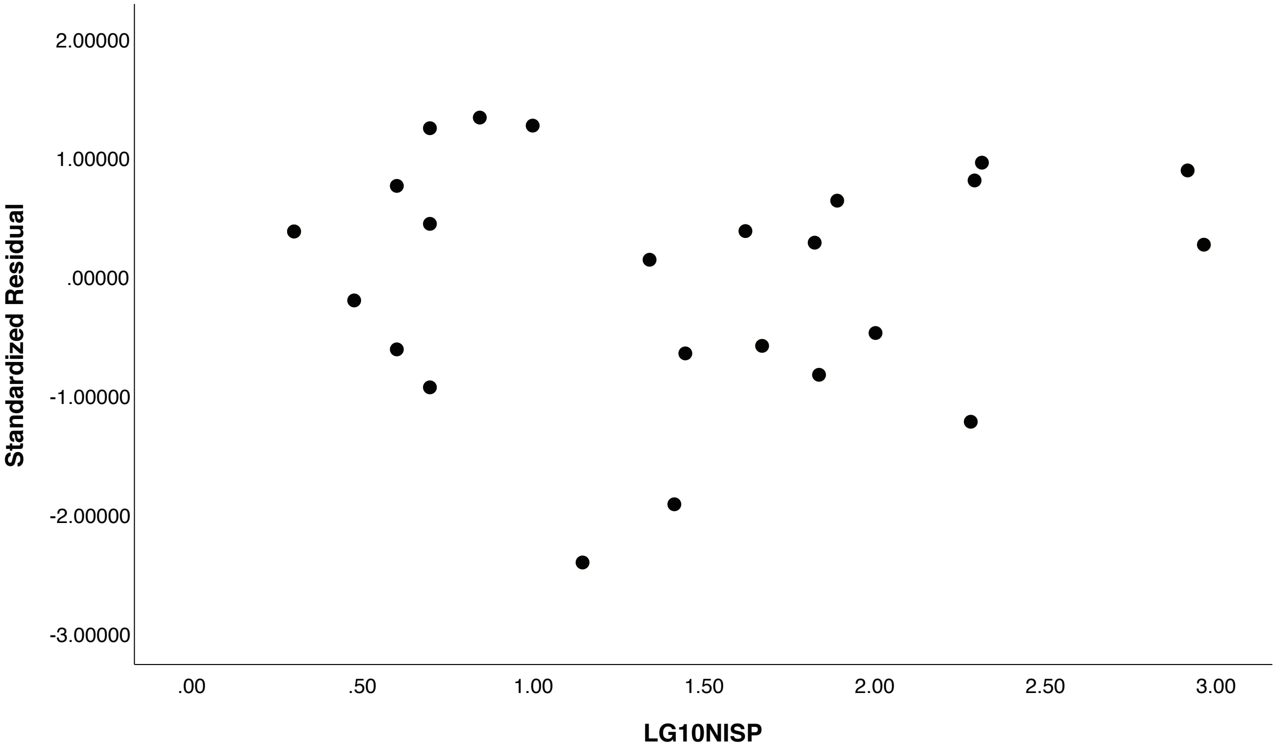


Figure 7.2. Plot of standardized residuals against log NISP of fish fauna, Mussau site ECA. (Diagram by V. Butler.)

could reflect true differences in the population of fish remains in those contexts—or simply differences in the mesh size used.

The Mussau fish faunal study may be affected by mesh size. As Kirch (2001a) explained in his overview of Mussau project excavation methods, in 1985 the Lapita Homeland Project supplied the Mussau field crew with 7 mm (0.275 in) and 5 mm (0.197 in) mesh screens, and only one 3 mm (0.118 in) mesh screen. The field crews used the 5 mm mesh as much as possible, and at most sites only the upper 2–3 levels were excavated with 7 mm mesh, with most matrix being screened with 5 mm mesh (Table 7.1). However, at EHB, 7 mm mesh was used exclusively, and at EKS, three of the four excavated grid units were screened with 7 mm mesh. Only one grid unit at ECA that was studied for fish remains was screened using 3 mm mesh. The dominant use of the relatively large 5 mm mesh suggests remains from small fish taxa could have been lost during screening. Moreover, the fact that different mesh sizes were used to screen matrix within and between sites could affect intra- (and inter-)site comparisons.

To identify potential impacts of screen size on taxonomic representation, the most direct approach would have compared faunal representation from excavated matrix that was put through a series of nested screens of different mesh size (e.g., Partlow 2006). Since such a test was not carried out during excavation at Mussau, I compared fish faunal representation from adjacent grid units in ECA-B that were excavated with 3 mm and 5 mm mesh. The limitation with this test is that differences observed *could* reflect actual differences in representation of fish in adjacent units, versus mesh size. I also compared fauna representation between 5 mm and 7 mm matrix for the ECA-B assemblage overall.

As seen in Table 7.2, fish family representation is highly consistent between the two grid units screened using 3 mm and 5 mm mesh respectively: the rank orders are significantly correlated ($r_s = 0.761$, $p < 0.001$). With one exception, Serranidae, the same families fall in the top five ranks; and almost the same families fall in the top 10 ranks (Table 7.2). As well, fish family representation in the samples retained in the 5 mm vs. 7 mm mesh, based on remains from 14 grid units at ECA-B, is also consistent

(Table 7.3); the rank order correlation is high and significant ($r_s = 0.903$, $p < 0.001$). Almost the same families fall in the top ten ranks for all three mesh size samples. The only exception is Lujanidae, which is ranked 13.5 in the 7 mm mesh vs. 7 in the 5 mm. The most abundant families in the 5 mm mesh, including lethrinids, scarids, serranids, balistids, and labrids, are the best represented in the two other screen fractions as well.

Given the ubiquitous effects of mesh size on fish taxonomic representation reported in other parts of the world (e.g., Zohar and Belmaker 2005), the fact that the relative frequencies of fish taxa are consistent across the mesh size samples requires some comment. At least for Oceania studies, screen size bias has been noted especially for the five main jaw elements. For example, in experimental sieving, Nagaoka (2005) showed that acanthurid premaxillae, dentaries, maxilla, and quadrates have extremely low recovery rates in 6.4 mm mesh. Pomacentrid (damselfishes) maxillae, quadrates, and articulars were not recovered in 6.4 mm mesh at all. For Mussau, 32 skeletal elements were studied (see below). Perhaps including a larger range of elements of different sizes and robusticity has reduced the magnitude of mesh size bias. As well, the similarity in representation may only be apparent because of the family level of comparison. Body size of species within the dominant fish families is extremely variable. For example, New Guinea lethrinid species range between 240 mm and 800 mm in total length; serranid and scarid species can vary from 150 mm to over 1000 mm in length (Munro 1967; Myers 1989). Obviously size of the skeletal remains from these fishes would also vary considerably. It is possible that remains of smaller-bodied species are relatively more

Table 7.2. Comparison of fish family frequency (NISP) and rank order based on adjacent grid units screened using two mesh sizes, 3 mm (Square 53) and 5 mm (Square 52), ECA area B (rs = 0.761, p < 0.001)

Family	3mm Mesh	Rank Order	5mm Mesh	Rank Order
Lethrinidae	16	1	31	1
Scaridae	12	2	16	2
Lutjanidae	6	3.5	7	3
Balistidae	6	3.5	5	5.5
Labridae	4	5.5	5	5.5
Non-Scaridae/ non-Lethrinidae	4	5.5	4	7
Carangidae	3	7	3	9.5
Serranidae	2	9	6	4
Belonidae	2	9	3	9.5
Holocentridae	2	9	1	14
Acanthuridae	1	10.5	1	14
Dasyatidae	1	10.5	0	16
Muraenidae	0	14.5	3	9.5
Scombridae	0	14.5	3	9.5
Diodontidae	0	14.5	2	12
Scorpaenidae	0	14.5	1	14
Total	59		91	

Table 7.3. Comparison of fish family frequency (NISP) and rank order based on all matrix from ECA, Area B, screened through 5 mm and 7 mm mesh (rs = 0.903, p < 0.001).

Family	5mm Mesh	Rank Order	7mm Mesh	Rank Order
Lethrinidae	208	1	72	1
Scaridae	157	2	52	2
Non-Scaridae/non-Lethrinidae	62	3	27	4
Serranidae	61	4	16	5.5
Balistidae	48	5	29	3
Labridae	41	6	16	5.5
Lutjanidae	30	7	3	13.5
Belonidae	20	8	7	9
Carangidae	16	9	8	8
Acanthuridae	14	10	10	7
Scombridae	12	11	2	16.5
Diodontidae	8	12	4	11
Muraenidae	6	13	0	22
Holocentridae	3	14.5	4	11
Elasmobranch	3	14.5	3	13.5
Tetraodontidae	2	17	4	11
Sciaenidae	2	17	2	16.5
Serranidae-Lutjanidae	2	17	2	16.5
Haemulidae	1	22	2	16.5
Carcharhinidae	1	22	0	22
Mugilidae	1	22	0	22
Myliobatidae	1	22	0	22
Ostraciidae	1	22	0	22
Scorpaenidae	1	22	0	22
Sphyraenidae	1	22	0	22
Total	702		263	

abundant in finer mesh, but because only family level identifications are compared, such differences are obscured. Of course, one way to account for the *lack of mesh size bias* at Mussau is that the recovery methods used—mainly 5 mm with some 7 mm mesh size—accurately sampled the fish remains in the Mussau deposits. In other words, perhaps Mussau people simply focused most fishing on large-bodied fishes—remains of which are retained in the 5 and 7 mm mesh screens used.

It is worth emphasizing that the test for recovery bias is not very robust. A single grid unit was screened with 3 mm mesh (relative to 106 1 x 1 m units in the study); a small number of specimens (NISP = 150) were used in the comparison of 3 mm vs. 5 mm mesh recovery. One could argue that such a small scale test is hardly a test at all. For the current project, since I cannot empirically point to a mesh size effect on family level representation, analyses are based on the aggregate sample of all mesh size fractions for each site context; and I move forward under the assumption that mesh size does not affect inter-and intra-site comparisons.

Skeletal Element Selection

Until the mid-2000s, analyses of fish remains in Oceania focused on a relatively small number of skeletal elements: five paired jaw elements (dentary, premaxilla, maxilla, quadrate, articular) and the so-called *special bones*, which are skeletal elements that are distinctive of particular taxa (e.g, caudal tangs for acanthurids; pharyngeal jaws for scarids, labrids; caudal scutes for carangids; dorsal spines for balistids) (Best 1984; Green 1986; Leach 1986; Masse 1986, 1989). Butler (1988, 1994) and more recently others (Bouffandeau et al. 2018; Campbell 2016; Giovas 2018; Lambrides and Weisler 2015; O'Connor et al. 2011; Ono and Clark 2010; Ono and Intoh 2011) have argued that restriction of analysis to primarily mouth parts may bias estimates of taxonomic abundance for a variety of reasons. Reliance on a few head parts to estimate faunal abundance requires the assumption that cultural processing and disposal patterns are random with respect to body part or taxonomic category affected, an assumption that may not be justified. Restricting analysis to mouth parts, in conjunction with use of large mesh screens, also biases the sample in favor of larger-mouthed fishes (e.g., serranids) and against smaller-mouthed forms (e.g., acanthurids). Further, Masse (1986) argued that inclusion of only mouth parts, particularly the premaxillae and dentaries, biased the results in favor of taxa whose jaw parts are more durable (e.g., labrids). Building on this concern, Ono and Clark (2010) point out that vertebrae need to be studied to document scombrids (tunas and mackerels) and sharks (Elasmobranchs), which have either very lightly built jaws or cartilaginous mouth parts. Extending this further, Lambrides and Weisler (2015) and Bouffandeau and others (2018) suggest that vertebrae from all fish taxa be incorporated in faunal analysis in Oceania archaeology (see Giovas 2018 for similar argument in the Caribbean.)

Aware of these concerns during project design in the late 1980s, I explicitly broadened the range of elements to study well beyond the five jaw elements and a handful of "special" bones to include a total of 32 elements (Table 7.4). Twelve elements are unique to a subset of families and would be labeled as "special" bones in Oceania parlance (as noted above; see Table 7.4). For the bony fishes, I attempted to identify 20 distinct elements from the cranium (including the jaw, the neurocranium, and the suspensorium) and the paired fins. Unfortunately, notwithstanding the importance of including vertebrae, my attempts to distinguish vertebrae for the bony fishes were not successful. For Mussau, I only identified caudal vertebrae of scombrids and all vertebrae of elasmobranchs.

To assess the effects of element selection on fish family representation for Mussau, I compared the rank order representation of fish families based on three sets of elements. The first set (hereafter Set I) includes the five jaw elements used in all Oceania studies. The second set (Set II) includes the jaw elements and commonly used "special bones" (caudal tangs for acanthurids; pharyngeal for multiple taxa; and dorsal spines for balistids). The third set (Set III) includes the jaw elements, the "specials," and an additional 15 skeletal elements for a total of 32 elements. For the comparison, I aggregated records from all the Mussau assemblages and used Spearman Rank order correlation statistics to test for significant differences.

Differences in family representation were less pronounced than expected. As shown in Table 7.5 comparing results for Set I and Set II, almost the same taxa are ranked in the top ten ranks. The rank order correlation is high and significant ($r_s = 0.780$, $p < 0.001$). The main discrepancy occurs with acanthurids, which are ranked twentieth with Set I and fourteenth with Set II. This striking shift is likely because acanthurids have relatively small jaws, coupled with the dominant use of relatively large mesh screens, 5 and 7 mm. Notably, the first and second ranked fishes (lethrinids, scarids) switch rank order between Set I and II. More important than rank order perhaps is that adding the "special bones" identified 8 additional taxa, most notably the elasmobranchs, the sharks and rays, identified by teeth and vertebrae. Expanding the elements further with Set III provided a rank order that was extremely similar to that from Set II ($r_s = 0.945$; $p < 0.001$) (Table 7.5). The top 10 ranked taxa are almost identical (Table 7.5). The two top-ranked families, scarids and lethrinids, switch order again. The greatest discrepancy occurs with Acanthuridae, which

Table 7.4. List of skeletal elements included in Mussau fish faunal analysis. Elements that were only identified for a restricted set of families are the so-called special bones

Cranial		**Postcranial—pectoral fin**	
Element	**Taxon identified (if restricted)**	**Element**	**Taxon identified (if restricted)**
Articular		Cleithrum	
Basioccipital		Postcleithrum	Balistidae
Ceratohyal		Posttemporal	
Dentary		Scapula	
Epihyal		Supracleithrum	
Ethmoid	Balistidae		
Exoccipital		**Postcranial—pelvic fin**	
Hyomandibula		Basipterygium	
Infraorbital	Synanceiidae		
Maxilla		**Postcranial—unpaired fin**	
Opercle		Dorsal spine	Balistidae
Palatine			
Parasphenoid		**Postcranial—vertebral column**	
Pharyng, upper	all Perciformes	Vertebra, caudal	Scombridae
Pharyng, lower	all Perciformes	Vertebra, misc.	Elasmobranch
Pharyngobranchial	Scaridae		
Premaxilla		**Postcranial—tubercles, tangs**	
Preopercle		Caudal tang	Acanthuridae
Quadrate		Scale/tubercle	Ostraciidae, Dasyatidae
Tooth	Elasmobranchs		
Vomer			

moves up to eighth rank in Set III, from fourteenth in Set II. Notably, additional families were not added with the expanded set of elements with Set III.

I have illustrated some of these trends by plotting the rank order abundance of fish families for each element set (Figure 7.3). The rank orders of fish families for Set II and III are generally consistent, while trends for Set I are distinct, especially for ranked abundance greater than 10, the less abundant families. One way to interpret the consistency in Sets II and III is that the Set II sample is "reasonably" estimating Mussau fish family representation, and adding the Set III provides redundant information. In turn, the most restricted Set I sample is not estimating fish representation well, especially for families with small sample sizes.

For the Mussau project, all of the elements are included in the analysis. While Set II appears to provide a reasonably robust estimate of fish family abundance, increasing the number of elements to include Set III enlarges the sample sizes, which facilitates inter- and intra-site comparisons of fauna. For this study, Set III provided twice as many specimens as Set I (Table 7.5).

Table 7.5. Comparison of fish family frequency (NISP) and rank order based on three sets of skeletal elements, all Mussau sites combined ("N Family" excludes joint categories)

Family	Set I	Rank order	Set II	Rank order	Set III	Rank order
Lethrinidae	812	1	821	2	1,289	1
Scaridae	565	2	1,076	1	1,186	2
Serranidae	219	3	219	4	319	4
Non-Scaridae/ non-Lethrinidae	140	4	140	6	406	3
Labridae	106	5	238	3	277	5
Lutjanidae	98	6	98	7	164	7
Balistidae	90	7	162	5	264	6
Belonidae	65	8	65	10.5	74	12
Carangidae	61	9	65	10.5	98	9
Tetraodontidae	58	10	58	12	65	13
Muraenidae	38	11	38	15	49	14
Holocentridae	27	12	27	16	44	16
Diodontidae	19	13	85	8	90	10
Mullidae	8	14	8	19.5	20	17
Sphyraenidae	7	15	7	21.5	9	22
Haemulidae	5	16	5	23	6	26.5
Gerreidae	4	17	4	24	7	24.5
Scombridae	3	18	68	9	80	11
Acanthuridae	2	20	41	14	108	8
Mugilidae	2	20	2	25	14	19
Scombridae-Sphyraenidae	2	20	2	25	2	28.5
Kyphosidae	1	23	1	30	1	31
Platycephalidae	1	23	1	30	1	31
Serranidae-Lutjanidae	1	23	1	30	13	20
Carcharhinidae	0	28.5	8	19.5	8	23
Carcharhiniformes	0	28.5	1	30	1	31
Dasyatidae	0	28.5	2	25	2	28.5
Elasmobranch	0	28.5	46	13	46	15
Myliobatidae	0	28.5	7	21.5	7	24.5
Ostraciidae	0	28.5	19	17	19	18
Sciaenidae	0	28.5	12	18	12	21
Scorpaenidae	0	28.5	1	30	6	26.5
Total	2,334		3,328		4,687	
N Family	21		27		27	

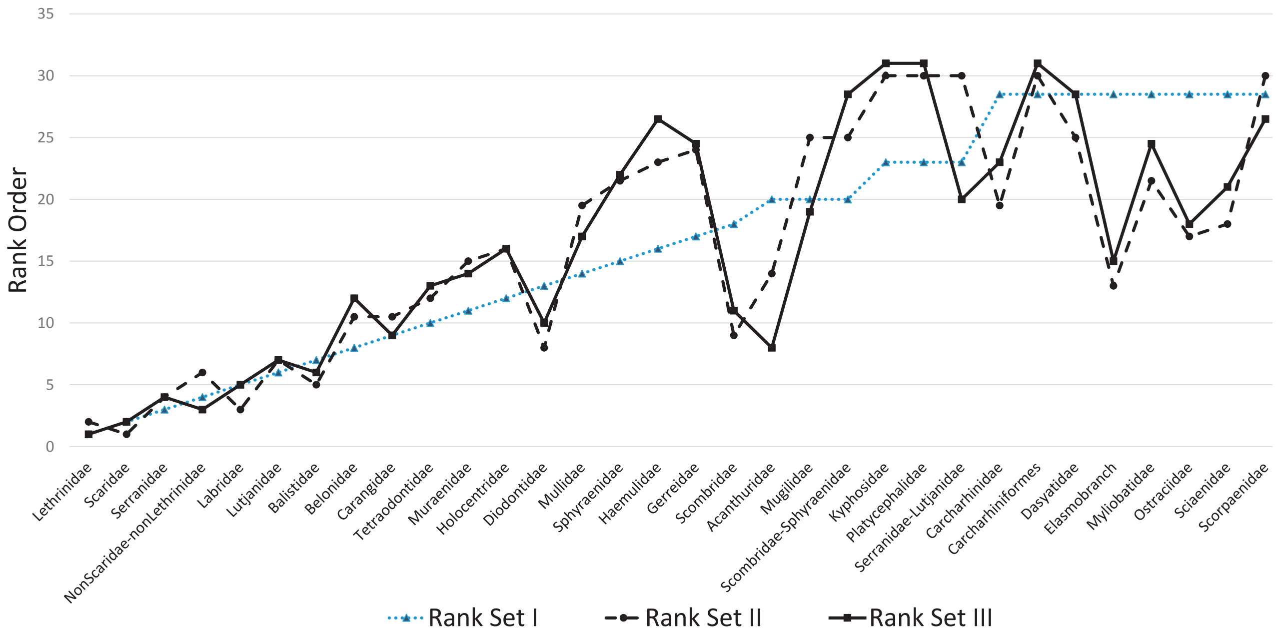


Figure 7.3. Comparison of fish family rank order by skeletal element set, all Mussau fish faunas combined. Dashed horizontal line is drawn at rank 10, demarcating the higher vs. lower ranked families. (Diagram by V. Butler.)

Body Size Reconstruction

One goal of the study was to examine trends in fish body size that might relate to fishing intensity (e.g., Giovas et al. 2016; Leach and Davidson 2001; Masse 1989), variations in capture techniques, or other cultural factors. That declines in body size are caused by exploitation pressure is based on the idea that high levels of predation effectively limit the number of individuals living to older age/larger size, resulting in a more rapid turnover of the population and a reduction in age/size in the demographic profile. Studies that use archaeological faunal remains to examine size class variation within prehistoric prey populations are based on the assumption that bone size and body size (e.g., total length, total live weight) are strongly and positively correlated, a relationship that has been substantiated in countless studies (e.g., Granadeiro and Silva 2000). For the Mussau study, I did not have access to a large series of modern skeletons for any taxa, thus body size reconstructions were not possible. Rather, I compared sizes of the archaeological specimens from different contexts to identify size variation across spatial and temporal components of the Mussau sites.

Taxa within two families, Scaridae and Lethrinidae, were selected for study for several reasons. First, these families dominate every site assemblage, suggesting that members of the families were exploited to a significant degree, perhaps at a level that altered population dynamics. On the practical side, such taxonomic abundance also insured the largest sample sizes for temporal and spatial comparisons. Scarids and lethrinids were also selected for measurement because elements belonging to these families could be assigned to a subfamily category (for scarids) or species, *Monotaxis grandoculis* (lethrinid). As noted previously, most taxonomic identifications in the Mussau assemblages were to the family level. Most of the fish families are represented by a large number of genera/species, which in turn may vary tremendously in body size. Because I wanted to examine size class variation within a relatively tightly defined taxonomic unit—not document size variation, which might simply reflect variation in the genera/species represented—I sought to measure elements distinctive of particular subfamily groups.

I modeled the Mussau bone size analysis on Masse's study (1989:499; see also Masse et al. 2006), which examined size variation for *Monotaxis* and scarids for archaeological contexts in Palau, Micronesia. Masse divided the distinctive lower pharyngeal of scarids into three morphological types mainly based on the ratio of width to length of the grinding mill portion of the element (see Masse et al. 2006:Figure 8): Type I (~*Bolbometopon*), Type II (*Calotomus*), and Type III (~*Scarus*). Masse linked the pharyngeals to three different parrotfish genera, though he admitted that the "types" could include additional genera (e.g., *Cetoscarus* with Type 1). One apparently common scarid genus in Palau not mentioned by Masse and others (2006), *Chlorurus*, was targeted by Giovas and others (2016) in their study of ancient scarid body size in Palau, which suggests some limitations with the Masse types.

Protocols followed Masse (1989). I measured the maximum width of the tooth row of lower pharyngeals (Masse et al. 2006:Figure 8; see also Giovas et al. 2016). I assigned the pharyngeals to Masse's types, using the tilde symbol, ~*Bolbometopon,* ~*Calotomus*, and ~*Scarus,* indicating the tentative nature of the assignment.

For *Monotaxis*, I measured the length of the premaxilla. I used digital calipers, taking the average of two measures, with precision to the nearest 0.01 mm. To increase the sample size from ECA-B, *Monotaxis* premaxillae and scarid lower pharyngeals were included from grid units not part of the original sample of grid units analyzed (see Table 7.1). Remains from sites EKQ, EKS, EHB, ECB, and EKU were not available for measurement and hence not included in analysis.

Descriptive Summary

This section presents information on habitat preferences and ethnographic fishing techniques of the families represented in the Mussau assemblages as well as criteria used for subfamily and generic assignments. Systematic nomenclature and organization follows Nelson and others (2016).

Class Chondrichthyes—cartilaginous fishes
Infraclass Elasmobranchii—sharks and rays

Material: 46 miscellaneous vertebrae: 46 specimens

Remarks: Elasmobranchs include the ~ 1149 cartilaginous shark and ray species distributed worldwide (Nelson et al. 2016); about 90 species inhabit waters within the political boundaries of PNG (Kailola 1987a). Some forms are largely pelagic while others reside in or periodically visit nearshore reef environments. The calcified vertebrae recovered from the Mussau sites could be from any of the shark and ray species known for PNG.

Order Carcharhiniformes

Material: 1 tooth: 1 specimen

Family Carcharhinidae—requiem sharks

Material: 3 teeth: 3 specimens

cf. *Galeocerdo* sp.

Material: 1 tooth: 1 specimen

Negaprion acutidens—sicklefin lemon shark

Material: 3 teeth: 3 specimens

Carcharhinus hemiodon—pondicherry shark

Material: 1 tooth: 1 specimen

Remarks: The shark teeth were identified by George Burgess (Florida Museum of Natural History, personal communication, January 24, 1991). The carcharhinid family is represented by 25 species in PNG (Kailola 1987a:14). A single species of *Galeocerdo* is known for PNG, *G. cuvier* (Kailola 1987a:14), a voracious scavenger occupying the open sea and frequenting shallow reefs (Munro 1967:9). *Negaprion acutidens* occurs both in lagoons and on seaward reefs, but at least in Micronesia, prefers turbid inshore lagoons less than 30 m deep (Myers 1989:36).

Order Myliobatiformes
Family Dasyatidae—stingrays

Material: 2 tubercles: 2 specimens

Family Myliobatidae—eagle rays

Material: 6 dental plate fragments: 6 specimens

Aetobatus cf. *narinari*—spotted eagle ray

Material: 1 dental plate fragment: 1 specimen

Remarks: The ray and skate remains were identified by John D. McEachran and Tsutomu Miyake (Texas A & M, personal communication, March 11, 1988, March

27, 1991). About 14 stingray species are found in PNG (Kailola 1987a:28). Shallow-water, bottom fishes inhabiting estuaries, bays, and lagoons, stingrays consume worms, mollusks, and crustaceans buried in bottom sediment (Munro 1967:14).

Four species of eagle rays occur in PNG (Kailola 1987a:33). *A. narinari* is common in shallow coastal waters of PNG (Munro 1967:16), while in Micronesia, the spotted eagle ray occurs from shallow sand flats to outer reef slopes and, unlike most rays, spends much time swimming above the bottom (Myers 1989:39).

Class Osteichthyes—bony fishes
Order Anguilliformes
Family Muraenidae—moray eels

Material: 10 articulars, 18 dentaries, 7 hyomandibulae, 4 maxillae, 6 quadrates, 4 vomers: 49 specimens

Remarks: Skeletal reference material for the eels was not available during analysis. David G. Smith (Smithsonian, National Museum of Natural History, personal communication, December 12, 1990) confirmed the assignment of the Mussau remains to the muraenid family, based on direct examination of specimens and comparison with other eel groups. Muraenid hyomandibula/quadrates are distinct from other eels in having the point of articulation with the mandible and the opercle relatively close together (David G. Smith, National Museum of Natural History, personal communication, December 12, 1990). The posterior arm of the hyomandibula, which articulates with the opercle, is located near the ventral end of the element, adjacent to the quadrate.

About 41 species of moray eels occur in PNG (Kailola 1987a:42). Most species inhabit shallow, coastal waters close to rocks and coral heads (Munro 1967:94); many forms are nocturnal (Hiatt and Strasburg 1960:73; Myers 1989:40). Crustaceans dominate the diet, with small fish also being taken (Hiatt and Strasburg 1969:73).

Order Holocentriformes
Family Holocentridae—squirrelfishes

Material: 9 articulars, 3 hyomandibulae, 2 maxillae, 4 opercles, 2 premaxillae, 2 quadrates, 4 posttemporals, 2 supracleithra: 28 specimens

Taxon A

Material: 9 dentaries: 9 specimens

Taxon B

Material: 3 dentaries: 3 specimens

Subfamily Holocentrinae

Material: 4 preopercles: 4 specimens

Remarks: About 26 species of holocentrids occur in PNG (Kailola 1987a:174), most of which are nocturnally active (Munro 1967:139). Some forms occupy the water column above the reef and consume mainly zooplankton; others forage closer to the bottom for crustaceans, worms, or small fishes (Myers 1989:74). Masse (1986:106) indicates that in Palau, holocentrids are most often caught with a baited hook, but may also be taken with a trolling lure, net, or hand spear.

Archaeological specimens assigned to Holocentrinae have a strong spine at the angle of the preopercula, characteristic of this subfamily (Nelson et al. 2016:304). Dentaries were divided into forms that had a tooth patch on the anterior end (Taxon A) and those which lacked such a tooth patch (Taxon B). The tooth patch forms may represent the subfamily Myripristinae. Myers (1989:74) notes that two species of Myripristinae (*Myripristis* spp.) have a dentary tooth patch while none of the species from the second Holocentrid subfamily, Holocentrinae, have one.

Order Mugiliformes
Family Mugilidae—mullets

Material: 1 articular, 2 hyomandibulae, 5 opercles, 1 quadrate, 1 cleithrum, 3 scapulae, 1 supracleithrum: 14 specimens

Remarks: Mullets are represented by 18 species in PNG (Kailola 1987a:361). They are coastal, primarily schooling fishes that mainly feed on fine algae and detritus from bottom sediments (Munro 1967:164).

Order Beloniformes
Family Belonidae—needlefishes

Material: 13 articulars, 9 hyomandibulae, 50 indeterminate premaxillae/dentaries, 2 quadrates: 74 specimens

Remarks: Eleven species of belonids are found in PNG (Kailola 1987b:156). Generally voracious consumers of small schooling fishes (Munro 1967:105), many species travel in small schools themselves, just beneath the surface (Hiatt and Strasburg 1960:74). Some species are exclusively pelagic, while most range into inshore reefs (Myers 1989:71).

Order Carangiformes

Family Carangidae—jacks

Material: 3 articulars, 3 ceratohyals, 26 dentaries, 1 epihyal, 2 exoccipitals, 1 hyomandibula, 13 maxillae, 6 opercles, 2 palatines, 1 parasphenoid, 4 lower pharyngeals, 13 premaxillae, 2 preopercles, 6 quadrates, 7 cleithra, 2 posttemporals, 5 scapulae, 1 supracleithrum: 98 specimens

Remarks: The family Carangidae is comprised of about 30 genera and 147 species worldwide (Nelson et al. 2016:386). Almost exclusively carnivorous, most are active, fast-swimming, schooling fishes common in coastal waters of bays and estuaries (Munro 1967:221). Masse (1986:106) suggests that jacks are mainly taken with a baited hook, but are also captured by trolling lure, net, hand spear, and weir.

Order Istiophoriformes

Family Sphyraenidae—barracudas

Sphyraena spp.

Material: 2 articulars, 5 dentaries, 1 opercle, 1 palatine: 9 specimens

Remarks: One genus and 27 species of barracuda are known worldwide (Nelson et al. 2016:388). Carnivorous, fast-swimming fishes, barracudas typically slash their prey with their sharp teeth (Munro 1967:161). Larger forms occur in coastal waters around reefs while smaller species congregate in schools in estuaries (Munro 1967:161).

Order Scombriformes

Family Scombridae—tunas and mackerels

Material: 1 articular, 1 hyomandibula, 2 maxillae, 2 opercles, 9 scapulae, 65 caudal vertebrae: 80 specimens

Remarks: The scombrid family is represented by about 21 species in PNG (Kailola 1987b). Scombrids are mainly pelagic, open-water fishes although they may be found in shallow water, especially in places adjacent to deeper water (Herald 1961:231). All are carnivorous, fast-swimming, schooling fishes that consume mainly schooling fishes, crustaceans, and squid (Hiatt and Strasburg 1960:79). They are mainly caught with trolling lures in Palau (Masse 1986:106) and in Guam (Amesbury et al. 1986:83). Scombrids are highly prized food fish wherever they occur.

Order Labriformes

Family Labridae—wrasses

Material: 6 articulars, 2 basioccipitals, 2 ceratohyals, 5 dentaries, 2 epihyals, 2 exoccipitals, 5 hyomandibulae, 13 maxillae, 1 opercle, 3 parasphenoids, 44 upper pharyngeals, 83 lower pharyngeals, 5 indeterminate pharnygeals, 24 premaxillae, 9 indeterminate premaxillae/dentaries, 9 preopercles, 11 quadrates, 3 cleithra, 2 posttemporals, 8 supracleithra: 239 specimens

Taxon A

Material: 22 dentaries: 22 specimens

Taxon B

Material: 16 dentaries: 16 specimens

Remarks: The labrid family is highly diverse in shape, color, and size; 71 genera are known worldwide (Nelson et al. 2016:428). Eighty-nine species occur in PNG (Kailola 1987b:366). Most forms are carnivorous, feeding on benthic invertebrates, and all have well-developed pharyngeal teeth for crushing prey (Hiatt and Strasberg 1960). Labrids primarily occupy shallow waters among coral reefs and rocks. Green (1986:128) reports that wrasses are taken by angling, netting, spearing, and poisoning. Masse (1986:106) states that in Palau, the fish are most often caught with baited hooks, but are also netted and trapped.

Dentaries of Taxon A are relatively straight along the anterior–posterior axis and laterally compressed. Taxon B dentaries have significant curvature along the anterior–posterior axis and have distinctive canines, one directed in an anterio-dorsal direction and a second directed posterio-laterally. Taxon A specimens resemble comparative specimens from the subfamily Cheilininae, while Taxon B dentaries are similar to those from species in the subfamily Bodianinae.

Family Scaridae—parrotfishes

Material: 19 articulars, 11 basioccipitals, 183 dentaries, 4 exoccipitals, 21 hyomandibulae, 38 maxillae, 23 opercles, 15 palatines, 18 parasphenoids, 230 upper pharyngeals, 235 lower pharyngeals, 8 indeterminate pharyngeals, 38 pharyngobranchials, 167 premaxillae, 89 indeterminate premaxillae/dentaries, 2 preopercles, 69 quadrates, 2 vomers, 1 cleithrum, 6 scapulae, 7 basipterygia: 1186 specimens

Remarks: The largely tropical scarid family is represented by 27 species in PNG (Kailola 1987b:377). Parrotfishes are found in all coral reef habitats and most travel in small schools (Hiatt and Strasberg 1960). They feed mainly on coral polyps, their strong beaklike jaws biting off chunks of coral and robust pharyngeal teeth in the back of the mouth crushing the hard matrix. Marshall (1964) writes that scarids are rarely caught with a hook and line because of their eating habits. Masse (1986:106) reports that in Palau, scarids are mainly netted, although they also are taken with baited hook, spear, and trap. Amesbury and others (1986) note that in Guam, parrotfishes are netted, trapped, and speared.

Order Perciformes

Family Gerreidae—mojarras

Material: 1 ceratohyal, 1 dentary, 1 epihyal, 2 premaxillae, 1 quadrate, 1 posttemporal: 7 specimens

Remarks: Mojarras, represented by 10 species in PNG (Kailola 1987b:308), are carnivorous, small to moderate-sized schooling fishes typically found along sandy shorelines (Munro 1967:331).

Family Mullidae—goatfishes

Material: 1 articular, 2 dentaries, 5 hyomandibulae, 3 maxillae, 1 opercle, 2 palatines, 2 quadrates, 1 scapula, 1 supracleithrum, 2 basipterygia: 20 specimens

Remarks: Mullids are represented by 17 species in PNG (Kailola 1987b:322). Goatfishes are small to medium-sized fishes, schooling and solitary, and are common on sandy reef bottoms, where they subsist mainly on crustaceans (Hiatt and Strasburg 1960:88).

Family Kyphosidae—sea chubs

Material: 1 premaxilla: 1 specimen

Remarks: Three species of sea chubs are found in PNG (Kailola 1987b:330). Kyphosids are mainly herbivorous, subsisting chiefly on algae, and mostly occur in shallow coastal water around rocks and reefs (Munro 1967:352).

Family Serranidae—sea basses

Material: 22 articulars, 1 basioccipital, 5 ceratohyals, 83 dentaries, 3 exoccipitals, 7 hyomandibulae, 32 maxillae, 9 opercles, 11 palatines, 4 parasphenoids, 47 premaxillae, 5 indeterminate premaxillae/dentaries, 18 preopercles, 30 quadrates, 8 vomers, 11 cleithra, 6 posttemporals, 4 scapulae, 9 supracleithra, 4 basipterygia: 319 specimens

Remarks: The Serranidae family is represented by 63 species in PNG (Kailola 1987b:224). This large family contains deep- and shallow-water forms (Gosline and Brock 1960:155), which frequent rocky shores and reefs. Many serranids are bottom fishes and sedentary. The sea basses are highly prized food in many parts of the tropics (Green 1986). Nearly all species are voracious carnivores and readily take a hook and line (Marshall 1964:149). Green (1986:128) reports that Pacific Island peoples less often net, trap, and spear individuals in this family. Masse's analysis (1986:106) of Palauan fishing practices suggests that Epinephelidae (family name superseded by Serranidae [Nelson et al. 2016]) are most often caught with baited hooks, but also are speared and trapped.

Family Haemulidae—grunts

Material: 1 hyomandibula, 2 premaxillae, 3 quadrates: 6 specimens

Remarks: About 18 species of haemulids are found in PNG (Kailola 1987b:310). Munro notes (1967:314–315) that members of this family (which he refers to as Pomadasyidae/Plectorhynchidae—superseded by Haemulidae [Nelson et al. 2016]) are omnivorous fishes that inhabit shallow coastal waters around coral reefs and estuaries.

Family Lutjanidae—snappers

Material: 11 articulars, 6 ceratohyals, 32 dentaries, 3 exocciptals, 9 hyomandibulae, 18 maxillae, 4 opercles, 2 palatines, 1 parasphenoid, 20 premaxillae, 13 preopercles, 17 quadrates, 3 vomers, 5 cleithra, 10 posttemporals, 2 scapulae, 4 supracleithra, 4 basipterygia: 164 specimens

Remarks: About 53 species of snapper are found in PNG (Kailola 1987b:292). Most species inhabit shallow water and inshore environments, but some forms occupy deep and offshore habitats (Gosline and Brock 1960:182). Like the sea basses, snappers are important food fishes in the Pacific today. Lutjanids are also carnivorous and commonly taken by angling, although individuals are also netted, poisoned, and speared (Green 1986:128). In Palau, Masse (1986:106) notes that snappers are captured mainly with baited hooks but are also netted.

Order Scorpaeniformes
Family Scorpaenidae—scorpionfishes
Tribe Synanceiini—stonefishes

Material: 1 third infraorbital, 5 opercles: 6 specimens

Remarks: Remains were examined and identified by Stuart Poss (Gulf Coast Research Laboratory Museum, personal communication, February 14, 1991). These specimens are probably from the tribe Synanceiini, the stonefishes, which are represented by four species in PNG (Kailola 1987b:203). Opercles from this subfamily differ from the other two subfamilies within the family in being larger and more robust. The Mussau opercles resemble the specimen illustrated in Fowler (1955:Figure 8g, noted as Cataphracti?).

Like numerous other scorpaeniform fishes, stonefish are shallow-water bottom-dwelling carnivores that spend most of their time concealed in mud or among rock and corals (Munro 1967:538). Stonefishes have venom glands at the base of their dorsal fin spines that can inject an extremely painful and sometimes fatal neurotoxin (Munro 1967).

Family Platycephalidae—flatheads

Material: 1 maxilla: 1 specimen

Remarks: PNG is home to 16 species of flatheads (Kailola 1987b:211). Primarily carnivorous, platycephalids have a compressed body form; they bury themselves in sand or mud and ambush fishes and crustaceans that swim by (Munro 1967:526; Myers 1989:90).

Order Acanthuriformes
Family Sciaenidae—drums, croakers

Material: 1 upper pharyngeal, 11 lower pharyngeals: 12 specimens

Remarks: The lower pharyngeals (fifth ceratobranchials) have a prominent medial suture indicating that a pair of pharyngeals interdigitate, forming a tight bond. Such a condition is distinctive of several species of drum, but is atypical of other percoids (e.g., serranids, lutjanids, carangids, gerreids, haemulids, lethrinids, mullids, and kyphosids) (Sasaki 1989). Great similarity of the Mussau specimens indicates a single species is represented. The lower pharyngeals most closely resemble *Nibea* sp. (Melanie Stiassny, American Museum of Natural History, personal communication, January 11, 1991, February 12, 1991).

Kailola (1987b:320) lists 17 sciaenid species for PNG. Sciaenids are carnivorous coastal fishes that occupy sandy shores and muddy bottoms. Many take bait (Munro 1967:340).

Family Acanthuridae—surgeonfishes

Material: 1 dentary, 1 exoccipital, 15 hyomandibulae, 9 opercles, 1 parasphenoid, 1 quadrate, 31 cleithra, 8 scapulae, 2 supracleithra, 2 caudal tangs: 71 specimens

Subfamily Nasinae (unicornfishes)

Material: 27 caudal tangs: 27 specimens

Subfamily Acanthurinae

Material: 10 caudal tangs: 10 specimens

Remarks: About 30 species of surgeonfishes occur in PNG (Kailola 1987b). Exclusively herbivorous, surgeonfishes mainly eat algae, which they scrape from rocks and coral. In Palau, Masse (1986:106) states that acanthurids are most often netted, but also taken with baited hook and trapped. Amesbury and others (1986) report that in Guam, surgeonfishes are netted, speared, and taken with hook-and-line.

In the subfamily Nasinae, the caudal tang consists of one or two plates on each side of the caudal peduncle (Nelson et al. 2016:502); each plate has a wing-like strut perpendicular to the plate and directed posteriorly. These tangs are immovable structures that remain erect at all times. Tangs of the Acanthurinae subfamily are wedge-shaped, and have jackknife-type structures that are hinged so that the blade drops into a hidden groove (Herald 1961:208).

Order Spariformes

Family Lethrinidae—emperors

Material: 85 articulars, 4 basioccipital, 34 ceratohyals, 139 dentaries, 22 epihyals, 11 exoccipitals, 50 hyomandibulae, 99 maxillae, 31 opercles, 134 palatines, 66 parasphenoids, 9 lower pharyngeals, 199 premaxillae, 29 preopercles, 88 quadrates, 16 vomers, 11 cleithra, 6 posttemporals, 12 scapulae, 14 supracleithra, 6 basipterygia: 1065 specimens

Monotaxis grandoculis

Material: 15 articulars, 63 dentaries, 11 hyomandibulae, 22 maxillae, 11 palatines, 78 premaxillae, 13 indeterminate premaxillae/dentaries, 11 quadrates: 224 specimens

Remarks: Twenty-five species of lethrinids occur in PNG (Kailola 1987b:313). Lethrinds are inshore reef fish, generally carnivorous, and are valuable food fish throughout their range—from Polynesia to Africa (Herald 1961). Masse (1986:106) notes that in Palau, these fish are most often taken with baited hooks but are also netted. In Guam, emperors are commonly trapped in fish weirs (Amesbury et al. 1986:26).

The *Monotaxis grandoculis* remains were easily distinguished from other lethrinids in being much more robust. While juveniles are solitary, adults may form loose aggregations during the day and disperse at night to hunt for hard-shelled sand-dwelling invertebrates (Myers 1989:143). This species is caught with methods similar to other lethrinids (Green 1986:127).

Order Tetraodontiformes

Family Ostraciidae—boxfishes

Material: 19 scales: 19 specimens

Remarks: PNG is home to 6 species of boxfishes (Kailola 1987b). Weak swimmers, ostraciids are sedentary, slow-moving omnivores that subsist on invertebrates and benthonic algae (Hiatt and Strasburg 1960:110).

Family Balistidae—triggerfishes

Material: 15 articulars, 1 ceratohyal, 21 dentaries, 22 ethmoids, 34 hyomandibulae, 10 maxillae, 2 opercles, 3 parasphenoids, 18 premaxillae, 2 indeterminate premaxillae/dentaries, 18 preopercles, 24 quadrates, 25 cleithra, 8 postcleithra, 1 scapula, 10 supracleithra, 50 dorsal spines: 264 specimens

Remarks: Nineteen balistid species are found in PNG (Kailola 1987b). Triggerfishes are primarily shallow-water, tropical marine species and are usually solitary and slow-moving (Herald 1961:275). Most species are omnivores and consume invertebrates and algae (Hiatt and Strasberg 1960). In Palau, Masse (1986:106) suggests that balistids are netted primarily, and less often hooked and speared. Green (1986:128) reports that triggers may be taken by poisons and hook and line.

Tetraodontidae—puffers

Material: 1 articular, 1 ceratohyal, 11 dentaries, 3 hyomandibulae, 2 opercles, 1 palatine, 14 premaxillae, 29 indeterminate premaxillae/dentaries, 3 quadrates: 65 specimens

Remarks: Puffers are represented by 28 species in PNG (Kailola 1987b). Like the boxfishes, tetradontids are weak swimmers that occupy moderately shallow coastal waters (Munro 1967:551). Puffers are generalized, opportunistic feeders that consume mollusks and coral tips (Hiatt and Strasburg 1960:111).

Family Diodontidae—porcupinefishes

Material: 2 ceratohyals, 4 dentaries, 2 palatines, 12 premaxillae, 66 indeterminate premaxillae/dentaries, 3 quadrates, 1 supracleithrum: 90 specimens

Remarks: Nine species of diodontids are found in PNG (Kailola 1987b). Diodontids forage mainly at night for mollusks, crustaceans, and gastropods, which are easily crushed with their strong jaws (Hiatt and Strasburg 1960:111). Masse (1986:106) notes that in Palau, porcupinefishes are mainly netted and handspeared.

Additional Categories

Serranidae-Lutjanidae

Material: 1 ceratohyal, 1 dentary, 11 cleithra: 13 specimens

Scombridae-Sphyraenidae

Material: 2 indeterminate premaxillae/dentaries: 2 specimens

non-Scaridae/non-Lethrinidae

Material: 51 articulars, 6 basioccipitals, 22 ceratohyals, 13 dentaries, 15 epihyals, 11 exoccipitals, 37 hyomandibulae, 17 maxillae, 27 opercles, 13 palatines, 35 parasphenoids, 11 premaxillae, 12 preopercles, 48 quadrates, 21 vomers, 46 cleithra, 1 postcleithrum, 4 posttemporals, 8 scapulae, 7 supracleithra, 1 basipterygium: 406 specimens

Remarks: The Serranidae/Lutjanidae and Scombridae/Sphyraenidae specimens were complete enough to link them to one of the families in the pair but too fragmentary for confident assignment to a single family. Specimens assigned to non-Scaridae/non-Lethrinidae were too fragmentary or eroded to assign to any family, but complete enough to show they *were not* from Scaridae or Lethrinidae.

Results

A total of 4,687 fish remains representing 44 taxonomic categories was identified from the eight Mussau sites with fishbone (Table 7.6). A total of 49,848 specimens were identified as "fish" (see Chapter 6). These categories include high level taxa such as Elasmobranch (subclass that includes sharks, rays, skates), and finer-level groupings—families (N = 27), subfamilies, tentative species, and analytic categories I created to characterize morphological distinctions not directly related to Linnaean classification. Mussau fishers overall were catching a huge variety of fish types, including several taxa common in offshore waters (e.g., sharks, scombrids, *Sphyraena*, carangids, belonids), with most forms occupying nearshore reefs and lagoons. Importantly, because most remains were only identified to family level and most fish families are represented by dozens or more species, the archaeo-faunal record almost certainly underestimates the range of fish species captured.

While a wide range of fishes are represented, when we consider patterns at the family level and relative abundance, most of the remains come from just two families: lethrinids (emperors) and scarids (parrotfish), which together contribute 53% of the identified specimens (Figure 7.4). Taking this further, the top ten ranked families represent 91% of the fauna. A bar chart showing the descending frequency of NISP by family illustrates the highly uneven distribution of specimens across fish families (Figure 7.4). Thus while the records indicate Mussau people used a wide variety of fishes, they mainly focused on a small subset of fish families.

Identification bias does not account for the dominance of scarids and lethrinids. As noted in Methods and Materials, fish remains that could not be assigned to a fish family with confidence, but which clearly were not from these two families, were assigned to the category "non-Scaridae/non-Lethrinidae." This category is the third most abundant overall (NISP = 406, 8.7% of total), which suggests that several families *are underrepresented* because their remains are simply less distinctive. On the other hand, the frequency of this category is still three times lower than the NISP for scarid and lethrinid (Figure 7.4). Thus, even if the non-Scaridae/non-Lethrinidae specimens *could have been identified* to other fish families (Serranidae, Labridae, Balistidae, etc.), the abundances of such families would still be far less than that from scarids or lethrinids.

The frequency of remains assigned to the other two joint categories, Serranidae/Lutjanidae and Scombridae/Sphyraenidae, is very low, with NISPs of 13 and 2 respectively (Table 7.6). These low values suggest that difficulties in distinguishing these two sets of taxa did not much affect taxonomic assignments and ultimately the relative abundance of these four families.

The overall pattern—a great variety of fish taxa represented, yet emphasis on a relatively small subset—has been highlighted by numerous scholars reviewing Oceania fisheries, past and present (e.g., M. S. Allen 2017; Butler 2017; Leach and Davidson 2000). Leach and Davidson (2000) found that across Oceania archaeo-faunal assemblages, six fish families account for nearly 84% of all identified fish remains, when all assemblages are aggregated. While one could argue that this apparently narrow focus is a product of the family-level identifications typical of archaeological analysis in the region, in a modern-day study of fisheries in the Torres Strait, researchers report that just five species contributed nearly 86% to the fishery, even though 75 species were captured (Johannes and MacFarlane [1991:120], cited in Clark and Szabó [2009]).

Table 7.6. Frequency (NISP) of fish taxa by Mussau sites. (Note that 15 specimens listed for site ECA lacked more specific provenience)

Finest Taxon	ECA	ECA-A	ECA-B	ECA-C	ECA-T	ECB	EHB	EHK	EKE	EKQ	EKS	EKU	Grand Total
Elasmobranch		1	7		16			3	1	16	2		46
Carcharhiniformes										1			1
Carcharhinidae										3			3
cf. *Galeocerdo*					1								1
Negaprion acutidens					3								3
Carcharhinus hemiodon			1										1
Dasyatidae			1						1				2
Myliobatidae			2	1	1	1			1				6
Aetobatus cf. *narinari*							1						1
Muraenidae	1		6		21	1	1	8	2	7	1	1	49
Holocentridae			3	4	5				1	15			28
Holocentridae A			5		2					2			9
Holocentridae B			1							2			3
Holocentrinae			2							2			4
Mugilidae			1		4				6	2	1		14
Belonidae			33	5	31				5				74
Carangidae			28	8	31	2		3	15	2	8	1	98
Sphyraena spp.	1		1		5				1		1		9
Scombridae		2	14	5	21	2	2			34			80
Labridae		8	58	6	94	8	7	4	34	5	10	5	239
Labridae A	1	1	9		7				2	1	1		22
Labridae B	1		2	1	9			1	2				16
Scaridae		48	233	46	502	28	39	20	107	60	93	10	1186
Gerreidae				1	2				4				7
Mullidae					4		1		4	10	1		20
Kyphosidae									1				1
Serranidae		2	83	40	82	7	12	11	32	25	25		319
Haemulidae			3		2						1		6
Lutjanidae		3	39	14	45	7	2	4	21	20	9		164
Synanceiini			1		1			1	1		2		6
Platycephalidae									1				1
Sciaenidae			4		6	2							12
Acanthuridae			15	4	34	2			7	8	1		71
Nasinae			11		8				1	7			27
Acanthurinae		2	1		3				3	1			10
Lethrinidae	4	10	223	56	468	27	3	22	151	49	52		1065
Monotaxis grandoculis		1	85	6	72	5	18	5	9	9	12	2	224
Ostraciidae			1	1	12			1	2	2			19
Balistidae	1	2	87	20	82	2	5	6	30	14	13	2	264
Tetraodontidae		3	6	3	14	3	4	5	23		4		65
Diodontidae			14		33	29	8		4		2		90
Non-Scaridae/ non-Lethrinidae	6	3	102	34	146	8	5	4	42	34	22		406
Serranidae-Lutjanidae		1	5		3					4			13
Scombridae-Sphyraenidae					2								2
Grand total	15	87	1087	255	1772	134	108	98	514	335	261	21	4687

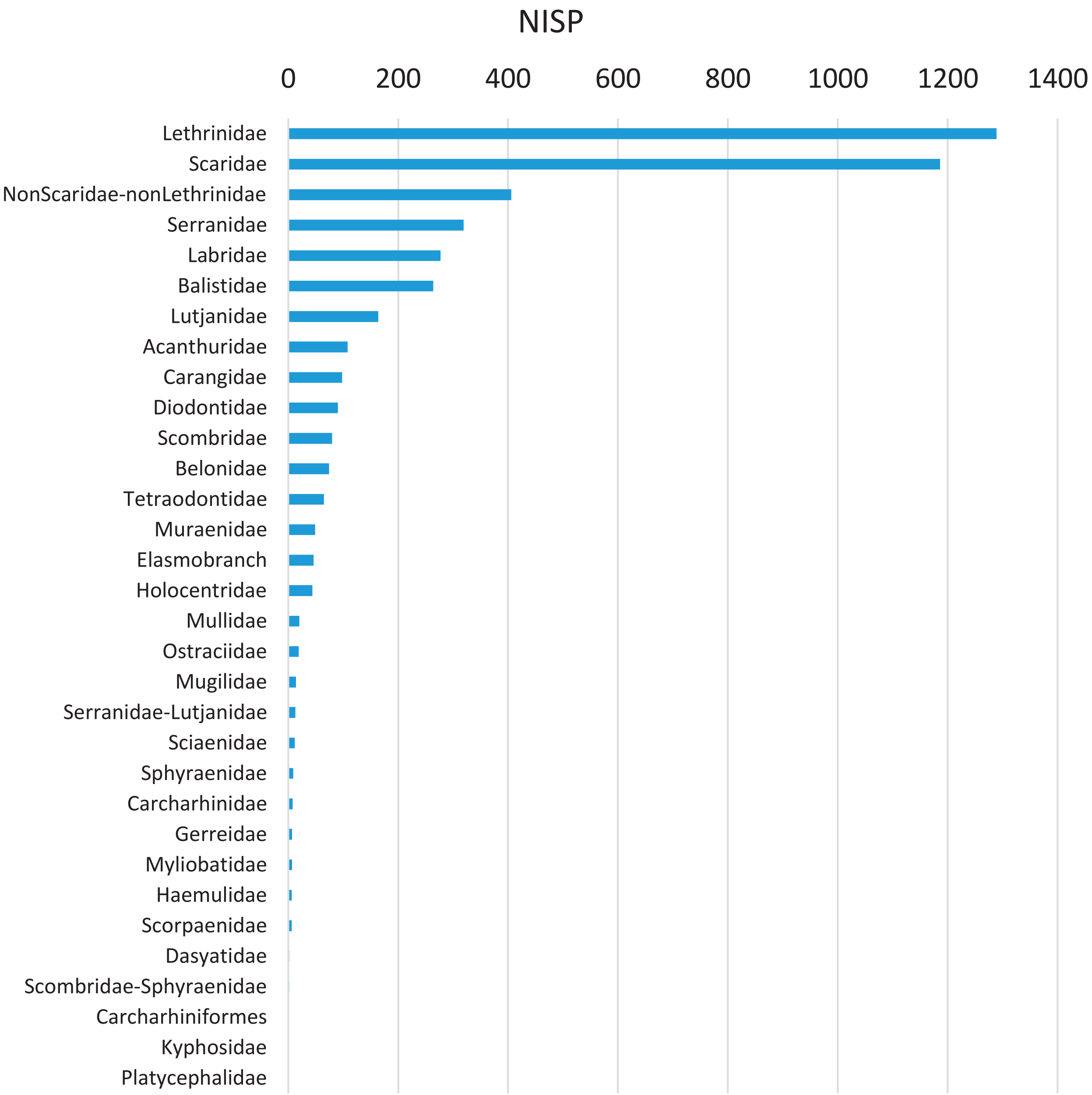


Figure 7.4. Frequency (NISP) of fish family in order of abundance, all Mussau fish faunas combined. (Diagram by V. Butler.)

Background to Mussau Site Records and Environmental Trends

Before reviewing patterning in the records over time and space, it is important to consider the context of the eight Mussau sites with fish remains (Table 7.7). Over two-thirds of the fish remains are from site ECA, located on Eloaua Island, a large low-lying island, one of several located in the relatively shallow protected area on the southwest side of Mussau Island (see Figure 2.1). ECA is comprised of four spatially distinct loci, ECA-A, ECA-B, ECA-C, and ECA-T (= transect). ECA as a whole is strictly tied to Lapita occupation, including both "Early" and "Late" occupation phases. A second Lapita-era site, ECB, is located on Eloaua Island, northwest of ECA. A third site on Eloaua Island with fish remains, site EHK, was assigned to a post-Lapita occupation (Table 7.7; see Chapters 3 and 4 for information on temporal assignments of site deposits).

Table 7.7. Background information on Mussau sites

Site	NISP	Cultural Affiliation	Marine Habitat
ECA*	15	Lapita	reef flats, lagoon, deep water offshore
ECA, Area A	87	Early Lapita	reef flats, lagoon, deep water offshore
ECA, Area B	1,087	Early & Late Lapita	reef flats, lagoon, deep water offshore
ECA, Area C	255	Late Lapita	reef flats, lagoon, deep water offshore
ECA, transects	1,772	Lapita	reef flats, lagoon, deep water offshore
ECB	134	Lapita	reef flats, lagoon, deep water offshore
EHB	108	Early Lapita	reef flats, lagoon, deep water offshore
EHK	98	post-Lapita	reef flats, lagoon, deep water offshore
EKE	514	Early Lapita, post-Lapita	reef flats, lagoon, deep water offshore
EKQ	335	Late Lapita, post-Lapita	narrow fringing reef, deep water offshore
EKS	261	Post-Lapita	narrow fringing reef, deep water offshore
EKU	21	Post-Lapita	narrow fringing reef, deep water offshore

Site EHB on the relatively large Emananus Island, southwest of Eloaua Island, was assigned to Lapita occupation, and is regarded as the earliest Lapita site in Mussau. Together, Eloaua and Emananus Islands, along with a few other islets, create an atoll-like formation that encloses a lagoon (Kirch and Catterall 2001). Site EKS on Emussau Island, a small islet surrounded by a narrow fringing reef northeast of Eloaua Island, represents a post-Lapita occupation. Site EKE is found on Boliu Island, northwest of Emussau Island, and is adjacent to an expansive reef complex that wraps around the southwest side of Mussau Island. EKE holds both Lapita and post-Lapita occupations. Site EKU is a post-Lapita occupation found on a small peninsula on the southeast end of Mussau Island proper. The final site, EKQ, is a rockshelter also located on Mussau Island, on its northwest side, far removed from all the other tested sites. EKQ primarily holds late Lapita–aged deposits, with limited representation of post-Lapita occupation in the uppermost levels.

Except for EKQ, the sites are "open sites" and appear to represent domestic occupations. The ECA loci bear evidence of architecture and extensive residential use. The EKQ rockshelter contained a range of artifact forms that suggest residential rather than specialized activities, and remains of one human burial (Weisler 2001). Differences in sampling intensities and faunal recovery have implications for interpreting the record. ECA was the most intensively sampled of all the Mussau sites and, given its large fishbone sample, any general interpretations about the Mussau records largely reflect this site's records. Several sites have small sample sizes, making it difficult to draw robust conclusions about resource use for these particular cultural contexts. On the other hand, it is reasonable to aggregate remains that date to particular time periods and to track change for fish records overall, especially if site-to-site differences are minimal, a review I turn to now.

As described by Kirch and Catterall (2001), the Mussau sites are adjacent to a range of environments that include different substrates, water depths, and reef configurations that create a complex mosaic of habitats for marine organisms. In very simple terms, people who occupied islands that were adjacent to extensive reefs and lagoons, such as the Eloaua and Emananus Island atoll system (sites ECA, EHB, ECB, EHK) and Boliu Island (site EKE), likely had access to the richest array if not abundance of marine resources, given the close proximity to broad reef flats, deep-water lagoons, and offshore zones. The primarily narrow fringing reefs on the southern side of Mussau Island where the EKS site is situated (on Emussau Is.), and around Mussau Island itself (where EKU lies), supported less abundant local resources. Importantly, people residing next to fringing reefs could have canoed to expansive reef flats and lagoons fairly readily. By contrast, people occupying the EKQ site on the northern side of Mussau Island would not have had this option, being limited to accessing resources in the narrow fringing reef, or capturing deep-water fish that came inshore, or pursuing fish offshore.

To see if these broad environmental differences had some effect on fish use across sites, I compared fish family representation across those site assemblages and loci of ECA containing at least 200 NISP. Figure 7.5 shows proportional representation of fish families for the six contexts (sites or loci) that met this requirement. Lethrinids and scarids comprise close to half of each assemblage except in the case of EKQ. The records for the ECA loci and EKS are roughly similar (Figure 7.5), even though one might expect differences, given EKS's location on Emussau Island adjacent to a narrow fringing reef.

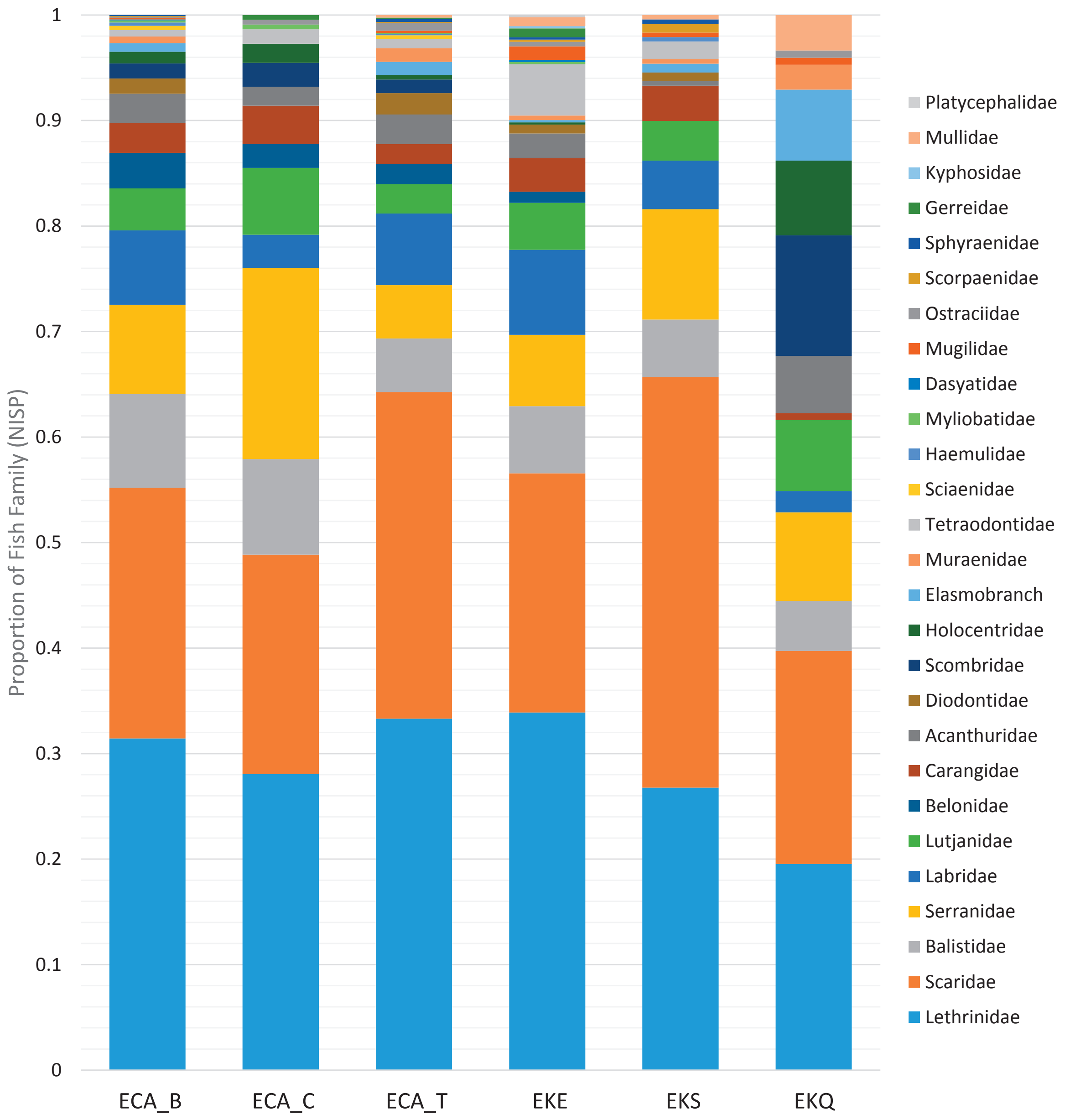


Figure 7.5. Proportion of fish family (NISP) by site. (Diagram by V. Butler.)

The EKQ assemblage stands apart. While Scaridae and Lethrinidae are still the top-ranked fish, various fish more common in offshore waters (Scombridae [tuna], Elasmobranchs) are relatively common at EKQ. Other families common to EKQ but rare in assemblages located on the southern waters of Mussau Islands are Mullidae (mullet), Holocentridae (squirrelfish), and Acanthuridae (surgeonfish). The EKQ fishery is still dominated by nearshore reef fish, with heavy use of scarids and lethrinids, and others; but the use of offshore fish sets this site apart. In addition, the proportion of fish is much more even at EKQ than for the other assemblages from sites located on the south side of Mussau Island.

I used Spearman's rank order correlation of assemblage pairs to empirically determine the degree of similarity between assemblages (Table 7.8). All the paired tests for the ECA loci, EKE, and EKS, show relatively high (between 0.761 and 0.929) and significant (0.05 or higher) correlations. Here again, EKQ stands apart, showing substantially lower correlations with the other five assemblages (generally lower than 0.4). Except for the comparison with ECA-C, these correlations are not significant at the 0.05 level (Table 7.8).

In sum, except for EKQ, fish representation across the Mussau sites is highly similar. People fishing the waters in the reef-lagoon systems off the southern shore of Mussau Island procured a very consistent set of fish, with a focus on nearshore fishes. Scarids and lethrinids are ranked first or second in each assemblage, with the same set of other fish types tending to be found in consistent rank order abundances. Given this high degree of similarity, I aggregate all the assemblages (except EKQ) to compare fisheries through time.

Temporal Trends in Fish Use

Faunal remains from all assemblages except EKQ were aggregated by main time period to examine the possibility that fishing activity changed over time. Remains were grouped into "Early Lapita," "Late Lapita," and "Post Lapita" (see Chapter 5 for an overview of methods used in creating temporal units). For this comparison, I focused on family-level comparisons, including only those families that provided NISP of at least 15.

As shown in Figure 7.6, the level of consistency through time is striking. The same six families are consistently the highest ranked fish (Scaridae, Lethrinidae, Serranidae, Labridae, Balisticad, Lutjanidae), which together comprise over 80% of each time period's fish record. Accordingly, the rank order correlation between the Early vs. Late Lapita is extremely high and significant (Early vs. Late, $r_s = 0.913, p < .001$), as is the correlation between Late Lapita and Post Lapita assemblages (Late Lapita vs. Post Lapita, $r_s = 0.727, p < 0.001$).

How do we account for this degree of stability in the Mussau fisheries? Perhaps it is more apparent than real, given the coarse-grained time periods used. There could be change at various temporal scales—seasonal, annual, and decadal to centennial—that is simply obscured by the long-duration time periods to which site deposits are assigned. Perhaps too, the family-level comparisons have limited our ability to detect finer-scale changes in fish use. On the other hand, we can work with the time units and taxonomic groupings we have and draw some tentative conclusions from the records. At the simplest level, the evidence suggests that once people established communities on the islands, they adapted the strategies for fish capture that they had developed in place or brought with them from their homeland. And these fishing strategies

Table 7.8. Matrix of Spearman rank order coefficients for pairs of Mussau fish assemblages with 200 NISP or greater

Site	ECA-B	ECA-C	ECA-T	EKE	EKS	EKQ
ECA-B		0.929	0.916	0.803	0.761	0.339
ECA-C			0.7911	0.7813	0.745	0.517
ECA-T				0.8259	0.7893	0.343
EKE					0.90	0.1831
EKS						0.3411

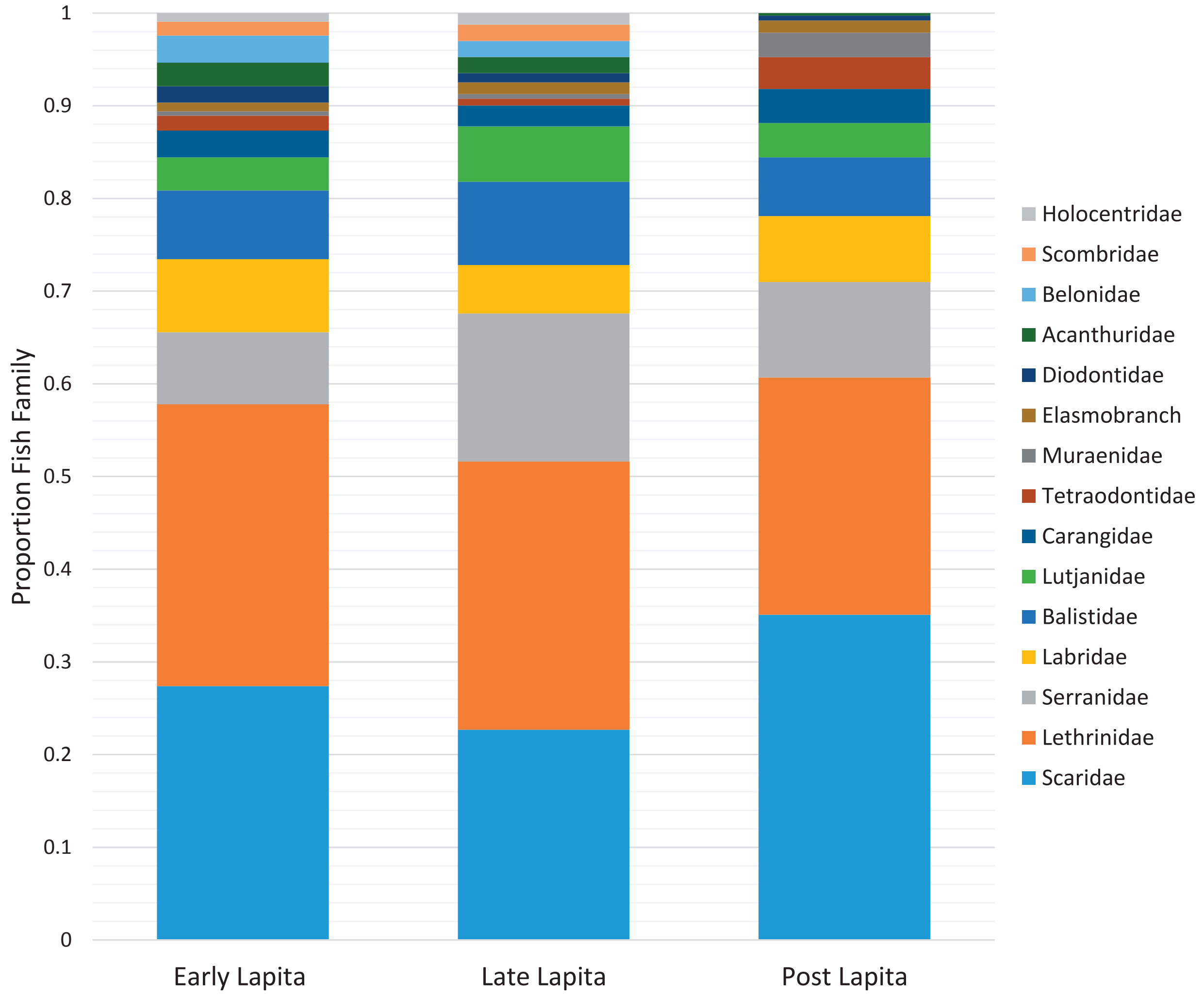


Figure 7.6. Proportion of fish family (NISP) by main time period. (Diagram by V. Butler.)

endured, despite potential shifts in population size, settlement pattern, labor organization, access to fishing grounds, and the plethora of other social factors that could affect fisheries.

Fish Body Size

As noted above in Methods and Materials, one goal of analysis was to examine patterns in fish body size, by using metric analysis of fish remains. In particular, I wanted to see if past human fishers caused resource depression of fish populations, or whether patterns reflect other cultural practices. Given the prominence of scarids and lethrinids (including the species *Monotaxis grandoculis*) in Mussau sites, I focused attention on their remains.

Masse (1989) analyzed size class variation of several genera of parrotfishes (Scaridae) and bream (*Monotaxis grandoculis*) from sites in Palau, 1,500 years old and younger. Both *Monotaxis* and his Type III (cf. *Scarus* sp.) show size class variation, which Masse argues results from differences in human predation pressure. Giovas and others (2016) studied scarid pharyngeals from multiple sites in Palau from deposits spanning 1,500 years and found that one form, *Scarus*, showed little change through time. The second taxon, *Chlorurus*, actually showed an *increase* in size through time, the reasons for which remain elusive (Giovas et al. 2016).

Besides human predation, multiple other factors might also account for size class variation in archaeological contexts including: biotic (interaction with nonhuman organisms); abiotic (climatic/environmental factors); cultural (prehistoric human practices); taphonomic (post-depositional processes); and archaeological (field collection) factors. Ancient human cultural factors include selection of habitats exploited, capture techniques, disposal patterns, and cultural preference. Selection of habitat exploited may directly affect the age/size classes represented in an assemblage. For example, it is common for size/age classes of fishes to shoal together at different locations (e.g., Cushing 1975). Regarding capture techniques, obviously hook and line and netting methods may result in different hauls; mesh size may greatly influence the size/age classes present in an assemblage (Greenspan 1998).

Social-cultural factors that link fish to luxury or prestige goods could also affect patterns in fish size, if different tiers of society had preferential rights to fish of certain sizes. Ethnographic records from across Oceania highlight ways ideology and prestige affect fisheries, including access to fishery resources (e.g., Leach and Davidson 2000; Kirch and O'Day 2003; Jones 2009). Dye (1983), in his review of ethnographic fishing in Niuatoputapu, writes that greater status is accorded a fisherman who captures a *menenga*, a large scarid (listed as *Scarus jonesi* [Dye 1983:262]). In his detailed review of Palauan fishing practices, Masse (1989:182) notes that extremely large wrasses (family Labridae, especially *Cheilinus undulatus*, which can attain lengths of over 2 m) were considered quite valuable. From archaeological contexts in Hawai'i, Kirch and Jones (2003) found that large carnivorous fishes such as grouper (family Serranidae) were associated with elite contexts while small, juvenile fish such as surgeonfish (Acanthuridae) and parrotfish (Scaridae) were associated with lower-status residences.

A total of 183 scarid lower pharyngeals and 60 bream premaxillae were measured from the Mussau sites (Table 7.9). Of the scarids, the majority (139 or 76%) are from ~*Scarus*, with a much smaller number from ~*Bolbometopon* (41 or 22%), and only 3 (2%) from ~*Calotomus*. Mean width of the archaeological ~*Scarus* and ~*Calotomus* pharyngeals is 9.37 mm and 9.32 mm respectively, while the mean width of ~*Bolbometopon* pharyngeals is over twice that (Table 7.9). These prominent size distinctions very well could be tied to the fact that *Scarus* and *Calotomus* tend to be much smaller fish than *Bolbometopon*. Drawing on maximum size information of scarids listed in Myers (1989), the standard length of 27 species of *Scarus* ranges from 210 to 510 mm; the two species of *Calotomus* have standard lengths of 154 and 398 mm. The standard length of the one species of *Bolbometopon (muricatum)* can exceed over 1 m.

Measurements of modern skeletal elements from fishes of known body size provide additional context for understanding the link between body size and genus (Table 7.10). Modern *Scarus* with body size roughly 200 mm long have lower pharyngeals between 5 and 5.5 mm wide (Table 7.10).

Table 7.9. Summary statistics on width of Scaridae lower pharyngeals and length of *Monotaxis* premaxilla, Mussau sites

Site	~ *Scarus*	~ *Bolbometopon*	~ *Calotomus*	Total Scarid	*Monotaxis grandoculis*
ECA, Area A	3	2	0	5	1
ECA, Area B	45	11	0	56	23
ECA, Area C	4	0	1	5	1
ECA, transects	67	27	2	96	34
EHK	3	0	0	3	
EKE	17	1	0	18	1
Total	139	41	3	183	60
Mean (mm)	9.37	22.93	9.32		33.61
s.d. (mm)	2.71	9.41	3.10		9.91

Table 7.10. Skeletal element measure and original body size of modern specimens. For scarids, the measure is the width of the lower pharyngeal; for *Monotaxis*, it is the length of the premaxilla (see Masse et al. [2006:Figure 8] for illustration)

Species	Element Measure (mm)	Body Length (mm)
Scarus capistatoidas	5.02	200 total length
Scarus rhoderopterus	5.49	185 total length
Scarus dimidiatus	5.12	212 total length
Monotaxis grandoculis	36.11	350 fork length

Recognizing that the element size/body size relationship is not strictly linear, it is reasonable to suggest that the archaeological ~*Scarus* pharyngeals (with ~9 mm mean width) are from fish probably less than 500 mm in length. In turn, at least some of the archaeological ~*Bolbometopon* pharyngeals are from fish that exceed 500 mm in length.

Contextualizing the size of bream, the modern *Monotaxis* with 350 mm in fork length has a premaxillae 36 mm long (Table 7.10), only 3 mm longer than the mean archaeological specimen size (Table 7.9). Thus the archaeological sample of *Monotaxis* represents fishes with a mean size of about 350 mm length.

With much larger reference collections and focused study, it would be possible to add rigor to these general statements about body size. On the other hand, even the limited information available from modern and archaeological samples provides a starting place for inferences about body size trends in the Mussau records.

If Mussau fishers exerted strong fishing pressure on the scarids or *Monotaxis*, we would expect declines in bone size representing these fish through time. The first comparison considers change between Lapita and Post-Lapita occupations. Changes in bone size were not evident, though the test is less than ideal, given the fairly coarse time periods for study and the small sample sizes for the Post-Lapita unit. For Scaride, only ~*Scarus* has samples for both time periods, and pharyngeal size hardly differs at all (Figure 7.7, Table 7.11, $t = -.621$, $p = 0.536$). All of the *Monotaxis* premaxillae date to Lapita contexts, precluding the opportunity to assess size shifts for this taxon.

We can consider finer time resolution for ECA, Area B, where analytic zones within the area were defined (Zone C oldest, A youngest), all representing Lapita. As seen in Figure 7.8 and Table 7.11, there is no change in ~*Scarus* size from the deepest/oldest to uppermost zones. Close to 90% of the samples are from the oldest/deepest unit, so this test is rather weak in any case. For ~*Bolbometopon*, there is an *increase* in size from Zone B to A, but with only 11 pharyngeals total, the comparison is not very robust and the difference is not significant (Figure 7.8 and Table 7.11 ($t = 1.752$, $p = 0.130$). For *Monotaxis*, the premaxilla length increases slightly between Zones C and B, but the difference is not significant (Table 7.12, $t = -0.561$, $p = 0.580$).

Overall, there is no evidence for any temporal change in bone size—and in turn body size, given the close relationship—for the fish taxa studied. Apparently, these fish were

Table 7.11. Summary statistics on width of Scaridae lower pharyngeals by genus and time period

Scaridae Type		Mean (mm)	N	s.d. (mm)
~ *Scarus*	*not assigned*	9.95	15	3.52
	Lapita	9.27	120	2.57
	Post Lapita	10.09	4	4.13
~ *Bolbometopon*	*not assigned*	33.65	1	
	Lapita	22.67	40	9.38
~ *Calotomus*	Lapita	9.32	3	3.10
	zone within ECA-Area B			
~ *Scarus*	A	13.4800	1	
	B	9.1575	4	2.52
	C	9.2898	40	2.81
~ *Bolbometopon*	A	35.7550	2	8.05
	B	27.0383	6	5.62
	C	26.3367	3	2.208

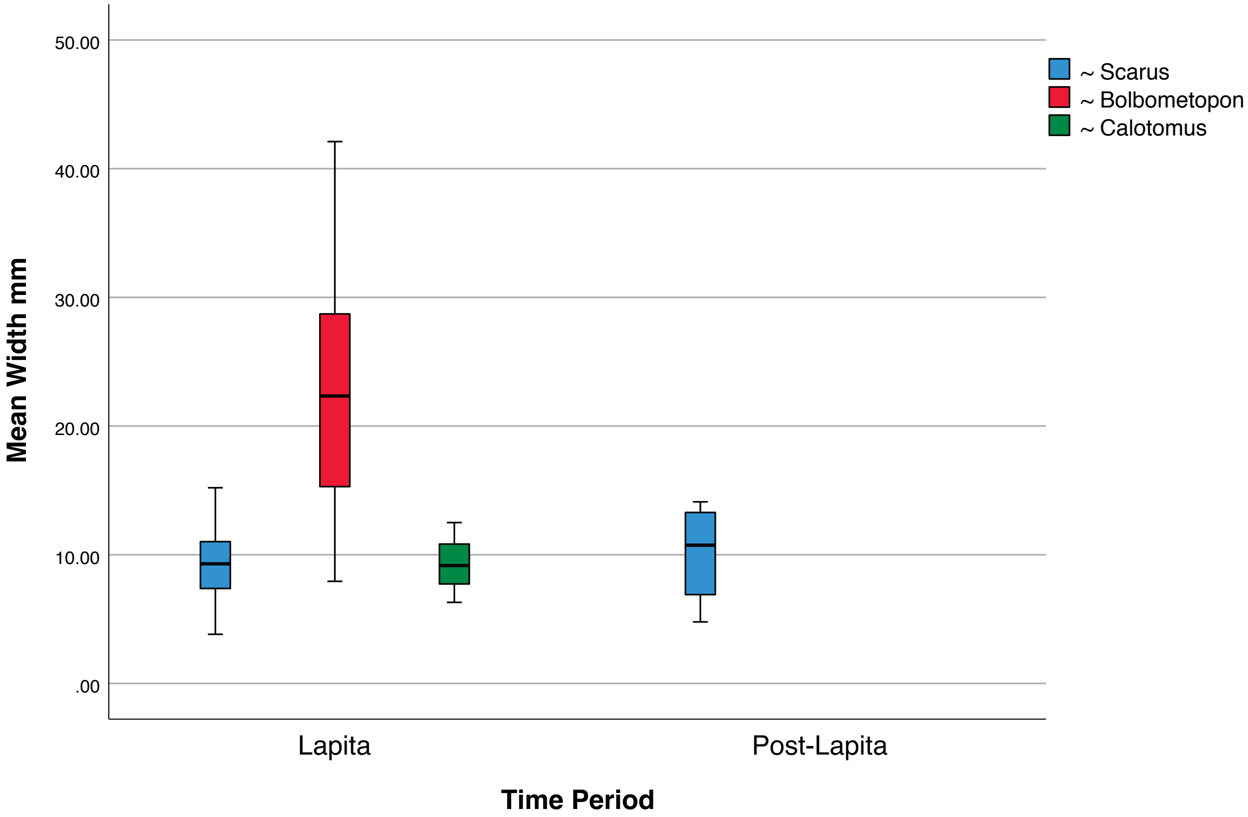


Figure 7.7. Box and whisker plot of scarid pharyngeal width by time period and genus. Box defines the upper and lower quartiles, horizontal line within box is the median, and bars extending vertically above and below box mark the maximum and minimum values, excluding outliers.

Table 7.12. Summary statistics on *Monotaxis* premaxilla length by analytic zone within ECA Area B

Analytic Zone	Mean (mm)	N	s.d. (mm)
Zone B	38.86	5	8.92
Zone C	36.22	18	9.37
Total	33.61	60	9.91

sustainably used over the time periods for which we have records. This finding is especially noteworthy, given that my analysis targeted the two most abundant fish groups in the Mussau site assemblages. If any fish taxa would have shown impacts from overfishing, it should have been these. This finding for Mussau is consistent with that from M. S. Allen's recent synthesis of East Polynesian fisheries (2017:737): "harvesting impacts are sometimes intimated but generally not well demonstrated."

Beyond using bone size to study exploitation pressure, however, I wanted to see if fish body size varied across Lapita-era contexts, the time unit that provided the largest sample sizes. Regarding *Monotaxis*, fish *are larger* at ECA Area B than in the ECA-T or transect units (Figure 7.9), though the difference is not significant at 0.05 ($t = 1.87, p = 0.067$). This tendency for larger fish at ECA Area B is more pronounced for ~*Bolbometopon* (Figure 7.10, Table 7.13), where pharyngeals are over one-third larger at ECA-B than ECA-T, a highly significant difference ($t = 2.563, p = 0.015$). (Note: ~*Bolbometopon* specimens were not recovered at ECA-C and EHK; and only very small numbers were from EKE and ECA-A). Size trends for ~*Calotomus* are not meaningful, given very small sample sizes. As well, the size of ~*Scarus* varies little across sites and loci within ECA (Figure 7.10). The mean size ranges between 7.53 (ECA-C) and 10.45 (EHK), but t-tests comparing mean size across the sites did not show any significant differences (Table 7.13).

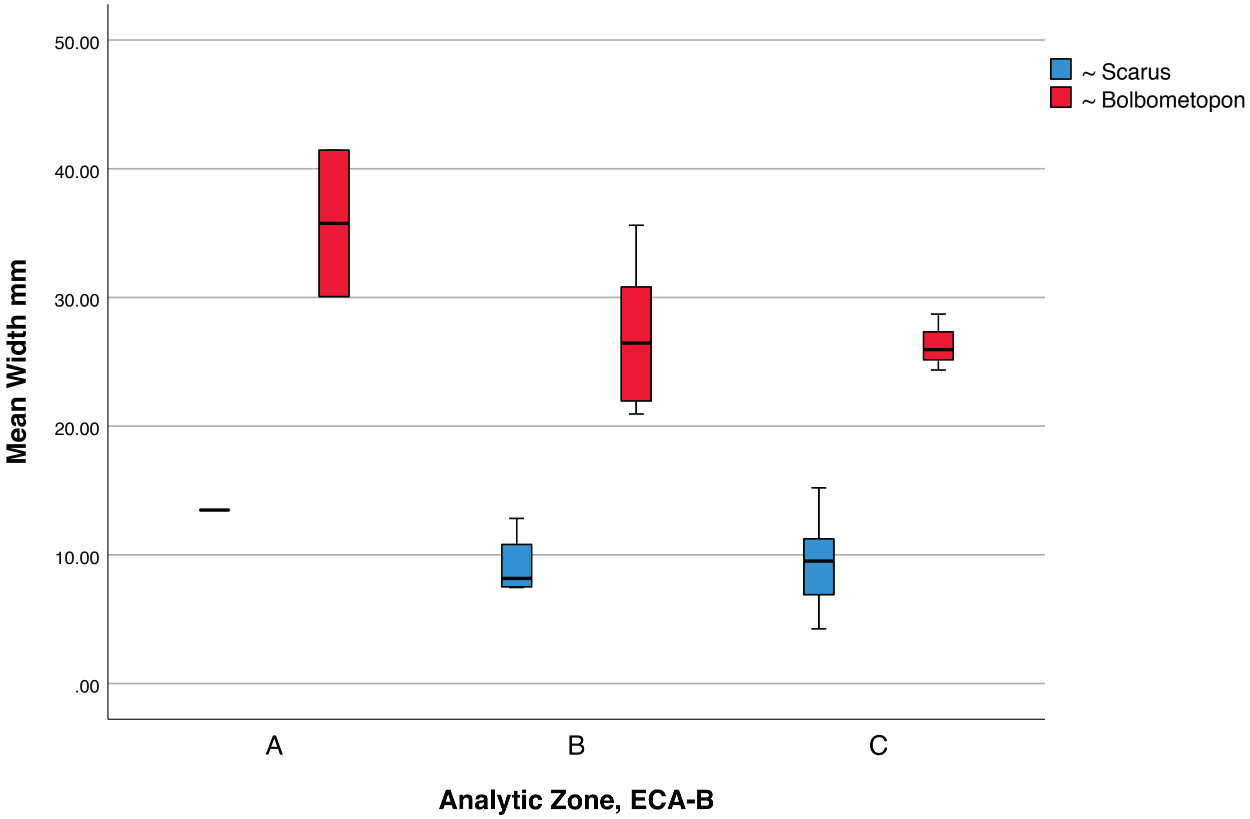


Figure 7.8. Box and whisker plot of scarid pharyngeal width by analytic zone within ECA-B (Lapita context) and genus. Box defines the upper and lower quartiles, horizontal line within box is the median, and bars extending vertically above and below box mark the maximum and minimum values, excluding outliers. (Diagram by V. Butler.)

That ~*Bolbometopon* and even *Monotaxis* tend to be larger at ECA Area B versus the transect units of ECA may be explained by several factors. Differences in habitats exploited is not satisfactory, as both ECA Area B and the transect units are adjacent to the same reef environment. Size differences may reflect differences in catchment techniques practiced by ECA Area B inhabitants and those of other ECA areas. Masse (1989:168) notes that historically in Palau, large nets (*direkorek*) were used to catch *Bolbometopon*; whether fishing techniques varied with fish size is not noted. Johannes (1981) notes that *Bolbometopon* is heavily exploited by spear in Palau today, but again, no mention is made of the fish sizes involved.

Another hypothesis is that ECA Area B was the setting for higher-status residents or special activities and therefore larger fish were explicitly procured, then processed and consumed there. The Area B excavations revealed the presence of a large stilt-house structure and an exceptionally high concentration of well-crafted objects and finely decorated Lapita ceramics (see Chapter 3; also Kirch 2001a:102–103). Kirch (2001a:103) suggested that the Area B stilt house served as a special-function structure, though he notes that the area also generated typical domestic refuse associated with food preparation and thus could relate to day-to-day activities as well. The finding of large fish at ECA-B is consistent with the suggestion of special activities, including feasting, taking place there (see Chapter 18).

Mussau Fishing Strategies

In a previous publication (Butler 1994), and building on others' work (e.g., Leach and Davidson 1988; Allen 1992b; Kirch and Dye 1979), I laid out the logic for reconstructing fishing methods (e.g., hook and line, netting, etc.), using the strong relationship between fishing method and fish

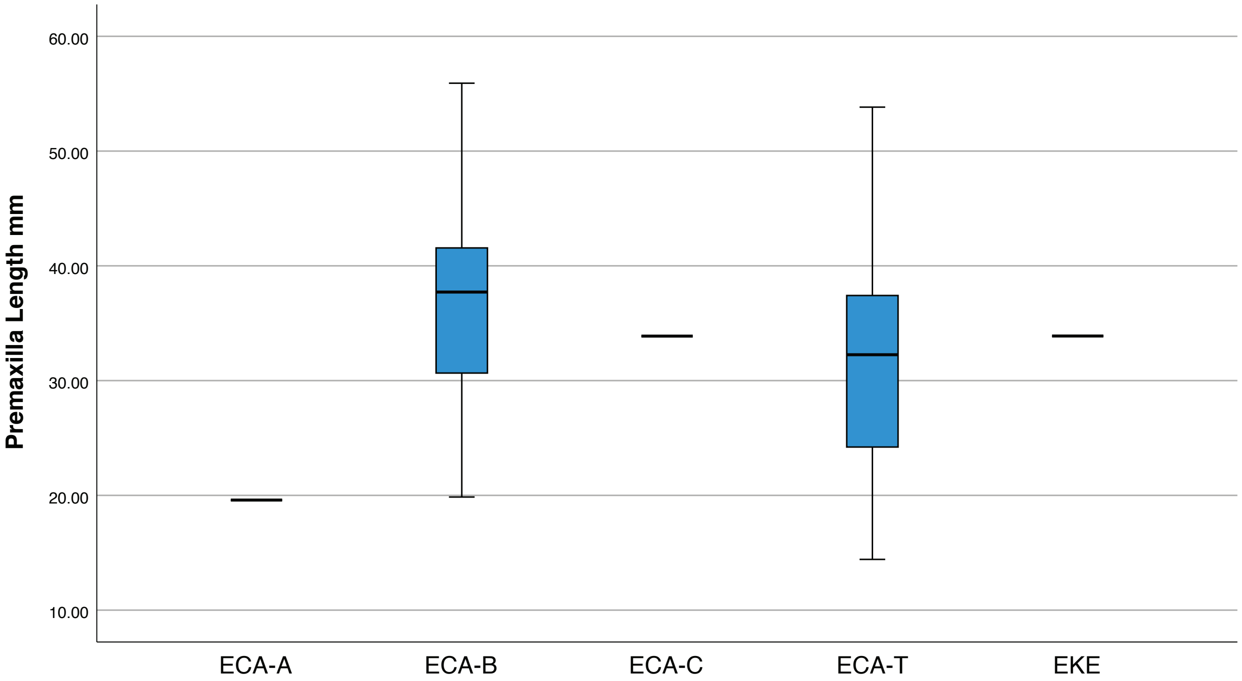


Figure 7.9. Box and whisker plot of *Monotaxis* premaxilla length by site. Box defines the upper and lower quartiles, horizontal line within box is the median, and bars extending vertically above and below box mark the maximum and minimum values, excluding outliers. (Diagram by V. Butler.)

Table 7.13. Summary statistics on width of Scaridae lower pharyngeals by genus and site

Scaridae Type		Mean (mm)	N	s.d. (mm)
~ *Scarus*	ECA-B	9.37	45	2.80
	ECA-T	9.34	67	2.48
	EHK	10.45	3	4.98
	EKE	9.72	17	3.37
	ECA-C	7.53	4	2.12
	ECA-A	9.16	3	0.70
	Total	9.37	139	2.71
~ *Bolbometopon*	ECA-B	28.43	11	6.04
	ECA-T	20.24	27	9.83
	EKE	33.65	1	
	ECA-A	23.75	2	5.03
	Total	22.93	41	9.42
~ *Calotomus*	ECA-T	9.40	2	4.38
	ECA-C	9.16	1	
	Total	9.32	3	3.10

feeding strategy. Carnivorous fishes will tend to take a hook and line while herbivores/omnivores tend to be taken by nets and spears, given that they tend to swim relatively slowly (Butler 1994). Multiple ethnographic case studies and modern fishery records support this general pattern, recognizing exceptions, especially when considering within-family variation in fish feeding strategies (e.g., wrasses, Labridae). Moreover, fish from both feeding groups can be taken by spear. Acknowledging the limitations, I applied this simple logic to the Mussau assemblages as a way of further characterizing fishing patterns.

Each family was assigned to one of three categories, Herbivore-Omnivore, Inshore Carnivore, and Offshore Carnivore, using the information from Butler (1994) (Table 7.14). I excluded assemblages (and loci of ECA) if they had less than 100 NISP, and focused strictly on the Lapita-era sites. As Figure 7.11 shows, the three ECA loci are extremely similar, being dominated by inshore carnivores, with a lower frequency of inshore herbivores/omnivores, and a modest input of offshore carnivores. ECB and EHB differ slightly from the ECA loci, with greater representation of inshore herbivores/carnivores and lower

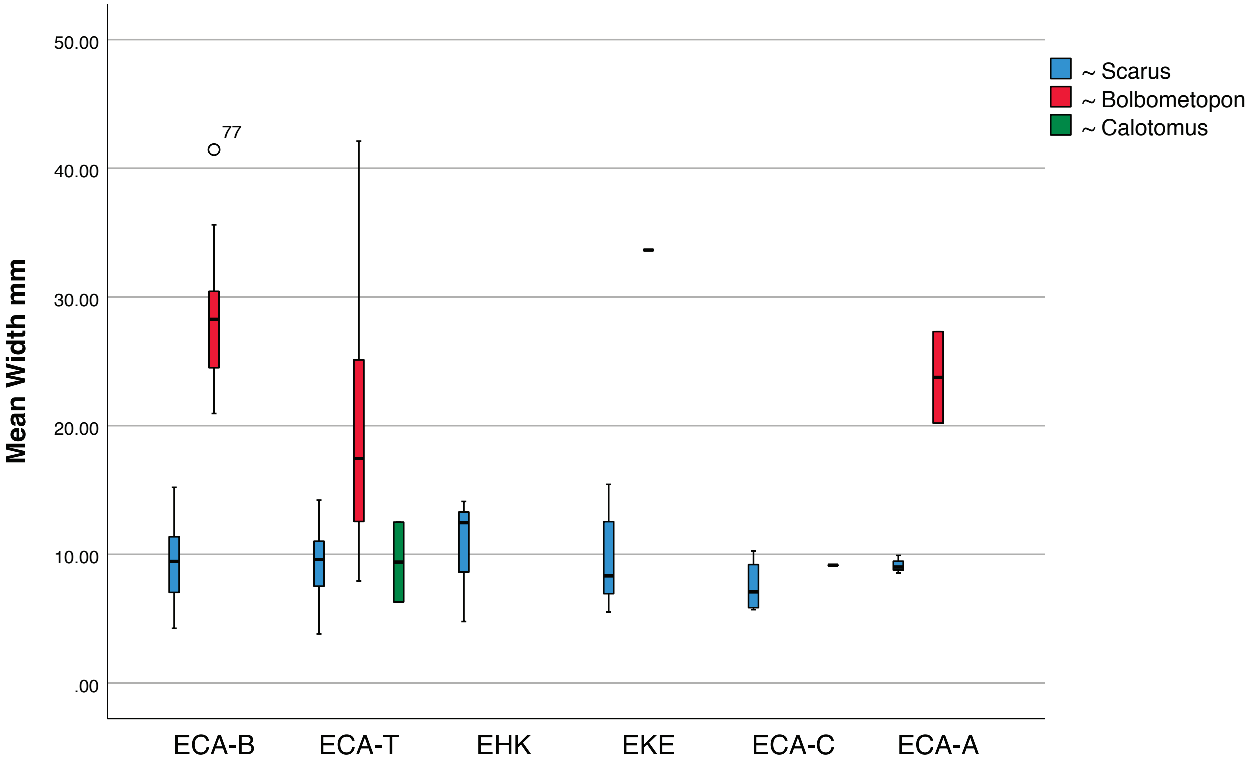


Figure 7.10. Box and whisker plot of scarid pharyngeal width by site and morphological type/genus. Box defines the upper and lower quartiles, horizontal line within box is the median, and bars extending vertically above and below box mark the maximum and minimum values, excluding outliers. A single outlier is present, marked "77," for *Bolbometopon*. (Diagram by V. Butler.)

frequency of inshore and offshore carnivorous fish. EKQ is distinct in having the greatest frequency of carnivores overall, especially of offshore fishes. As noted above, EKQ's location on the northwestern end of Mussau Island, adjacent to a narrow fringing reef, likely accounts for this striking difference in fish capture and hence fishing methods.

Overall these records suggest a mixed fishing strategy, with angling especially important at the ECA loci and site EKQ. The presence of fishhooks from various Lapita contexts in the Mussau Islands (see Chapter 13) provide independent evidence for the importance of angling. These trends are quite distinct from Lapita records from Tikopia and Niuatoputapu Islands, for which inshore netting and spearing were most commonly practiced (Butler 1994).

Lapita Fisheries: Opportunistic?

Based on detailed analysis of five Lapita-aged fishbone assemblages from Ha'api, Tonga, Cannon and others (2019) have recently characterized Lapita fisheries as

Table 7.14. Mussau fish families assigned to main feeding group

Inshore Carnivores	Offshore Carnivores	Inshore Herbivores/ Omnivores
Dasyatidae	Belonidae	Acanthuridae
Gerreidae	Carangidae	Balistidae
Haemulidae	Carcharhinidae	Diodontidae
Holocentridae	Elasmobranch	Kyphosidae
Labridae	Scombridae	Mugilidae
Lethrinidae	Sphyraenidae	Ostraciidae
Lutjanidae		Scaridae
Muraenidae		
Myliobatidae		
Platycephalidae		
Mullidae		
Sciaenidae		
Scorpaenidae		
Serranidae		

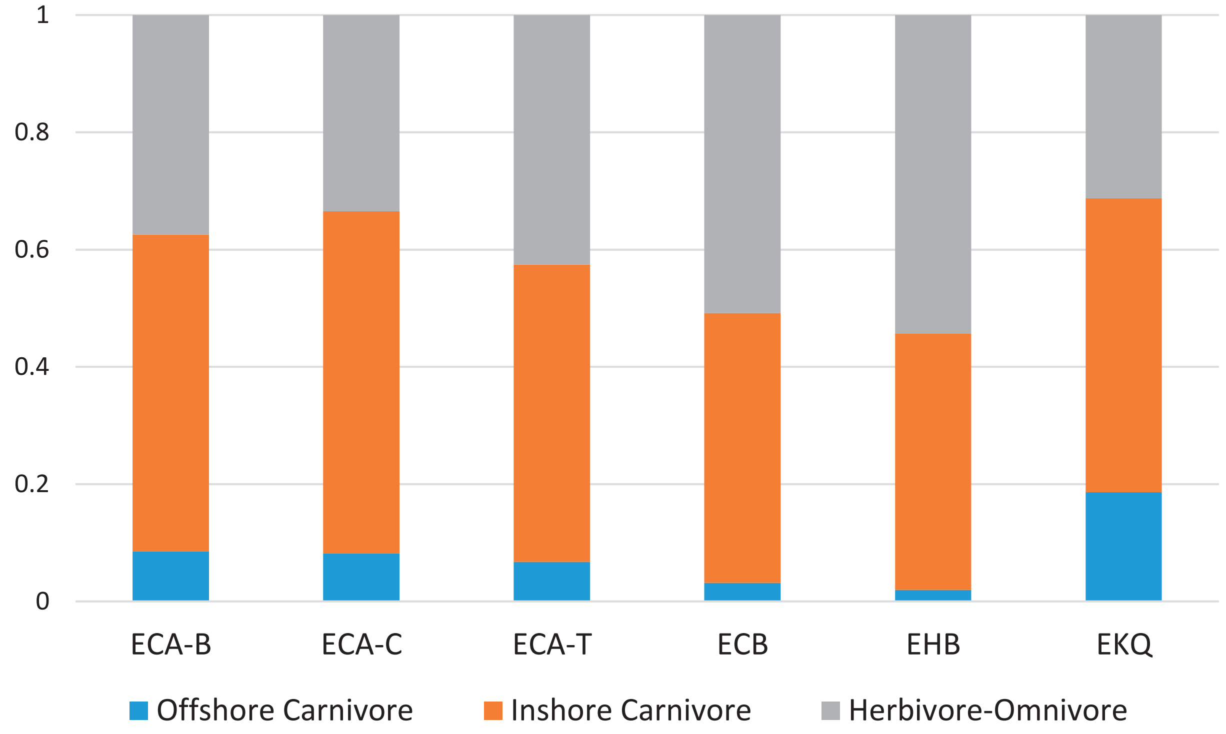


Figure 7.11. Proportion of fish remains from Lapita-era sites by fish feeding strategy and main habitat. (Diagram by V. Butler.)

"opportunistic." The authors observe mainly subtle differences across sites and through time, which they suggest do not reflect analytic differences or technological capacity. "These results do allow us to conclude that Lapita fishing is consistent with the characterization of early Ha'apai subsistence economy as largely based on *opportunistic foraging*, a pattern identified elsewhere in the Pacific (Bouffandeau et al. 2018)" (Cannon et al. 2019:537, emphasis added). The authors cite M. S. Allen (2017), who observed, based on a large-scale synthesis of East Polynesian fish assemblages, that archaeological abundances of reef fishes are in large part tied to natural abundances.

Given the strong pattern of consistency in the Mussau fishbone record over time and space, following Cannon and others, one might apply the term "opportunistic" to Mussau fisheries as well. Ahead of that, however, I wanted to unpack this concept and see what it implies, whether it can be operationalized, and in turn if it helps us conceptualize the nature of human–fish relationships in Oceania. In setting up this review, it is useful to define terms. According to *Merriam Webster* definition *b, opportunistic* means "taking advantage of opportunities as they arise: such as feeding on whatever food is available" (https://www.merriam-webster.com/dictionary/opportunistic). *Google Dictionary* defines opportunistic as "exploiting chances offered by immediate circumstances without reference to a general plan."

Bringing these definitions to Lapita fisheries, Cannon and others would appear to be asserting that past fishers were procuring available fish and that what was captured was tied to local abundance of different kinds of fish. While they do not specifically state this, Cannon and colleagues could also mean that people were fishing without a plan, that they were simply taking what was in the water. No one would question the notion that choices people make about resource procurement are constrained by habitat and food availability. The striking difference in fish records between the EKQ rockshelter located on the northwestern end of Mussau Island and the many open sites located on the smaller islands and islets adjacent to expansive reef and lagoon systems on the south side of Mussau Island must reflect the great environmental differences in habitats between these two areas. On the other hand, and in spite of the proximity of the sites to very different environments, it is striking that the *same two fish families, scarids and lethrinids*, are ranked first and second in all of the assemblages. One way to take this is that *despite* the habitat differences, people occupying the EKQ rockshelter sought out and targeted scarids and lethrinids.

Indeed—in all Mussau assemblages—these two fish types absolutely dominate. As demonstrated above, this prominence does not reflect identification bias that favored these two families. If we were to take the view that the fishery was opportunistic, would this mean these fish families are the most dominant in all of the habitats? Without local fishery survey and census data, this question is difficult to answer. However, we can examine fishery catch records from the Tigak Islands (New Ireland), an island group relatively close to the Mussau Islands, to estimate background fish abundance. If we take the Tigak Island fishery record as a crude estimate of "the fish in the water" adjacent to Mussau Island sites, and see differences between Tigak fish records and the Mussau archaeological assemblages, this would challenge the notion that Mussau fisheries were opportunistic.

Fishery research was carried out in this island group to document the artisanal fishery over a 13-month period in 1980–1981 (Wright and Richards 1985). Fishery stations were set up in Kavieng on the New Ireland mainland; Tigak islanders using a variety of fishing methods (angling, nets, trolling) brought their catch to recording stations, providing a total of 30,679 fish.

To compare the fishery records for Tigak Islands and Mussau, I created a simple bar chart, arraying the relative abundance of the Tigak Island fisheries with the Mussau fish families, focusing on the 14 most dominant families in the Tigak records (Figure 7.12). I recognize that the quantification units in the two data sets are different. The Tigak Island data are based on actual counts of fish over

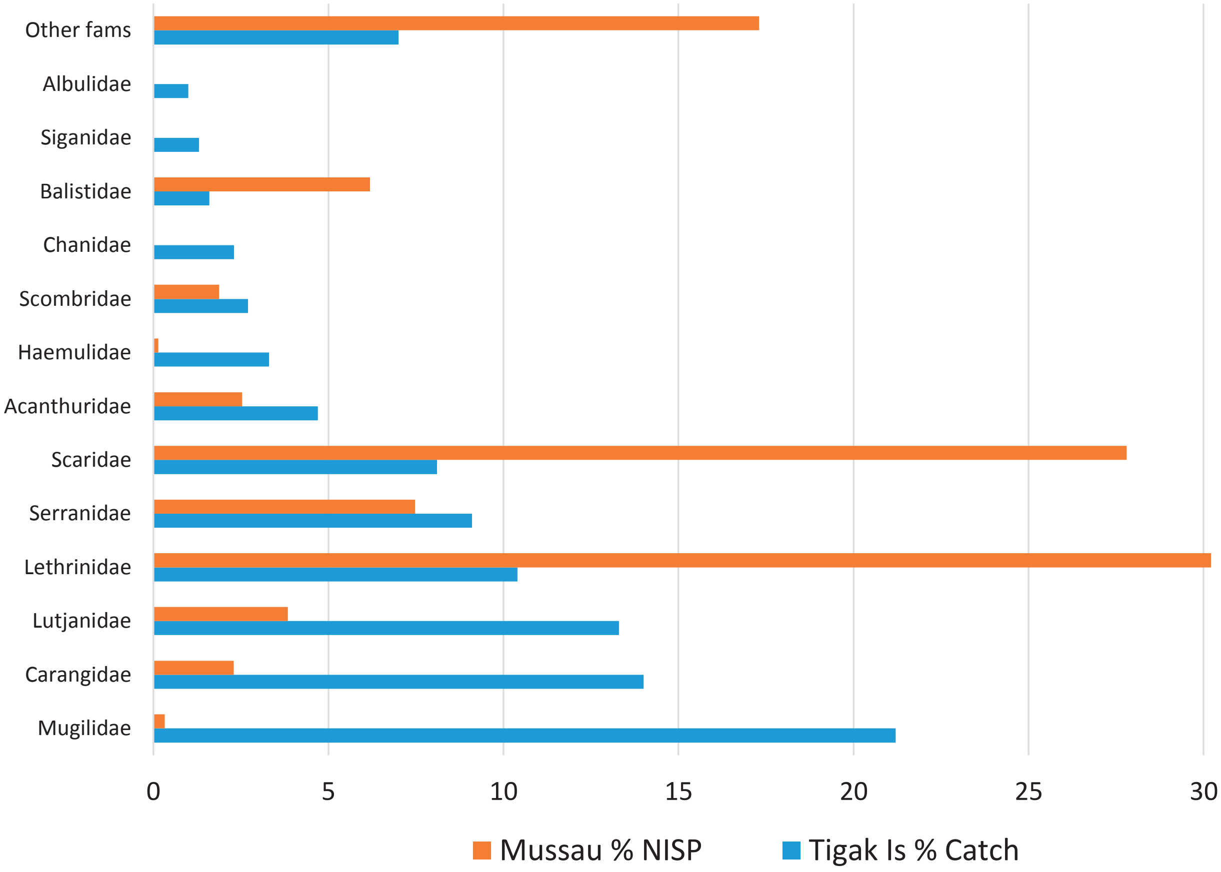


Figure 7.12. Percent frequency of fish family obtained in artisanal fishery in Tigak Island, PNG (fish count) versus the Mussau archaeological assemblages (percent NISP). (Diagram by V. Butler.)

a one-year period, while the Mussau records are percent NISP, collapsing large time periods. For this comparison, I am assuming that percent NISP is linked to fish captured. The point of the exercise is to highlight large-scale discrepancies, recognizing the limitations of the comparison.

The most dominant fish families in the Tigak Islands in descending order of abundance (Muglidae, Carangidae, Lutjanidae, Lethrinidae) are not the same as Mussau, which is dominated by Lethrinidae and Scaridae. Rank orders of the two datasets are only weakly correlated ($r_s = 0.50$) and not significant at the 0.05 level ($0.10 < p < 0.05$).

The striking differences between these data sets lead me to conclude that Mussau fisheries *were not opportunistic*. I propose an alternative hypothesis to account for the consistency in fish procured, especially the prevalence of scarids and lethrinids, and that is that Mussau people were explicitly targeting many of the fish they captured. I do not have independent justification for the choices made, but the notion that people were catching "what was available" is not supported by extensive ethnographies and more recent studies of traditional knowledge holders in Oceania (e.g., Aswani and Hamilton 2004; Hiroa 1944; Johannes 1981; Titcomb 1952). Such records speak to peoples' great depth of knowledge about marine systems, the fish, and the environments they occupied. To use the term "opportunistic" implies a passive relationship between people and fish that is contrary to most records of indigenous fishing practices.

Summary

O'Connor and others (2011) have shown that people occupying East Timor and other islands of Wallacea and Greater Australia had deep knowledge of fish and fishing gear by 42,000 years ago. The Mussau fishbone record adds to this long time line for fishing in the region, providing new insights on fisheries associated with Lapita and post-Lapita occupations from one of the most northernmost island groups of PNG. Based on remains from eight sites, I identified 4,687 fish remains from 27 families, primarily nearshore fishes, with some offshore taxa. There is a strong consistency in fish representation across sites and time periods—with the same set of families dominating assemblages. One site (EKQ) has higher representation of offshore fishes than other sites, which likely reflects its environmental context. However, two families, Scaridae and Lethrinidae, are the first or second ranked family in all contexts. Analytic bias does not appear to be responsible for this dominance. Fishery methods including hook and line, netting, and spearing are indicated for all the contexts. Body size (of scarids and *Monotaxis grandoculis*) as estimated from skeletal element measures does not vary through time, indicating sustainable fisheries were in place. One locale, ECA Area B, provides evidence for larger ~*Bolbometopon* than other contexts, which is consistent with independent evidence for ritual activities or feasting taking place there. A recent study of Lapita fisheries (Cannon et al. 2019) in Tonga argues that consistency in fisheries over time and space reflects opportunistic fishing. I argue this characterization is misplaced, that it flies in the face of what we know about Pacific Islander traditional fishing knowledge.

Acknowledgments

Principal Investigator Patrick V. Kirch provided excellent leadership and support for the study all along the way. Roger Green, always a champion of fish faunal analysis, provided numerous suggestions and friendship when I was developing the project in the late 1980s. Several individuals assisted with identification of obscure specimens or provided unpublished manuscripts or both: Melanie Stiassny, David Smith, George Burgess, Stuart Poss, John McEachran, Tsutomu Miyake, Patricia Kailola, Camm Swift, Lynn Parenti, and Bruce Masse. Toni Han (B. P. Bishop Museum) facilitated the loan of several reference skeletons. John Aini (Kavieng Fisheries Research Lab) collected 61 modern fish samples that were skeletonized by Kirch's team in Mussau. I carried out some of this work when I was a research associate at the University of Colorado–Boulder in the late 1980s/early 1990s. Jane Wheeler, then of the Department of Anthropology, and Peter Robinson (Curator, University of Colorado Museum of Paleontology) provided space and collegial support during that period. University of Colorado undergraduate student Laura Aldrete helped sort the fish remains. Terry Hunt, Melinda Allen, Gwen Bell, and Marshall Weisler provided general assistance and friendship during analysis. To all of these people I give my sincere thanks.

CHAPTER 8

Mollusks and Other Invertebrate Fauna from the Mussau Sites

Patrick Vinton Kirch

The presence in Lapita sites of marine mollusk shells was first noted by W. C. McKern in his pioneering excavations of "kitchen middens" on Tongatapu Island, where he observed that "marine shells were plentiful" in deposits containing potsherds (McKern 1929:111). The first serious study of marine invertebrates in a Lapita site was by Gifford and Shutler (1956), who identified and quantified the species present in one excavation unit at site 13 one the Koné Peninsula of New Caledonia (see also Miller 1997). The density of marine mollusks in Lapita sites on Tongatapu prompted Groube (1971) to hypothesize that the early Lapita colonizers of Tonga may have been "strandloopers," a hypothesis that has subsequently been refuted on multiple lines of evidence. Nagaoka (1988) synthesized the available data on marine shells in Lapita sites, with the most extensive analyses being those of Swadling (1986) for sites excavated by Green in the Santa Cruz Islands, Kirch and Yen (1982) for Tikopia, and Best (1984) for Lakeba in Fiji. Surprisingly, there has been relatively little zooarchaeological work on Lapita mollusks or other invertebrates since Nagaoka's summary. The most important contributions are surely those of Szabo (2001, 2009) on mollusks in the Lapita site of Natunuku in Fiji, and Szabó (2005, 2010) on shell-working in several selected Lapita sites including Kamgot in the Far Western Lapita region. For most other Far Western Lapita sites, however, data on mollusks or other invertebrates are cursory or lacking (e.g., Summerhayes et al. 2010). To my knowledge, the analysis of mollusks and other invertebrate remains from Talepakemalai and other Mussau sites presented here is the first comprehensive study of Lapita mollusk exploitation within the Bismarck Archipelago.

The coral reefs and lagoons that form an integument encompassing Eloaua, Emananus, Boliu, and the other islands of southwestern Mussau support an astonishing abundance of marine life, for indeed, Mussau lies within the core region of marine biodiversity of the Indo-Pacific biogeographic province (Stoddart 1992). In our initial reconnaissance forays the numbers of mollusk shells on the surface of sites such as ECA and ECB were notable; when we began to dig our first test pits it became apparent that our excavations would yield enormous quantities of mollusks. Realizing that it would be prohibitively expensive to ship all this material back to my laboratory in the United States, I made the decision in 1985 that we would process and analyze the shell midden in the field, a procedure we continued in 1986 and 1988. In 1988, I decided to bring additional expertise on marine biodiversity into the project, inviting marine biologists Carl Catterall and Mike Ritchie to join the team. Catterall and Ritchie carried out a field assessment of the marine habitats and biodiversity around Eloaua and Emananus (see Chapter 2), as well as an intensive analysis of temporal changes in mollusks at the ECA site, the subject of Chapter 9.

Materials and Methods

During excavation, mollusk shells and other invertebrate remains were collected and bagged from a total of 134 excavation units at eight sites (Table 8.1). In total, some 2.47 metric tons of mollusk remains were collected. In our field laboratory, days were periodically set aside for processing this material. For 70 of the excavation units, mollusks were simply bulk weighed by excavation level, without further sorting to taxonomic categories. For the other 64 excavation units, however, the mollusks were sorted into taxonomic categories, for the most abundant categories typically to genus and species. The sorting was done by all members of the field team including our local Mussau assistants. Although the latter have no knowledge of Western scientific taxonomy, they are astute observers of nature and readily understood how to distinguish key morphological attributes. For some of the less abundant categories, it was necessary to lump specimens at the genus or even family level, given our lack of access to reference materials in the field. For example, we separated out the large cone shells *Conus litteratus* and *C. leopardus* (whose shells were extensively worked to manufacture shell rings), but lumped together a number of smaller cone species that were present only in low frequency under the family taxon Conidae.

The Mussau excavation database records mollusk remains according to 152 taxonomic categories, ranging from family down to species level. A certain residuum of highly fragmented or otherwise unidentifiable shell was categorized as "miscellaneous shell." Assignment of taxonomic names follows Cernohorsky (1978), Kira (1962), and Habe (1964). The illustrated guides of Hinton ([1972]) were also useful. Taxonomic revisions since we undertook our fieldwork and identifications have subsequently resulted in some changes to the genera that we assigned to our specimens. In those cases, we retain the genus name that we used in our database, but have placed the revised genus name in parentheses; for example, what we referred to as *Strombus luhuanus* during our field sorting and identification has now been reassigned to *Conomurex luhuanus*; we therefore use the label *Strombus (Conomurex) luhuanus* in the text and tables in this chapter. We have referred to the online database WORMS, the *World Register of Marine Species* (http://www.marinespecies.org/index.php), for current taxonomic names. In addition, a set of reference specimens has been retained as vouchers to be permanently curated with the Mussau collections.

Table 8.1. Summary of mollusk analysis by site

	ECA	ECB	EHB	EHK	EKE	EKQ	EKS	EKU	Totals
Units with mollusks bulk weighed	47	5	1	2	11	2	2	0	70
Units with mollusks sorted and weighed by taxonomic category	32	14	8	2	1	0	2	5	64
Total weight of bulk unit mollusks (kg)	819.0	59.6	7.9	7.5	214.3	14.9	63.3	0	1,186.4
Total weight of speciated mollusks (kg)	607.4	195.2	220.4	43.1	155.5	0	44.9	21.0	1,287.5
Combined weight of all mollusks (kg)	1,426.4	254.9	228.2	50.6	369.8	14.9	108.2	21.0	2,473.9

Zooarchaeologists have debated the most appropriate methods for quantifying mollusk assemblages (e.g., Claassen 1998:91–121; Reitz and Wing 1999; Szabó 2009:186–188). For Pacific shell assemblages, shell weight has often been the preferred measure (e.g., Kirch and Yen 1982), although this has its detractors (Szabó 2009). The standard alternatives to weight are NISP (number of identified specimens) and MNI (minimum number of individuals). While MNI might in theory be preferable to either NISP or weight, it is difficult to apply when there is a high degree of shell fragmentation. I have opted to report and analyze the mollusk data by weight, not only because this is the most direct form of quantification, but because weight and NISP are highly correlated. For example, Figure 8.1 is a scatterplot and regression of mollusk weight versus NISP for 18 samples of *Anadara antiquata* bivalves from Area B of the ECA site. The strong correlation between NISP and weight is confirmed by an R^2 value of 0.75. Of course, different mollusk taxa have different average shell weights, so that, for example, a heavy *Tridacna crocea* shell weighs considerably more than the small shell of a *Strombus luhuanus*. Moreover, edible meat weight does not necessarily correspond to shell weight. These factors require caution in making interpretations involving comparisons between taxa. However, analysis of temporal trends within a site is not affected by these concerns, nor are inter-site comparisons.

In order to facilitate comparison between sites, as well as between areas within the ECA site, I have standardized the mollusk weight values by reporting them as "concentration indices" (C.I.), calculated as weight per cubic meter of excavated sediment (Ziegler 1973). By taking into account different excavated volumes, these C.I. values allow for direct comparison of mollusk midden densities between sites.

The Mussau Mollusk Assemblage

As noted above, the Mussau mollusk remains were sorted in the field into 152 taxonomic categories, ranging from family level to genus and species where these could be accurately determined given our resources. To simplify data analysis, many of these categories have been collapsed

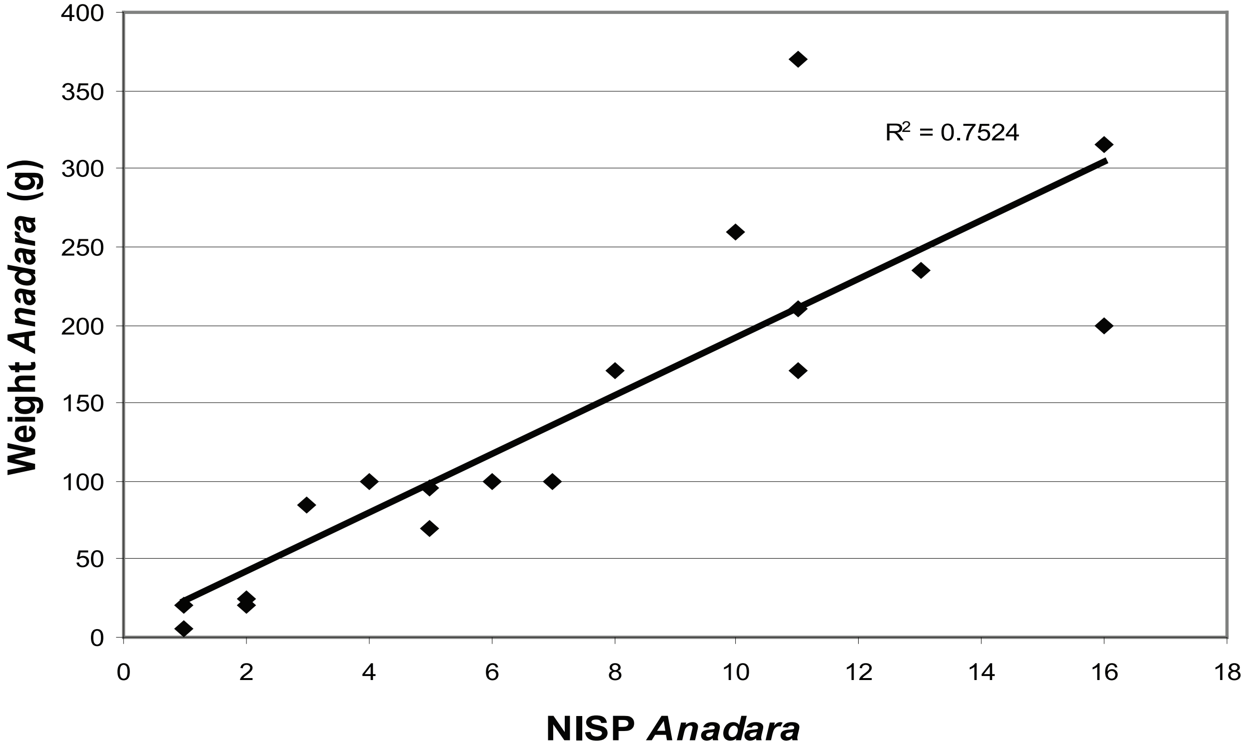


Figure 8.1. Scatterplot showing the relationship between weight and NISP for 18 samples of *Anadara antiquata* from site ECA, Area B.

or combined in the presentation of data in this chapter. However, the raw data on weights and NISP counts for these 152 categories, according to site, excavation unit, and level, are contained in the Mussau database. The following paragraphs describe the most important mollusk families, with notes on particularly abundant or otherwise significant species.

Gastropods

Some of the frequently occurring gastropods in the Mussau sites are illustrated in Figure 8.2.

Bullidae. Commonly referred to as "bubble shells," the bullids have very thin, light shells; they are herbivorous, feeding on sea grasses. The Mussau bullids all appear to be of a single species, which we identified as *Bulla vernicosa*, one of the larger bullids. Whether these were purposefully collected as food items, or whether they were inadvertently obtained while gathering edible sea grasses, is uncertain; in any case, they are a minor component of the mollusk assemblage.

Cassidae. Small numbers of two large helmet shell species, *Cassis cornuta* and *Cypraecassis rufa*, were present at sites ECA and EHB. The massive outer lips of the main whorl of these shells were sometimes shaped into chisels (see Chapter 13), while the entire shells (with a hole bored into the columella) were used as trumpets in some Pacific island cultures.

Cerithiidae. The ceriths comprise a large family of medium-size, elongate gastropods generally occupying sandy or coral reef substrates. At least four species are present in the Mussau material: *Cerithium aluco*, *Cerithium nodulosum*, *Rhinoclavis asper, and Rhinoclavis vertagus*. During field sorting, the shells of the distinctive *C. nodulosum* (the "giant knobbed cerith") were counted and weighed as a separate category; the other species were combined into a general Cerithiidae category. *C. nodulosum*, with shell lengths in the range of 12–15 cm, was almost certainly gathered for its food value (Poutiers 1998).

Conidae. The cones are an extremely diverse family with perhaps 800 named species, occupying a number of habitats including coral reef and sandy substrates. We identified the following species within the Mussau assemblage: *Conus eburneus*, *C. flavidus*, *C. lividus*, *C. miles*, *C. distans*, *C. litteratus*, *C. leopardus*, *C. pulicarius*, *C. quercinus*, and *C. striatus*. It is likely that there are additional species present that we did not identify. The species *Conus litteratus* and *C. leopardus* are significantly larger than the others, with lengths ranging from 15–20 cm. The broad, flat spires of *C. litteratus* and *C. leopardus* provided raw material for the manufacture of shell rings (see Chapter 13); their meat was likely also consumed. Unfortunately, the two species have similar morphologies and coloration patterns, making it difficult to accurately separate the species when confronted with often fragmentary and bleached shells. We therefore resorted to a category of combined *C. litteratus/C. leopardus* for this material. Other conids, present only in small numbers, were separated out and lumped as Conidae spp.

Cypraeidae. The cowries constitute another large and diverse family, with at least seven species present in the Mussau assemblage: *Cypraea annulus*, *C. arabica*, *C. caputserpentis*, *C. lynx*, *C. moneta*, *C. testudinaria*, and *C. tigris*. Most of these species are relatively small and were probably of little economic importance, but *C. tigris* (the "tiger cowrie") reaches lengths of up to 15 cm. Not only does *C. tigris* provide a large quantity of edible meat, but the dorsal portion of the shell was ground and sharpened along one side to provide a curved scraper used for the preparation of root, tuber, or tree crops such as taro, yams, or breadfruit (see Chapter 13). We therefore separated the *C. tigris* specimens as a distinct category, while combining other small cowries under a general Cypraeidae spp. category.

Mitridae. Mitre shells occur in limited numbers in the Mussau mollusk assemblage, the most commonly represented species being *Mitra mitra*.

Naticidae. This family is represented in our material by a single species, *Polinices tumidus*, notable for its brilliant white shell. Some specimens of *P. tumidus* were modified for use as ornaments (see Chapter 13).

Neritidae. These small gastropods, which frequent rocky substrates in the intertidal zone, occur in limited numbers in the Mussau assemblage.

Strombidae. The strombids, or true conchs, range from mid-sized to quite large gastropods that frequent sandy substrates with sea-grass beds, and hence are very common in the Mussau assemblage. These mollusks have a distinctive mode of locomotion using their uniquely adapted, sickle-like operculum to propel them through the sand. During the 1986 field season, a large *Lambis lambis* that we had

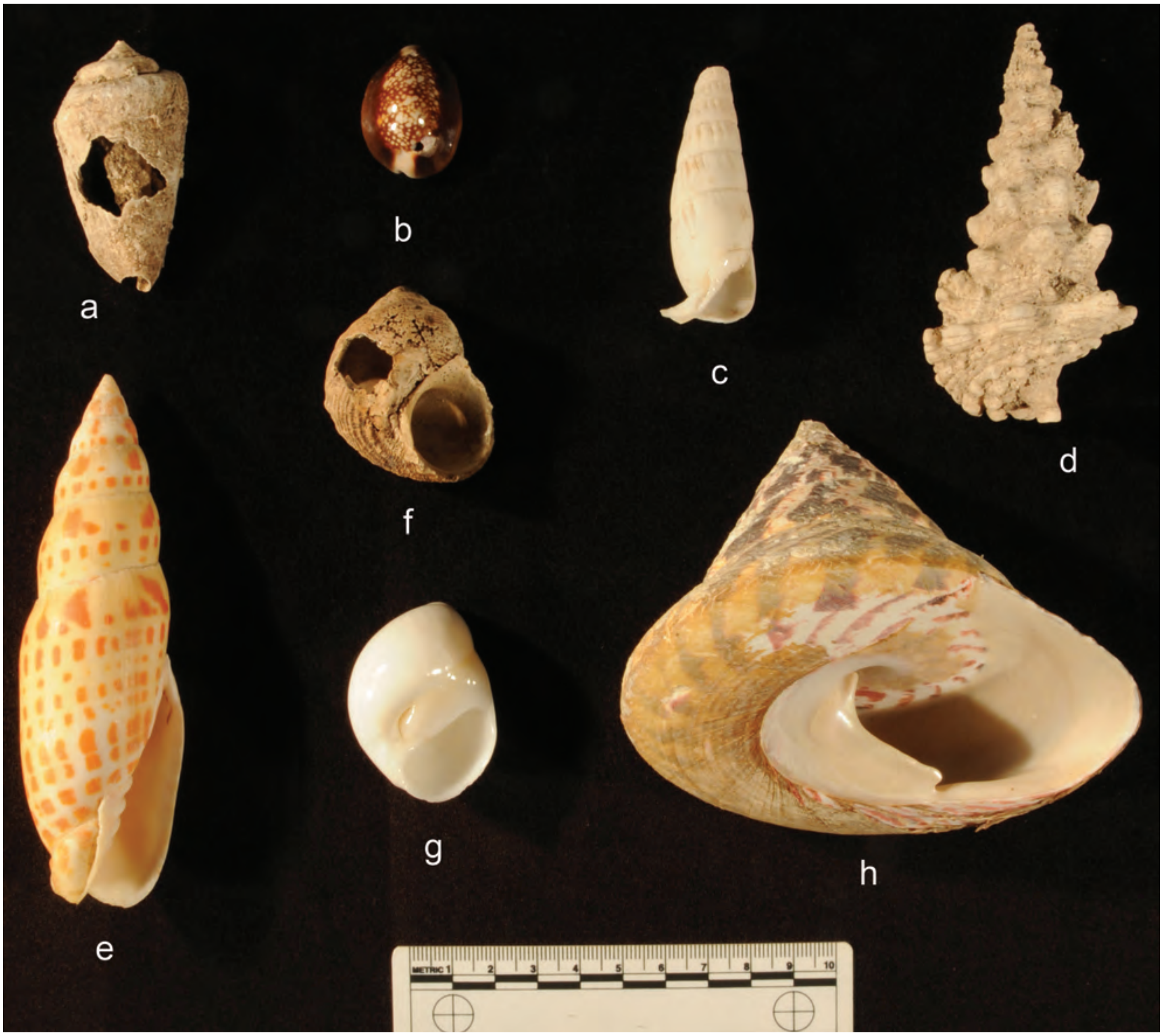


Figure 8.2. Gastropods from Mussau archaeological sites: *a*, *Strombus luhuanus*; *b*, *Cypraea caputserpentis*; *c*, *Rhinoclavis* sp.; *d*, *Cerithium nodulosum*; *e*, *Mitra mitra*; *f*, *Turbo argyrostomus*; *g*, *Polinices tumidus*; *h*, *Trochus niloticus*.

collected and set down on our field lab table startled us by rapidly moving by leaps across the table, nearly escaping its fate as a reference specimen.

Strombids make up a large percentage of the Mussau mollusk assemblage. Two large species, with lengths of up to 25 cm, provided substantial meat packages: *Lambis lambis* and *Lambis (Harpago) chiragra*. While the shells of these two species can be readily separated when one is dealing with intact, fresh material, discriminating between the two species with fragmentary and bleached shells was not always possible; we therefore resorted to a combined category of *Lambis lambis/L. chiragra*, which includes both of those species. The shells of *Lambis* in the ECA and other sites were almost invariably smashed for meat extraction (see Taphonomic Considerations, below).

The other conchs in our assemblage were all formerly classified as members of the genus *Strombus*, although more recent taxonomic revision has separated these into several genera. The species present in our Mussau material include *Strombus (Laevistrombus) canarium*, *Strombus (Gibberulus) gibberulus*, *Strombus (Lentigo) lentiginosus*, *Strombus (Conomurex) luhuanus*, *Strombus (Canarium)* *microurceus*, *Strombus (Canarium) mutabilis*, and *Strombus (Canarium) urceus*. By far the most common in our archaeological assemblage is *Strombus (Conomurex) luhuanus*. During field sorting of shells in 1985 and 1986, all of the small strombids were lumped under the category *S. luhuanus*. In 1988, we more carefully distinguished among *S. luhuanus*, *S. gibberulus*, and *S. lentiginosus*.

Terebridae. The terebrids, or augers, with their large, elongated, and sharply pointed shells, are predatory gastropods living primarily in sandy habitats. Three species are present in our assemblage, in relatively small numbers: *Terebra (Oxymeris) crenulata*, *Terebra (Oxymeris) maculata*, *and Terebra subulata*. In the tables, these are combined into a single category of *Terebra* spp. The shells of *T. maculata* were modified for use as adzes in the post-Lapita period in Mussau, by grinding down one side of the shell to create a curved cutting edge from the basal whorl, as described and illustrated in Chapter 13.

Trochidae. The trochids or "top snails" are herbivorous gastropods common on Indo-Pacific reefs. The most abundant in our assemblage is the large species *Trochus (Rochia) niloticus* (also sometimes called *Tectus niloticus*), with basal whorl diameters of 10–12 cm. Shells of *T. niloticus* are present in large numbers in the Lapita-period sites, where the basal whorl was worked into fishhooks, as described in Chapter 13. The large quantity of edible meat contained within these shells was also presumably eaten. In the post-Lapita phase of Mussau these large shells were worked into armbands, which are quite common in the post-Lapita sites (see Chapter 13). The somewhat smaller species *Tectus pyramis* and *Tectus fenestratus* are also present. Fragmentary material that could not readily be identified to any of these three species was combined under a Trochidae category.

Turbinidae. The turban shells are somewhat similar to top shells in overall morphology, but unlike the latter have a distinctively thick, calcareous operculum. The most common species in our assemblage is *Turbo argyrostomus*, common on the outer reef edges in Mussau; this provided an excellent source of meat. The much larger *Turbo marmoratus*, which can attain a length of up to 18 cm, is also present. We combined the opercula of all *Turbo* species into a single category as it was not possible to separate them by species.

Bivalves

Some of the most frequently occurring bivalves in the Mussau sites are illustrated in Figure 8.3.

Arcidae. One of the most abundant bivalves in the Mussau assemblage is *Anadara antiquata*, a medium-sized arc clam, which inhabits sandy patches in the lagoon floor. In addition to being a significant food item, the individual valves of *A. antiquata* were used as scrapers, indicated by use-wear along their ventral margins (see Chapter 13).

Cardiidae. Two genera within the cockle family are present in the Mussau mollusk assemblage. The first is *Fragum*, with the single species *Fragum fragum* represented in our collection, a distinctively shaped sand-burrowing bivalve. The second is the somewhat larger *Acrosterigma*, with several species that we were not able to definitively separate or identify conclusively. (We originally assigned these bivalves to the genus *Laevicardium*, but this appears to be incorrect.)

Chamidae. The genus *Chama* includes several species of sessile, "cemented saltwater clams" that affix one valve to the reef substrate. These are quite abundant in the Mussau assemblage, and all of the material appears to be of the species *Chama limbula*.

Gryphaeidae. The giant honeycomb oyster, *Hyotissa hyotis*, is quite abundant in a number of the Mussau sites. This bivalve contains a large meat package, and its presence in the sites is doubtless due to exploitation as a food source.

Lucinidae. At least one species of saltwater clam, in the genus *Codakia*, was represented in low frequency at Lapita sites ECB and EHB.

Ostreidae. At the ECA site we recovered small quantities of a true oyster, referred to the family Ostreidae, but were unable to identify this to a lower taxonomic category.

Pteriidae. The feather oysters or pearl oysters include several genera, although we were only able to definitively identify the large black-lip pearl oyster, *Pinctada margaritifera*, to species. Fragmentary material not clearly referable to *P. margaritifera* was combined under a category of Pteriidae spp. At the ECA site, a number of whole valves of *P. margaritifera* had been artificially modified for use as peeling knives or scrapers (see Chapter 13).

Spondylidae. The genus *Spondylus*, or "spiny oysters" (although they are not true oysters), is represented in the Mussau assemblage by at least three species: *Spondylus*

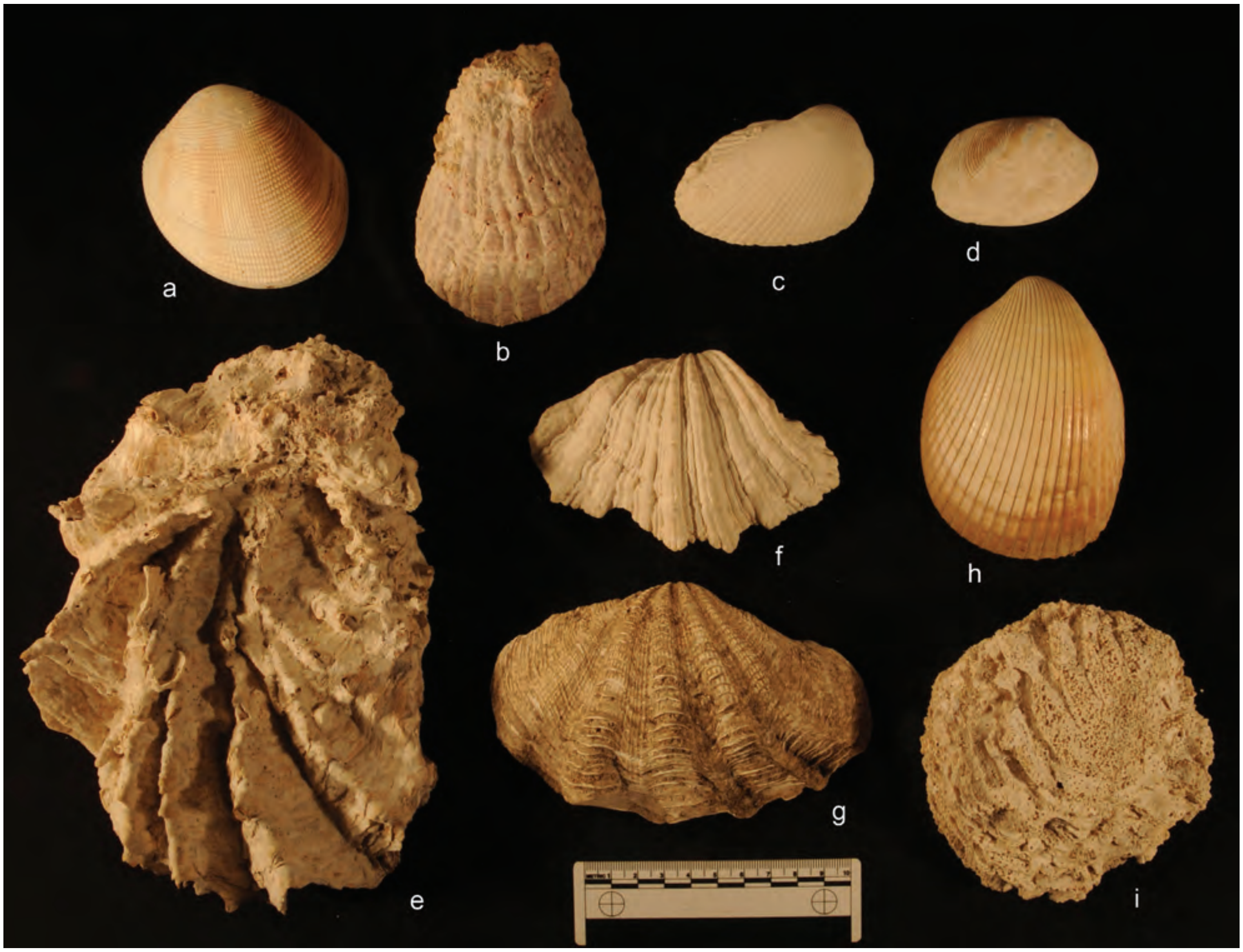


Figure 8.3. Bivalves from Mussau archaeological sites: *a*, *Periglypta albocancellata*; *b*, *Spondylus* sp.; *c*, *Anadara antiquata*; *d*, *Tapes literata*; *e*, *Hyotissa hyotis*; *f*, *Hippopus hippopus*; *g*, *Tridacna crocea*; *h*, *Acrosterigma* sp.; *i*, *Chama* sp.

lamarcki, *S. spinosus*, and *S. squamosus*, with *S. lamarcki* being the most abundant. In the field and faced with often fragmentary material, however, it was not possible to readily differentiate these species. All of the material was therefore combined into a single category of *Spondylus* spp. As in other parts of the world, the Lapita occupants of the Mussau sites worked *Spondylus* shells into a variety of ornaments, no doubt attracted by the subtle yellow-to-orange coloration of the shell (see Chapter 13). The meat was also very likely consumed.

Tellinidae. This is a large family of bivalves with numerous genera; the tellinids occupy soft sandy or silty sediments. The species *Quidnipagus palatam*, present at both Lapita and post-Lapita sites, was readily recognizable and we separated this out as a distinct category. Also present in small quantities were a number of other tellinids generally referable to the genus *Tellina*, and probably including the following species: *Tellina tongana*, *T. virgata*, and *T. staurella*. These were combined into a single category of *Tellina* spp. The larger *Quidnipagus palatam* bivalves as well as the smaller *Tellina* clams were likely naturally inhabiting the sandy and silty environments of the Lapita stilt-house villages. We often found matching, intact valves in the deeper deposits at ECA, suggesting that these mollusks had simply expired while inhabiting the shallow intertidal environment over which the stilt houses were constructed.

Tridacnidae. Originally considered to be a separate family, the giant clams are now classified as a subfamily, Tridacninae, under the family Cardiidae. The distinctive "horse's hoof clam," *Hippopus hippopus*, was readily identifiable and recorded as a separate category. The very large and massive *Tridacna gigas* was present, but could not always be distinguished from a similar large species *T. derasa*, so we recorded these two as a combined category. Of the smaller tridacnids, we were able to frequently distinguish both *Tridacna crocea* and *T. squamosa*; however, fragmentary material was often assigned to a category of *Tridacna* spp. The large retractor muscle of tridacnids is delicious eaten raw or cooked (as I can testify from experience), and most of the giant clam material in the Mussau assemblage doubtless represents food refuse. However, the heavy shells of *Tridacna gigas*, as well as the smaller shells of *T. crocea*, *T. squamosa*, or *T. maxima*, were used to fashion adzes (see Chapter 13).

Veneridae. Several genera and species of venus clams are present in the Mussau assemblage: *Asaphis violascens*, *Gafrarium pectinatum*, *Gafrarium tumidum*, *Periglypta albocancellata*, and *Tapes literata*. Some of these were undoubtedly taken as food items, although others may simply be present due to the fact that they inhabit the same sandy substrates where the Lapita people built their stilt-house villages.

Taphonomic Considerations: Breakage Patterns

As noted above, while some shells from the Mussau sites were whole and intact, many were fragmented. This was especially the case for certain gastropods, reflecting the difficulty of extracting the edible animal without breaking open its protective shell. However, some bivalves also display considerable damage and fragmentation. As we processed the Mussau mollusks, it became increasingly apparent that there were systematic breakage patterns; during the 1988 field season I made a series of observations on the more common patterns. Examples of typical shell breakage patterns are illustrated in Figure 8.4.

Shells of the large gastropods *Lambis lambis* and *L. chiragra* in ECA and other sites were almost invariably broken, with typical examples illustrated in Figure 8.4, b and c. The intent here was certainly to extract the large, edible animal, as the shells were not otherwise used for artifact production. The typical pattern was to smash and remove the dorsum, exposing the central columella; this sometimes resulted in a complete separation of the lip of the main whorl from the rest of the shell. Shells of the smaller *Strombus luhuanus* frequently also exhibit smashing of the dorsal portion of the main whorl to facilitate meat extraction (Figure 8.2, a); again, this sometimes resulted in the lip being completely separated from the rest of the shell.

The large cone species *Conus litteratus* and *C. leopardus* almost invariably were found in ECA and other Lapita sites in fragmentary condition. The pattern here is one of separating the large, flat spires (used to make cone shell rings) from the body whorl and columella, as seen in Figure 8.4, a. In this case, rather than simply smashing the shell, a methodical pattern of chipping around the spire is evidenced. The production of cone shell rings is discussed further in Chapter 13.

Shells of *Cerithium nodulosum* and other ceriths were most often found whole, but some exhibit signs of chipping around the aperture, presumably to facilitate removal of the operculum and extraction of the animal.

The smaller species of cowries (Cypraeidae) were typically intact, but those of the large species *Cypraea tigris* were almost always fragmented, the dorsal “cap” being separated from the lip and columella. This was presumably necessary to extract the edible animals, although as noted earlier, many of the caps were subsequently worked into scrapers or peelers (see Chapter 13).

In order to extract the edible animal from turban shells, it is necessary to remove the heavy operculum that tightly seals off the aperture. In the case of *Turbo argyrostomus*, a high degree of fragmentation indicates that the shells were almost always smashed in order to remove the operculum and obtain the meat. The larger *Turbo marmoratus* was a rare occurrence at the ECA site and when present was invariably in the form of small, smashed fragments.

In the case of the large gastropod *Trochus niloticus*, a distinctive pattern of fragmentation reflects the frequent use of this gastropod for the manufacture both of fishhooks (in the Lapita period) and of armrings (in the post-Lapita period). Whole shells were rarely present, with fragments consisting of chipped spires with the basal whorl absent, chipped basal whorls with the spire absent (such as shown in Figure 8.4, d), chipped basal whorl fragments, and fragments of the interior columella. The intent seems to have been to isolate an intact basal whorl

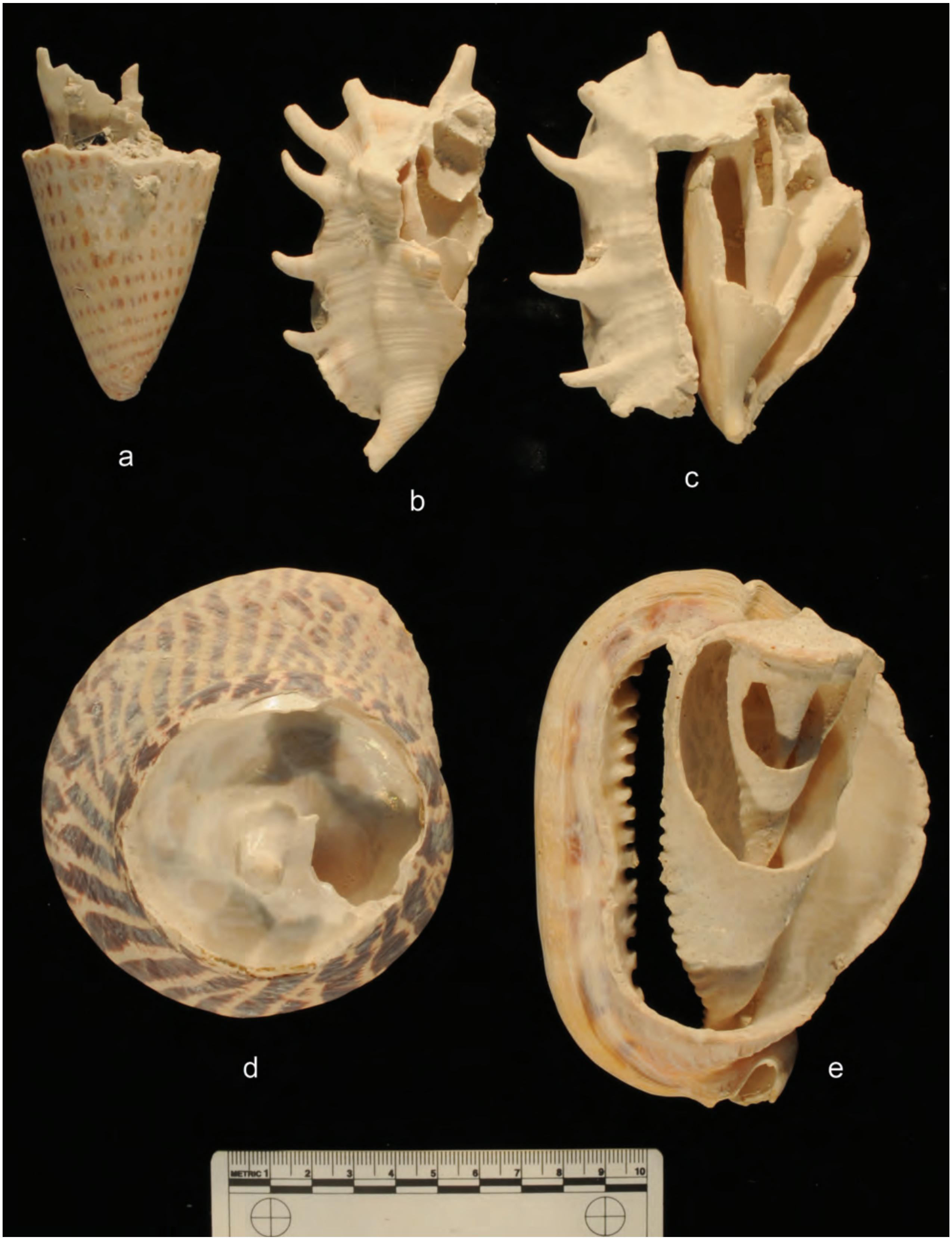


Figure 8.4. Typical breakage patterns in gastropods from Mussau archaeological sites: *a*, *Conus leopardus* with spire removed; *b*, *c*, *Lambis lambis* with dorsal region removed to facilitate meat extraction; *d*, *Trochus niloticus* with upper part of spire removed; *e*, *Cypraecassis rufa* with dorsal region removed to facilitate meat extraction.

from the remainder of the shell. The manufacture of fishhooks and armrings from *Trochus niloticus* shell is further described in Chapter 13. Shells of the smaller trochid *Tectus pyramis* did not exhibit the same kind of extensive working as with *Trochus niloticus*. However, for *Tectus pyramis* the basal whorl near the aperture was commonly chipped or smashed, presumably to facilitate meat extraction.

With respect to bivalves, shells of the large sessile clam *Chama* spp. were found both whole and fragmented. The large valves of *Hyotissa hyotis* were often intact, but smaller valve fragments were also present. These fragments usually displayed signs that they had been burned (fire blackening and calcined shell), suggesting that the *Hyotissa* bivalves may have been roasted on open fires. The giant clam *Tridacna gigas* typically was present only as small, broken fragments, possibly the residue of shell adze manufacture. The more frequent *Tridacna crocea* was present in ECA primarily as whole valves, suggesting that the shell could readily be opened and the meat extracted without smashing the shell (and probably eaten raw). The valves of *Hippopus hippopus*, not used for artifact manufacture, were found both intact and broken. The valves of *Periglypta albocancellata* often exhibit some fracturing or chipping along the ventral margin, presumably due to meat extraction.

The valves of *Spondylus* spp. at ECA were present in a roughly equal mix of entire and fragmented specimens. Interesting, however, although the ECA site yielded a number of beads, pendants, or other artifacts of *Spondylus* shell (see Chapter 13), there was little evidence of intermediate stages of manufacture of *Spondylus* shell artifacts. This contrasts with the extensive evidence for the production of *Conus* and *Trochus* artifacts at ECA, and might suggest that the *Spondylus* shell artifacts at ECA were imported from other Lapita communities.

Mollusk Exploitation at Lapita Sites ECA, ECB, and EHB

Mollusk shells were a dominant component of the faunal assemblages at all three Lapita sites on Eloaua and Emananus islands, the greatest density of shells being present at Area B in the ECA site with some 27.9 kg/m^3 (Table 8.2). However, the EHB site, with 23.3 kg/m^3 of mollusk shells, and the ECB site, with 19.7 kg/m^3, also evidence extensive exploitation of mollusks during the Lapita period in Mussau. Site ECA displays the greatest number of taxonomic categories (NTAXA = 48+), with sites ECB and EHB having nearly similar numbers of taxonomic categories present.

Within the ECA site, there are considerable differences between the mollusk assemblages at Areas B and C. Whereas at Area B the density of mollusks averages 27.9 kg/m^3, at Area C the density is only 6.3 kg/m^3. Similarly the number of taxonomic categories present at Area C is a mere 14. Whether the decline in the density of mollusk shells as well as the number of taxa represented, from Areas B to C, reflects an overall temporal decline in mollusk exploitation at ECA is not entirely clear. It may be that the high mollusk density at Area B reflects the special function of the stilt house there, associated both with shell artifact manufacture and probably also with periodic feasting.

Figure 8.5 shows the rank-ordered distribution of the 15 most common mollusk species at Areas B (data from the Area B Extension) and C in the ECA site. At Area B, *Chama* bivalves overwhelmingly dominate the assemblage, followed by the two strombids *Strombus luhuanus* and *Lambis lambis/L. chiragra*, and then the tridacnids *Tridacna gigas/T. derasa* and *Hippopus hippopus*. At Area C the large oyster-like bivalve *Hyotissa hyotis* dominates, followed by the tridacnids *Hippopus hippopus* and *Tridacna crocea*, and then by the strombids *S. luhuanus* and *L. lambis/L. chiragra*. Whether these differences reflect changing dietary preferences, changes in the frequency of different species in the marine environment, or changes in the local marine ecology, are questions that are further considered in Chapter 9.

The rank-order frequency of mollusk taxa at the ECB and EHB Lapita sites exhibit further variation in patterns of mollusk exploitation (Figure 8.6). At ECB, *Lambis lambis/L. chiragra* is the dominant taxon, while the bivalve *Anadara antiquata* (the eleventh-ranked taxon at ECA Area B) occupies the second rank position. At EHB, *Chama*, *Lambis lambis/L. chiragra*, and *Strombus luhuanus* are the most highly ranked, similar to the case at ECA Area B, but the fourth-ranked taxon is *Anadara antiquata*, a relatively minor taxon at ECA Area B. Again, the reasons for these differences—whether ecological or cultural (or some combination of the two)—are not entirely evident.

Table 8.2. Concentration indices (in g/m^3) for mollusk shells in Lapita sites ECA (Area B), ECB, and EHB. Values have been rounded to the nearest gram

Taxonomic Category	ECA, Area B	ECB	EHB
Gastropods			
Bullidae	4		
Cassis cornuta			25
Cerithiidae	9	14	39
Cerithium nodulosum	22	49	34
Conidae spp.	144	767	560
Conus leopardus/C. litteratus	422		
Cypraeidae	132	624	811
Cypraea tigris	96		
Cypraecassis rufa	31		
Lambis arthritica			798
Lambis lambis/L. chiragra	1,858	4,331	3,656
Mitridae	0.6		1.5
Muricidae	0.25		
Neritidae	1	2	5
Polinices tumidus	11	26	38
Strombus (Gibberulus) gibberulus	18		
Strombus (Lentigo) lentiginosus	11		
Strombus (Conomurex) luhuanus	1,998	1,507	2,787
Tectus pyramis	243	19	47
Terebra spp.	6	189	237
Tonna perdix		6	
Trochidae	29	280	237
Trochus (Rochia) niloticus	1,104	2,735	1,379
Turbo marmoratus	37	20	291
Turbo argyrostomus	32	55	104
Turbo spp. operculae	61	24	84
Volutidae		19	6
Bivalves			
Acrosterigma spp.	138		
Anadara antiquata	648	2,777	2,203
Asaphis violascens	51	4	4
Cardium sp.	136	260	314
Chama sp.	5,878	2,487	4,283
Codakia sp.		35	25
Fragum fragum	26	5	9
Gafrarium sp.	66	89	88
Hippopus hippopus	2,215	714	1,133
Hyotissa hyotis	2,647	634	701
Lucinidae	35	158	126
Ostreidae sp.	347	96	322
Pectinidae	1		
Periglypta albocancellata	40		
Pinctada margaritifera	19	0.1	1
Pteriidae spp.	43	66	117
Quidnipagus palatam	636	47	70
Spondylus spp.	1,273	306	593
Tapes literata	59	41	29
Tellina sp.	147	45	207
Tridacna gigas	1,101		
Tridacna gigas/T. derasa	701	508	1002
Tridacna crocea	1,314	516	
Tridacna squamosa	300	44	735
Tridacna spp.	281		
Veneridae	162		
Miscellaneous mollusks	2,656	188	284
Totals	27,896	19,689	23,345
NTAXA*	48+	37+	38+

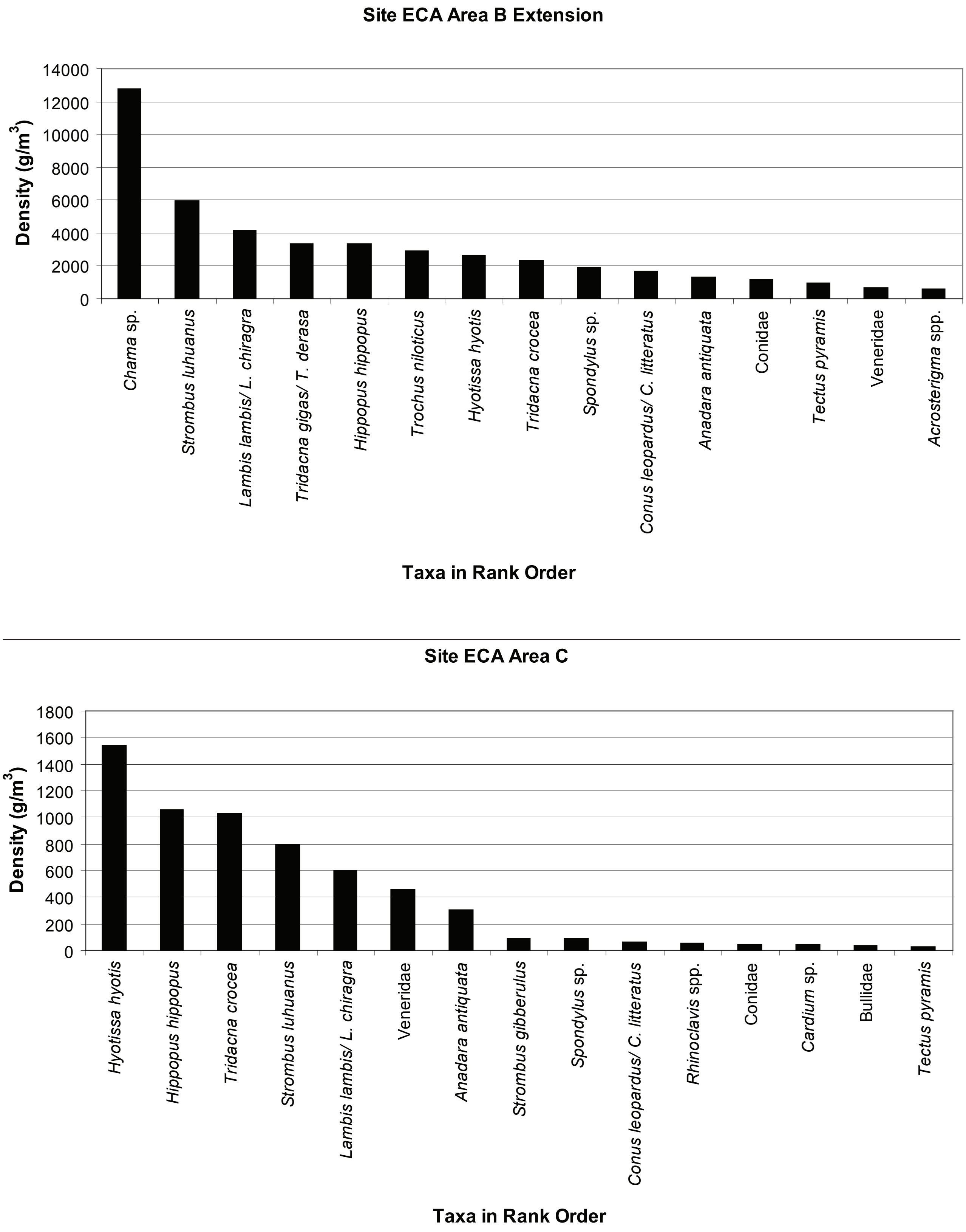


Figure 8.5. Rank-order plots of mollusk density in site ECA: top, Area B Extension; bottom, Area C.

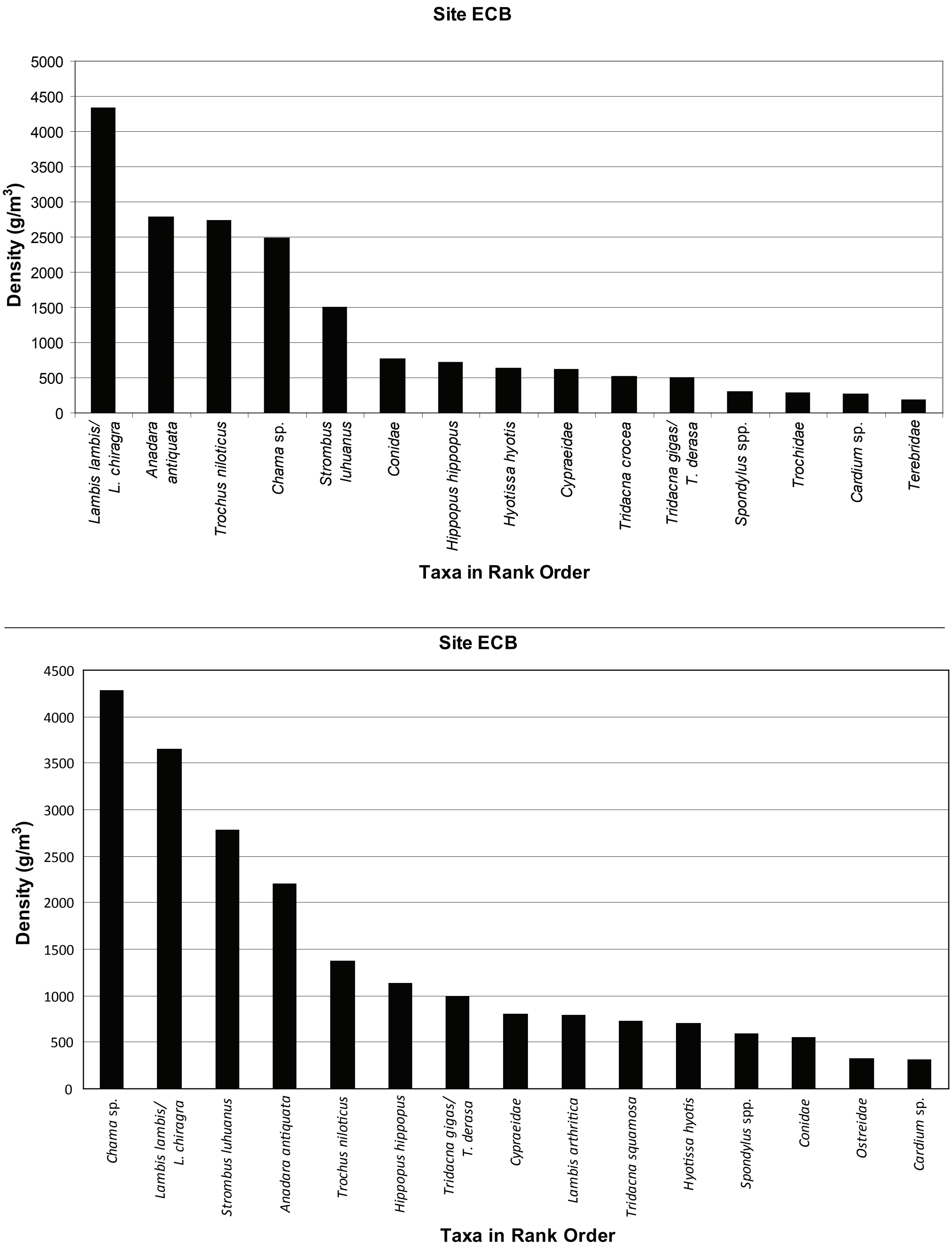


Figure 8.6. Rank-order plots of mollusk density at Lapita sites ECB (top) and EHB (bottom).

At ECA Area B, temporal changes in the frequency of mollusk taxa exploitation are indicated by the stratigraphic analysis of mollusks in two units of the Area B Extension, reported in Table 8.3 and in Figure 8.7. The most evident trend is the high peak in *Chama* sp. occurring in Zone C2; this may have been the result of one or more feasting events. The other significant trends are the rise in the frequency of *Strombus luhuanus* in Zones B2 and B1, and the overall increase in mollusk density in Zone B1.

Table 8.4 presents data on the stratigraphic distribution of mollusk taxa in Area C of the ECA site. Two overall trends are evident: a sharp decline in the density of mollusk shells from Zone D to Zone B, accompanied by a reduction in the number of taxa present (NTAXA = 14+ in Zone D compared to 9+ in Zone B). At face value, this would seem to indicate an overall decline in mollusk exploitation in the late Lapita period at Talepakemalai, although the causes of such a decline remain uncertain.

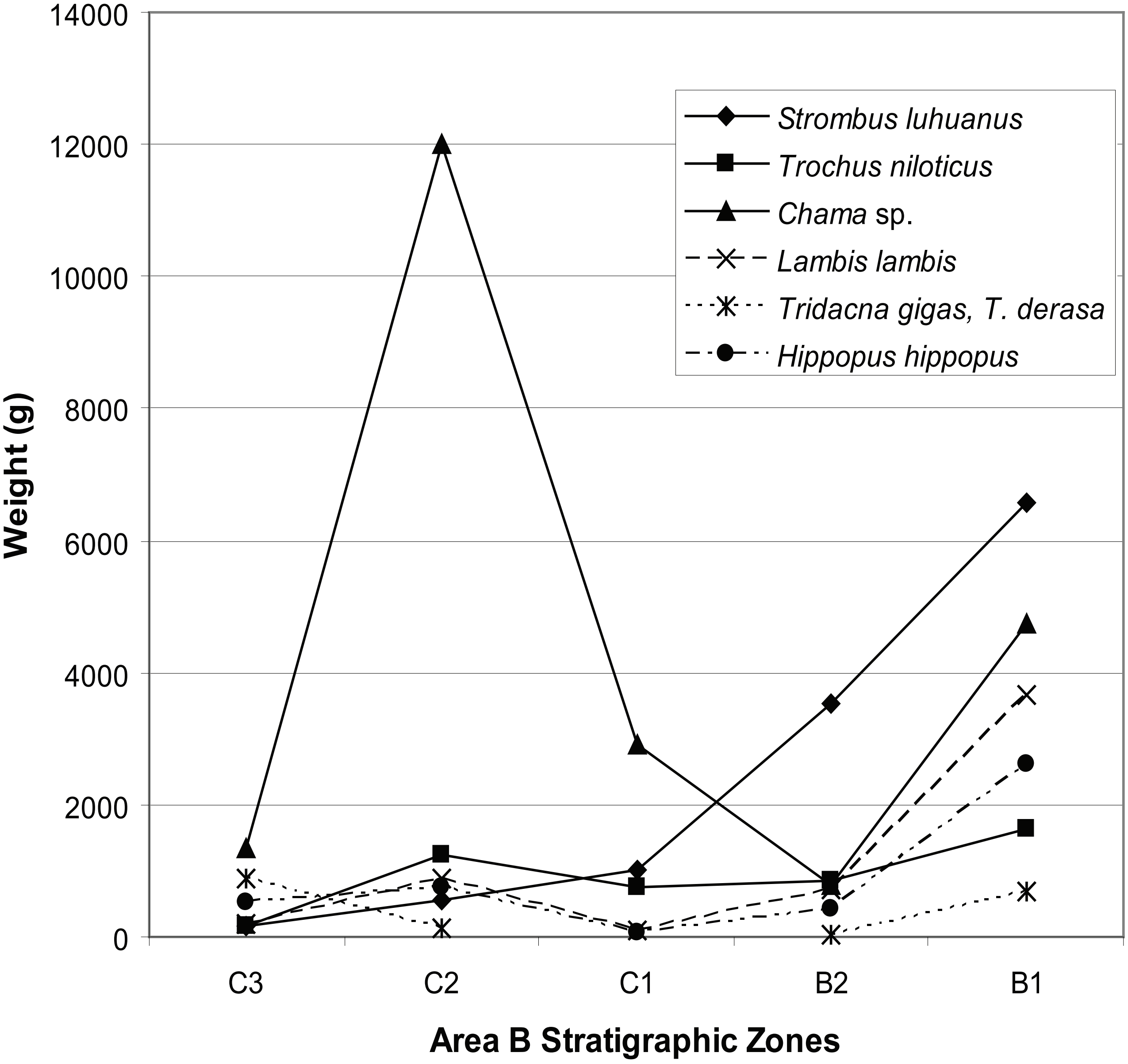


Figure 8.7. Temporal trends in mollusk frequency (by weight) in site ECA, Area B Extension.

Table 8.3. Stratigraphic distribution of mollusks in two of four units in the Area B extension of site ECA, weight in grams

Taxonomic Category	Stratigraphic Zones						Totals
	C3	C2	C1	B2	B1	A1	
Gastropods							
Bullidae	15	15					30
Cerithium nodulosum			10	30	80	55	175
Conidae		55	50	80	620	1,550	2,355
Conus leopardus/C. litteratus	20	250	105	650	1,840	490	3,355
Cypraeidae	5						5
Cypraea tigris		245	110		260	155	770
Lambis lambis/L. chiragra	180	870	100	720	3,655	2,720	8,245
Neritidae	10						10
Strombus (Gibberulus) gibberulus		20	75	10	35	10	150
Strombus (Conomurex) luhuanus	160	545	1,030	3,540	6,575		11,850
Tectus pyramis		100	210	1,280	230	30	1,850
Trochus niloticus	175	1,235	760	855	1,635	1,150	5,810
Turbo marmoratus				70	70		140
Turbo argyrostomus	10				175	35	220
Bivalves							
Anadara antiquata	190	885	310	145	470	550	2,550
Asaphis violascens		95	10	50	85	10	250
Cardium sp.		20					20
Chama sp.	1,330	12,000	2,900	800	4,735	3,720	25,485
Fragum sp.	40	30	20	20	20		130
Gafrarium spp.	25	50	5	20	50	40	190
Hippopus hippopus	525	760	50	415	2,605	2,375	6,730
Hyotissa hyotis	920	3,120		260	630	245	5,175
Laevicardium sp.	170	230	365		285	55	1,105
Periglypta albocancellata	30	125			45	120	320
Pinctada margaritifera		5	40			60	105
Spondylus spp.	360	1,825	780	40	500	230	3,735
Tapes literata	135	55	5		10	15	220
Tridacna gigas/T. derasa	890	145		30	700	4,980	6,745
Tridacna crocea	270	230		1,445	1,685	960	4,590
Tridacna squamosa					230		230
Tridacna spp.					375		375
Veneridae	50	410	220	175	200	225	1,280
Miscellaneous Mollusk	5	115			6,805	12,010	18,935
Totals	5,515	23,435	7,155	10,635	34,605	31,790	113,135

Table 8.4. Stratigraphic distribution of mollusks in a representative unit of Area C of site ECA, weight in grams

	Stratigraphic Zones			
Taxonomic Category	**Zone D**	**Zone C**	**Zone B**	**Totals**
Gastropods				
Bullidae	10	10	5	25
Conidae		10	20	30
Conus leopardus/C. litteratus			40	40
Lambis lambis/L. chiragra	190	200		390
Rhinoclavis spp.	30		5	35
Strombus gibberulus	10	35	15	60
Strombus luhuanus	280	130	110	520
Tectus pyramis	10	10		20
Turbo argyrostomus		10	5	15
Turbo spp. operculae	2			2
Bivalves				
Acrosterigma spp.		10		10
Anadara antiquata	170	30		200
Cardium sp.			30	30
Fragum fragum	15			15
Gafrarium spp.	10			10
Hippopus hippopus	210	480		690
Hyotissa hyotis	1,000			1,000
Spondylus spp.		60		60
Tapes literata		5		5
Tridacna crocea	670			670
Veneridae	205	70	20	295
Miscellaneous bivalve	60	90		150
Totals	2,872	1,150	250	4,272

Mollusk Exploitation at Post-Lapita Sites (EHK, EKE, EKU, EKS)

Mollusk assemblages were analyzed from four post-Lapita sites in Mussau: EHK, EKE, EKS, and EKU (Table 8.5). With the exception of site EKU, the densities of mollusk shells in these sites is very high, with the density at EKE reaching an astounding 85.9 kg/m^3, more than three times higher than the density at Area B of ECA. Thus in spite of the apparent trend toward declining mollusk exploitation at Area C of ECA, occupied toward the end of the Lapita phase, it is evident that mollusk gathering in Mussau remained an important component of the subsistence economy in the post-Lapita period.

Table 8.5. Concentration indices (in g/m^3) for mollusk shells in post-Lapita sites EHK, EKE, EKS, and EKU. Values have been rounded to the nearest gram

Taxonomic Category	Site EHK	Site EKE	Site EKS	Site EKU
Gastropods				
Bullidae		28		
Cerithiidae	90	30		39
Cerithium nodulosum		850		96
Conidae spp.	510	214		61
Conus leopardus/C. litteratus	610	2,153		
Cypraeidae			700	
Cypraea tigris	1,310	611		
Cypraecassis rufa		283		
Lambis lambis/L. chiragra	4,690	9,861	8,855	2,885
Mitridae			110	
Muricidae		114	145	
Nautilus sp.			60	
Neritidae			10	
Polinices tumidus		230	98	
Strombus (Gibberulus) gibberulus		428		
Strombus (Lentigo) lentiginosus	1,030	2,294		
Strombus (Conomurex) luhuanus	3,685	12,750	11,200	811
Tectus pyramis	380	2,333		
Terebra spp.	245	897	520	
Thaididae			280	
Trochidae			2,130	307
Trochus niloticus	220	672	1,765	32
Turbo marmoratus		153		
Turbo argyrostomus	30	5	780	
Turbo spp. operculae	20		25	
Volutidae		64		
Bivalves				
Acrosterigma spp.	930	2,433	100	
Anadara antiquata	8,195	9,200	6,270	2,664
Asaphis violascens	85	28	45	14
Cardium sp.		11	310	121

Table 8.5. Concentration indices (in g/m³) for mollusk shells in post-Lapita sites EHK, EKE, EKS, and EKU. Values have been rounded to the nearest gram *(continued)*

Taxonomic Category	Site EHK	Site EKE	Site EKS	Site EKU
Chama sp.	17,470	25,777	4,905	4,282
Codakia sp.			300	
Fragum fragum	155	167		
Gafrarium spp.	75	92	15	14
Hippopus hippopus	1,050	1,364	1,595	718
Hyotissa hyotis	190	2,739	50	86
Lucinidae				604
Pectinidae	10	111		7
Periglypta albocancellata	210	2,183		
Pinctada margaritifera		117	160	
Pteriidae				36
Quidnipagus palatam		211	145	
Spondylus spp.	160	2,172	955	32
Tapes literata	15	55	10	29
Tellina sp.			20	
Tridacna gigas/T. derasa	100	900	750	525
Tridacna crocea	1,200	4,105	2,610	1,593
Tridacna squamosa				29
Veneridae	17	322		
Miscellaneous mollusks	400			
Totals	43,082	85,957	44,918	14,985

The EHK, EKE, and EKS sites all have similar rank-order frequency distribution patterns for mollusks, as shown in Figures 8.8 and 8.9. Although the specific rank order varies, the four most frequent taxa in all of these sites are *Chama* sp., *Lambis lambis/L. chiragra*, *Strombus luhuanus*, and *Anadara antiquata*. At EKU, *Tridacna crocea* displaces *Strombus luhuanus*, leaving the latter in fifth rank. All of these are edible mollusks with substantial meat content.

Other Invertebrates: Sea Urchins and Crustacea

Surprisingly, sea urchin (Echinodermata) remains were not common in the Mussau sites. A total of 44 NISP were recorded during the entire site ECA excavation. Most if not all of these were spines of the large "slate pencil" sea urchins *Heterocentrotus mamillatus* or *H. trigonarius*.

Remains of crustacea including fragments of carapace or claws were also infrequent, although 154 NISP of crustacean remains were recorded at ECA, and 13 NISP at EHB. The fragmentary nature of this material and lack of an extensive reference collection precluded further identification. At the EKQ rockshelter, a total of 702 crustacean remains were recorded. At least some of the EKQ crustacean remains are of the giant coconut robber crab (*Birgus latro*), as illustrated for example by the pincer fragments shown in Figure 8.10.

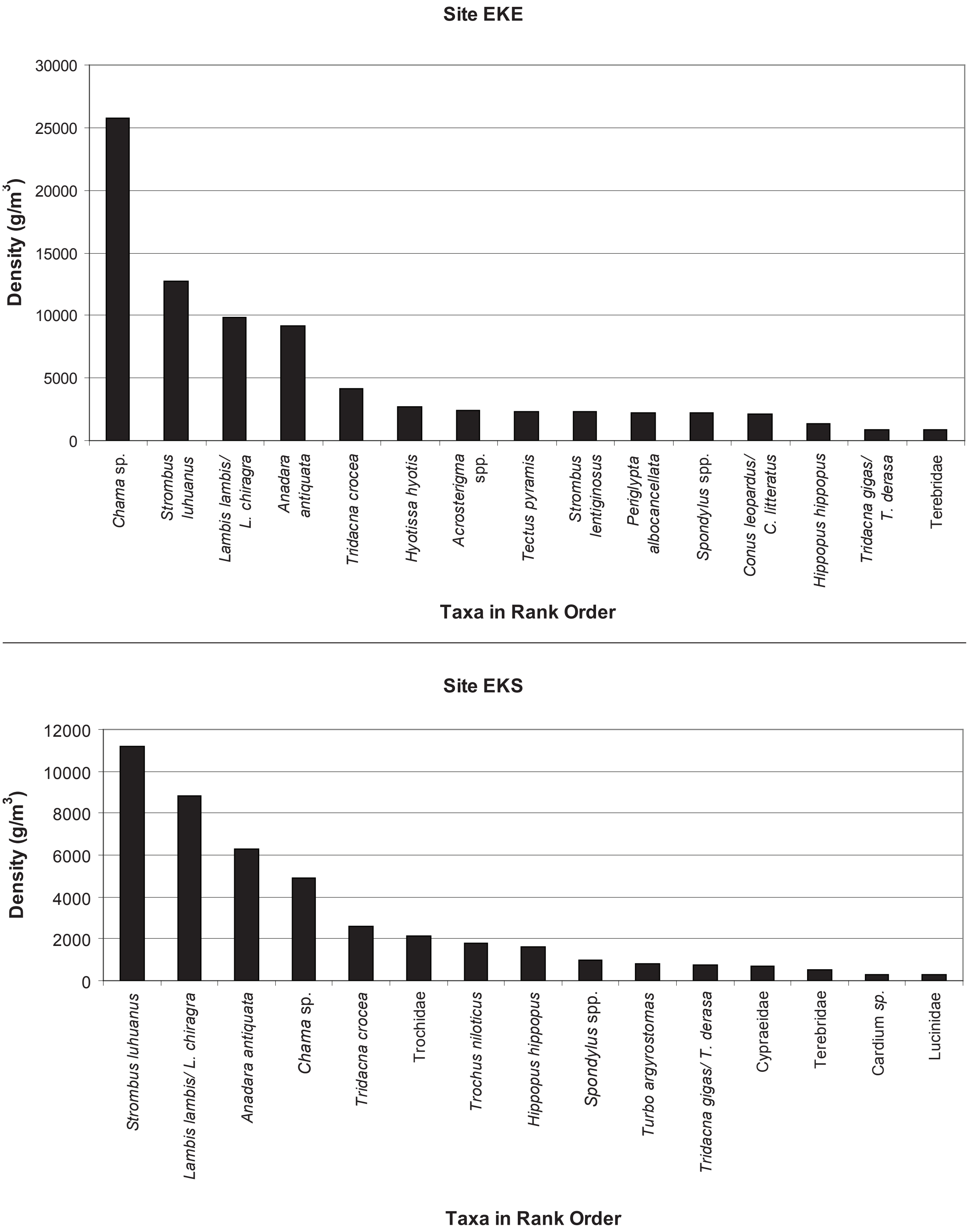
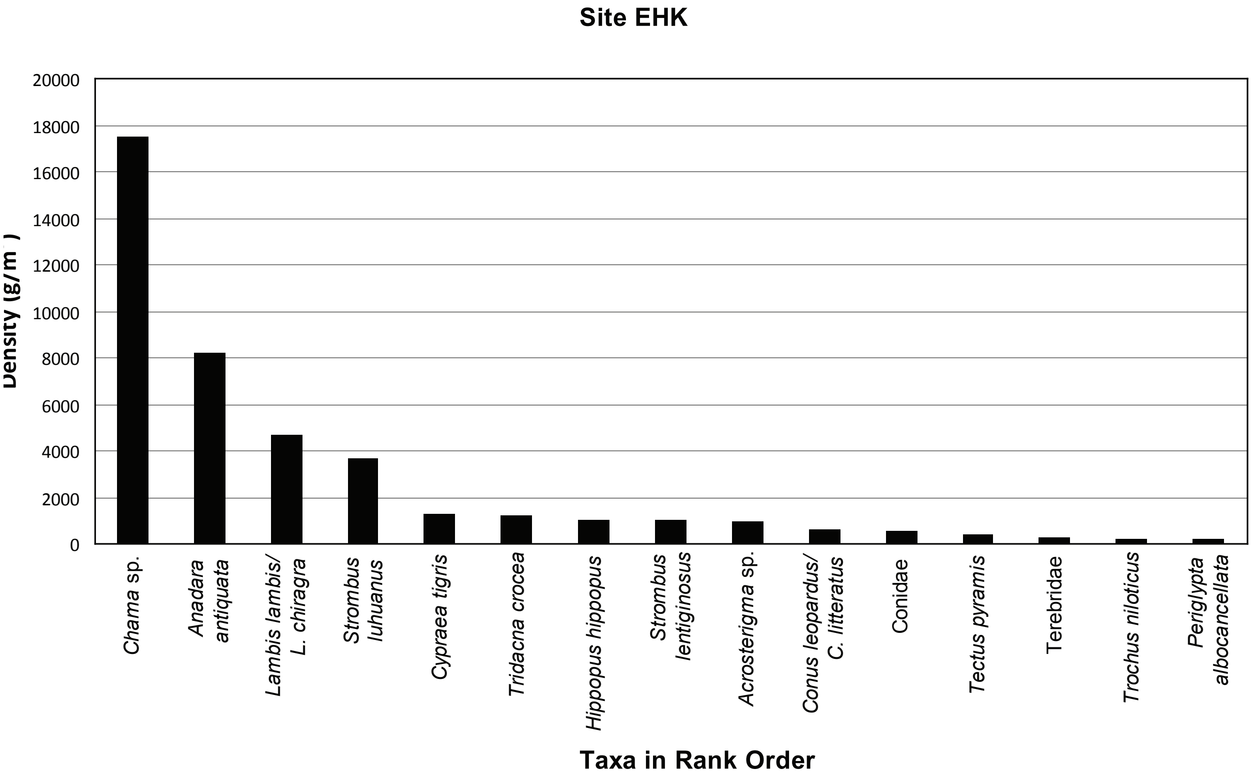


Figure 8.8. Rank-order plots of mollusk density at post-Lapita sites EKE (top) and EKS (bottom).



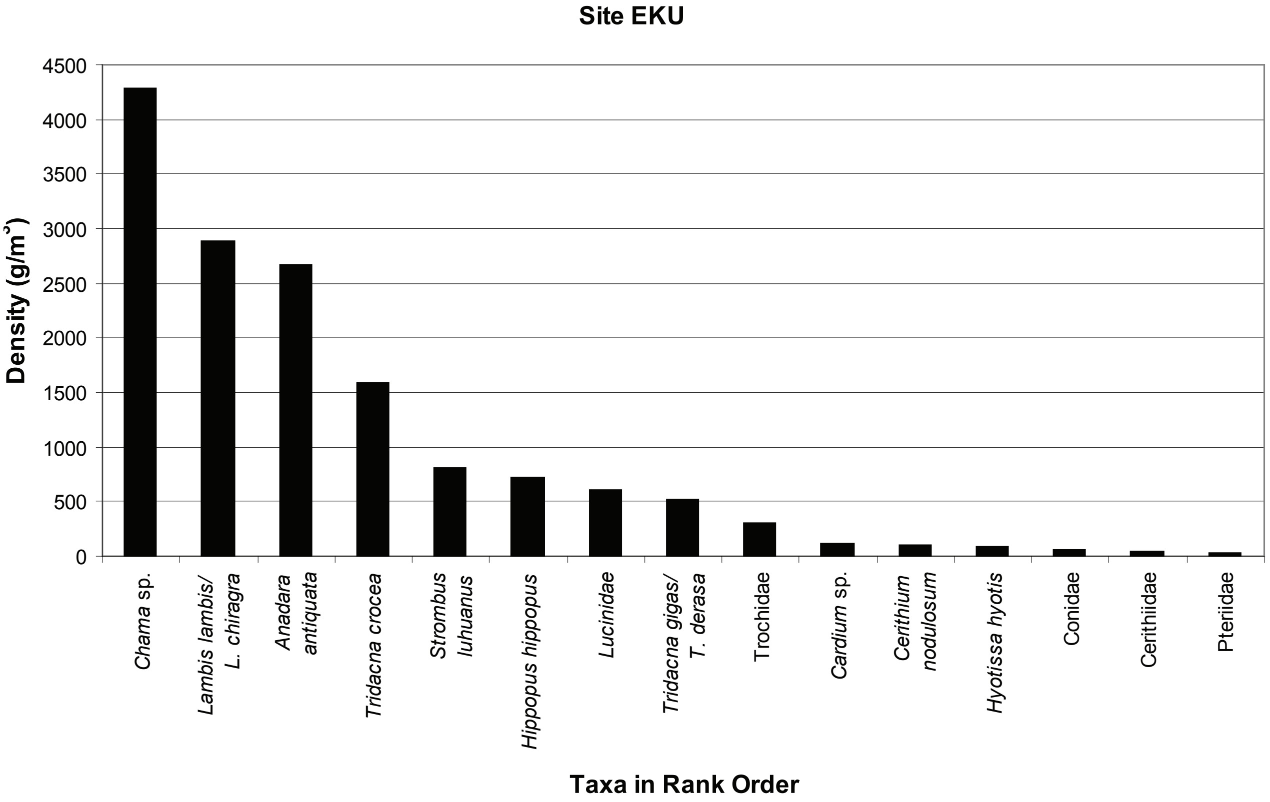


Figure 8.9. Rank-order plots of mollusk density at post-Lapita sites EHK (top) and EKU (bottom).

Figure 8.10. Pincer fragments of the giant coconut robber crab (*Birgus latro*) from TP-1, level 13, at site EKQ.

Conclusions

Analysis of the mollusk component of the archaeofauna at Lapita sites ECA, ECB, and EHB demonstrates that the exploitation of mollusks was a significant aspect of the Lapita subsistence economy. A wide variety of both gastropods and bivalves, from a diverse range of habitats, were gathered in often large quantities and brought back to these sites, where the meat was extracted and consumed, and the shells in some cases further processed for artifact manufacture. The most frequent taxa are all mollusks with significant meat value (such as the gastropods *Lambis lambis/L. chiragra* and *Strombus luhuanus*, and the bivalves *Andara antiquata*, *Chama* sp., and *Hyotissa hyotis*). Taxa whose shells were used to manufacture artifacts include *Trochus niloticus*, the large cones *Conus litteratus/C. leopardus*, the cowrie *Cypraea tigris*, and the giant clams *Tridacna gigas/T. derasa* and *Tridacna crocea*. The exploitation of mollusks continued in the post-Lapita period in Mussau, with shellfish density levels surpassing those of the Lapita-period sites.

CHAPTER 9

Human Impacts on Prehistoric Mollusk Populations of Mussau Coral Reef Habitats

Carla P. Catterall and I. R. Poiner

Introduction

Human Impacts on Mollusk Populations

Shellfish make up the bulk of material in many coastal archaeological deposits, and these are increasingly being studied to reveal new information about the ecological relationships of prehistoric humans, the nature of their environments, and the impacts of their activities on shallow-water marine ecosystems of tropical regions (Harris and Weisler 2017; Swadling 1976). Such inferences are possible through quantitative analyses based on counts that represent numbers of individual mollusks, identified to species level, and preferably complemented by shell measurements for the most abundant species. The effects of prehistoric humans on mollusk populations may have occurred either directly, from gathering of targeted species (e.g., Poiner and Catterall 1988; Spenneman 1987; Swadling 1976, 1977a), or indirectly through modification of the environment (e.g., Christensen and Kirch 1986).

With respect to the former, different mollusk species should vary in their resilience to traditional collecting, with some species being capable of persisting adequately in the face of intensive and regular collecting, and other species being vulnerable to population declines, shifts in age distribution, or even collapse (Catterall and Poiner 1987; Harris and Weisler 2017; Poiner and Catterall 1988). Furthermore, the relative resilience of a given species to traditional gathering should be predictable on the basis of knowledge of the following relatively simple set of ecological and life-history attributes (Figure 9.1; Catterall and Poiner 1987).

First, potential refugia from human predation occur when a species' ecological characteristics enable a substantial proportion of individuals to escape from human predators. This could occur through concealment in specific microhabitats (such as when the mollusks bury in soft substrates or retreat into crevices), or through their occupation of unreachable locations such as subtidal areas, below the limit of spring low tides (Catterall and Poiner 1987; Dumas et al. 2013). Second, a species' typical body size at reproductive maturity can provide a different form of refuge, when collectors ignore mollusks below some size

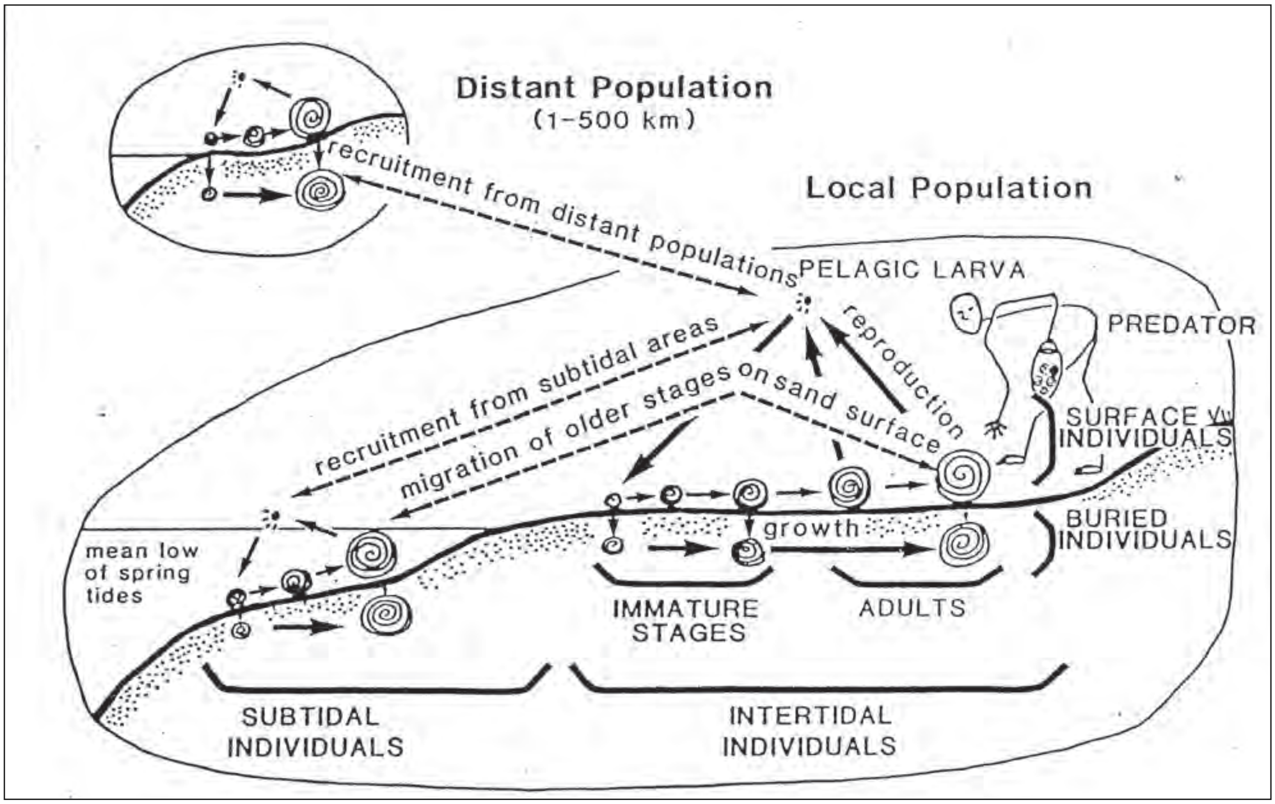


Figure 9.1. Diagrammatic model of the factors affecting mollusk populations; see text for discussion. (Diagram by C. Catterall.)

threshold (often about 30 mm, as reviewed in Catterall and Poiner 1987). In a species that reaches maturity sufficiently below this size a substantial proportion of breeding individuals would escape collection, while a species that is large-bodied at maturity may suffer depletion of its breeding population. Third, a life history that includes mobile stages enables dispersal and recolonization of depleted areas. This would occur either if adults or adult-like immatures have high mobility on the substrate or if the life cycle includes a minute free-swimming pelagic larval stage that is transported by ocean currents (as is typical for many mollusks).

Different mollusk species vary considerably in these characteristics, as illustrated in Table 9.1 for some common large mollusks of Indo-Pacific coral reefs. A species would be most vulnerable to the effects of human gathering if it possessed the following combination of "risky" attributes: never buries; rarely found deeper than 1 m at low tide; reaches sexual maturity at a large size; is immobile and firmly fixed to the substrate surface; and hatches a shelled juvenile directly from the egg, with no free-swimming pelagic larva. Such a species could be rapidly removed from a particular area, and would be incapable of recolonizing from other areas once depletion had occurred.

None of the species shown in Table 9.1, or any other mollusks, possess all of these traits, which is not surprising in evolutionary terms. However, species such as the top shell *Trochus* (*Tectus*) *niloticus* and reef clam *Hippopus hippopus* are predicted to be relatively more vulnerable to adverse effects of intensive human predation, by virtue of the number of risky attributes that they possess (Table 9.1). Indeed, present-day declines in both these species, associated with heavy human exploitation, have been reported from many locations across the Pacific region (Dumas et al. 2013; Harris and Weisler 2017). In contrast, other heavily exploited species, such as the red-lipped stromb *Strombus* (*Conomurex*) *luhuanus* and ark shells *Anadara* species, are predicted to be relatively resilient to adverse effects of intensive human predation, for which there is also some supporting evidence (Faulkner 2009; Poiner and Catterall 1988).

Table 9.1. Ecological traits of mollusk species which should be important determinants of the degree of impact of gathering on their populations. The way in which species (or in some cases higher-level taxa) typically vary in these properties is illustrated with reference to species occurring in the Mussau environmental system. Predictions are modified from Catterall and Poiner (1987) and Poiner and Catterall (1988), with specific reference to the known characteristics of the Mussau area, and more recent life history information

	Gastropods			**Bivalves**		
Taxon	*Strombus luhuanus*	*Lambis lambis*	*Trochus niloticus*	*Anadara* spp.	*Hippopus hippopus*	*Tridacna* spp.
Ecological traits:						
Refugia: burying	yes	no	no*	yes	no	no
subtidal	some	some	some	some	no*	yes
size	some	no	?some	some	no	no
Benthic mobility	yes	yes	yes	little	no	no
Pelagic larva	2–3 weeks	2–3 weeks	3–5 days	2–3 weeks	1–2 weeks	1–2 weeks
Predicted resilience to gathering	very high	moderate	moderate	high	low	low

* Refugia in crevices may be available for *T. niloticus*; *H. hippopus* may sometimes occur subtidally, but is confined mainly to shallow-water “reef top” habitat.

Inferences from Midden Samples

Archaeological excavations provide a quantitative temporal sequence of data on mollusk species, their relative abundance, and often their age composition. Changes in the relative abundances of different species could be due either to factors intrinsic to the human population (changes in: areas, species, or size classes targeted for collecting; collecting technology; treatment of shells; export of shells through trading); or to ecological factors involving the mollusks themselves (changes in population density in response to collecting pressures) and their environments (such as altered habitats in the catchment area of the midden), as variously discussed by J. Allen (2017), Faulkner (2009), Giovas and others (2010), Seeto and others (2012), and Swadling (2017). The effects of exploitation on the shellfish population densities cannot be disentangled from the effects of the other factors without independent information on these factors, although some inferences may be possible. Information on the distribution of mollusk species across habitats in the marine environment, derived from ecological studies, is an important aid to such inferences.

With sufficient knowledge or standardization of various factors, it should in theory be possible to either: (1) use the record of changes in the mollusks to test predictions (e.g., Table 9.1) regarding different susceptibility of different species; or (2) assuming the predictions are correct, to use the record of changes in the mollusks to infer the extent to which these are a consequence of changes in the level of exploitation.

Analyses of the age composition of samples for particular shellfish species may provide further information which can be more closely related to the effects of exploitation. A shift in the age distribution toward a preponderance of younger individuals is expected in heavily exploited populations, and has been observed in both analysis of shell midden samples and studies of present-day shell gatherers (reviewed in Harris and Weisler 2017; see also Faulkner 2009; Hockey and Bosman 1986; Poiner and Catterall 1988; Swadling 2017).

Shell size (e.g., from length measurement) has frequently been used as a proxy for age in the analysis of chronological sequences of prehistoric midden samples (Harris and Weisler 2017). However, attempts to derive unambiguous inferences about rates or impacts of human exploitation from shell size data are fraught with difficulties, because the size distributions of midden shellfish samples are influenced by the same complex set of additional factors that induce changes in species composition (see above). Moreover, while an increase in the proportion of smaller shells may indicate a shift in age distribution toward younger mollusks (as would be expected in a heavily exploited population), lower densities in the marine environment in heavily exploited populations may also result in larger age-specific shell sizes due to reduced intraspecific competition (Faulkner 2009; Giovas et al. 2010). In the latter case, a preponderance of smaller shells would signal light, rather than heavy, exploitation. For a small proportion of species, these problems can be avoided by using age indicators that are unrelated to shell size; for example, through the measurement of shell lip thickness in *Strombus* species (Poiner and Catterall 1988; Swadling 1976, 2017)

Accordingly, interpretations of both species composition and within-species size and age frequency distributions from midden data need to be carefully and cautiously made, using whatever relevant background information is available. If similar interpretations with respect to human exploitation patterns arise from both types of data, then stronger inferences may be possible.

This Study

The present study has the following aims: (1) To provide a description of the shallow-water marine molluskan species assemblage of the Mussau system, including those from archaeological (Lapita and post-Lapita) sites and present-day (late twentieth century) marine coral reef habitats. (2) To assess the degree of correspondence between the midden assemblages and those in the present-day marine environment. (3) For the midden samples, to describe quantitatively the temporal changes in both species' relative abundances and relative within-species representation of different age classes (where feasible). (4) To identify any changes in either relative species' abundances or age-frequency distributions that indicate responses of the mollusk populations to either altered surrounding environments or altered human exploitation.

The information used for these analyses consisted of the molluskan material extracted from archaeological excavation units on Eloaua and Boliu islands, both of which are surrounded by extensive coral reef systems. Data were also gathered from the present-day marine environment on: the distribution of mollusk species across habitats (the latter are described in Chapter 2); the relative abundances of mollusk species within habitats; and the age distributions of several mollusk species within habitats. Most present-day Mussau islanders no longer gather shellfish for eating, in accordance with the customs of the Seventh-Day Adventist religion, and hence the present-day marine mollusk populations are largely unexploited stocks. Shell gathering at the time of the present study involved mainly *Trochus* species (exported for shell buttons) and certain *Cypraea* (cowrie) species made into artifacts and exported for sale to tourists in Kavieng or elsewhere.

Methods

Midden Data

Most midden analyses in this chapter are based on molluskan material excavated in 1988 from sites on Eloaua Island. These were: the Lapita sites Talepakemalai or ECA (material from 15 grid units along the W250 transect); two grid units from the Area B Extension (and one unit on each of the W200 and W201 transects); and the post-Lapita site EHK (material from grid Unit W300N300). A small amount of material was also used from grid Unit W200N175 of the EKE site on Boliu Island (site EKE has both Lapita and post-Lapita deposits; see Chapter 4). Table 9.2 lists the precise grid units involved in this analysis.

During the process of excavation, any mollusk material that consisted of artifacts or possible worked shell was removed at an early stage; however, this was a very small proportion of the total. All material was screened through a 5 mm sieve, and sieved shells from a particular excavation unit were then removed and bagged together prior to further sorting. During this process, small (20 mm or less) shells were frequently discarded, as were shells of several bivalve species believed to be resident in the fine silty shallow-water marine zone within which the midden material was originally deposited. Hence these species were not reliably sampled.

All shells were then sorted at the base camp within a few days of collecting, to a predetermined taxonomic level. In some cases the taxon recognized was a putative species; in others a genus, set of similar genera, family, or set of similar families. This was necessary because of the extremely high diversity and poor status of taxonomic knowledge of the molluskan fauna of the tropical Indo-Pacific; the prohibitively long time that would be involved

Table 9.2. Grouping of excavation units to form shell sampling units for the analysis of temporal changes in molluskan species. Within the ECA site, excavation units with the same number (e.g., E1) were pooled to create shell sampling units, within two time periods: Early Lapita (E) and Late Lapita (L). For the EHK and EKE sites, P indicates post-Lapita excavation units that were pooled together, and E indicates Early Lapita. Asterisks show excavation units for which molluskan samples were available, but which were not used in the analyses, either because they were transitional between time periods, or came from a disturbed surface layer

Excavation Levels	ECA W250 Transect Units															ECA Area B Ext.		EHK	EKE
	W250N70	W250N80	W250N90	W250N100	W250N110	W250N120	W250N130	W250N140	W250N150	W250N160	W250N170	W250N181	W250N187	W250N190	W250N200	W200N145	W201N145	W300N300	W200N175
1	*	*	*	*	*	*	*	*			*	*		L6		L8	L9	P	P
2	E1	E1	E1	*	*	L1		L1	L1	L2	L3	L4	L5	L6	L7	L8	L9	P	P
3	E1	E1	E1	*	*	L1	*	L1			L3	L4	L5		L7	L8	L9	P	P
4				E2	*	*	*	*	L1	L2	L3		L5	L6		*	*	P	P
5				E2	E3	*	*	*	*	L2	L3	L4	L5	L6	L7	E10	*		P
6				E2	E3	E4	E5	E6	*	*	L3	L4		L6	L7	E10	E11	P	P
7				E2	E3	E4	E5	E6	E7	*	L3	L4		*		E10	E11		
8				E2	E3	E4	E5	E6	E7	E8	*			L6	L7	E10	E11		E
9	*			E2	E3	E4	E5	E6	E7	E8	*			L6		E10	E11		E
10					*		E5			E8	E9			L6					E
11					*		E5												E
12					*		E5												E
13					*		E5												
14					*														
15					*														

in attempts to sort all species; the variable expertise in the identification of mollusks among the people sorting the samples; and the absence of a reference collection at the field camp. Reliable identification was possible for certain species (for example *Hippopus hippopus*, *Trochus* (*Tectus*) *niloticus*, *Strombus* (*Conomurex*) *luhuanus*, *Cypraea tigris*), and a number of genera (including *Anadara*, *Acrosterigma*, *Chama*, *Tridacna*, *Spondylus*, *Hyotissa*, *Gafrarium*, *Lambis*, *Conus*, *Cypraea*). Many taxa were too rare for reliable identification to be important. The most difficult common group was the small bivalves, which belong to a variety of families.

Once the mollusk material from a particular excavation unit had been sorted, a count was made of the minimum total number of recognizable individual shells (MNI) within each taxon. For gastropod mollusks, the minimum required was a shell spire; for bivalves it was the hinge of a single shell valve. In later analyses of relative frequency, the number of counted valves was divided by two, to give a minimum number of individual bivalves.

Size measurements were made of either all, or a large random sample, of individual shells within each taxon for each excavation unit. Figure 9.2 shows the shell dimension measured for each taxon. For most taxa linear shell dimensions increase with the age of individuals, although the rate of increase slows in older individuals. A few taxa (including *Strombus*, *Lambis*, *Cypraea*, *Cerithium*) have determinate

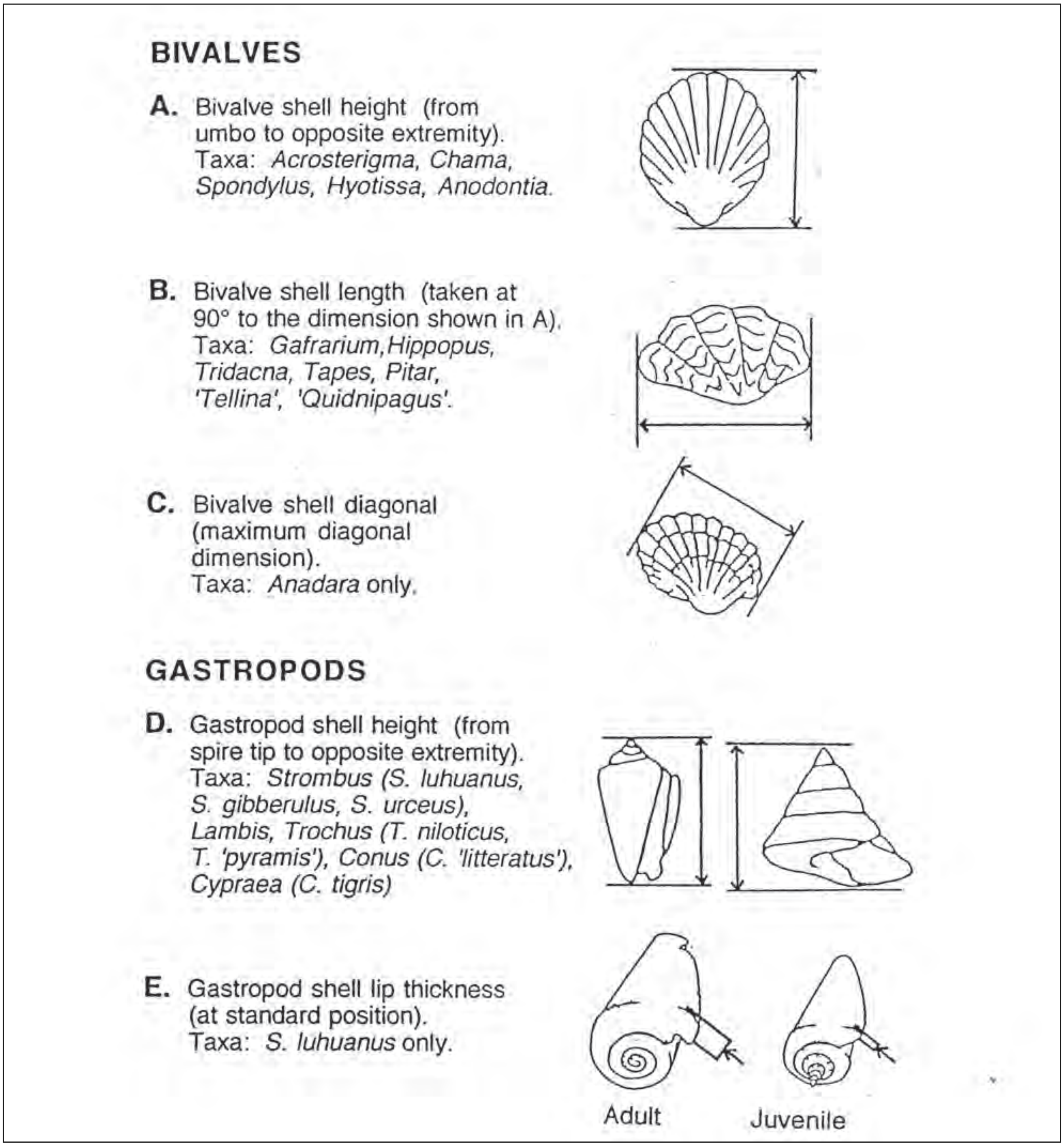


Figure 9.2. Measurements taken on bivalve and gastropod shells for this study. (Diagram by C. Catterall.)

growth in which the shell size ceases to increase at a certain age. In *Strombus*, the shell lip thickness was also measured to provide further discrimination of age classes, since the lip thickness continues to increase after growth in shell length has stopped. Vernier calipers were used for all except very large shells (e.g., *Tridacna*). Some sessile bivalve species (especially *Chama*, *Spondylus*, *Hyotissa*) had shells that were very heavily calcified and encrusted with other organisms. In these cases, the accuracy of shell measurements was low.

A few excavation units yielded large numbers (sometimes hundreds) of individuals within a taxon. In these cases random subsamples were obtained by spreading all shells of that taxon on the sorting sheet, dividing it into fractions, and choosing an appropriate proportion for measurement. In such cases, the number measured was normally more than 30.

Several representative specimens from each taxon recognized were retained, and these were later formally identified by T. Whitehead of the Queensland Museum. The remainder of these extremely bulky samples was discarded in the field. The species lists, therefore, are underestimates of the total number of species actually present, because careful examination in the laboratory by taxonomic specialists invariably reveals more species.

Since the expertise in sorting and identification varied among different people involved in the collection of data, certain taxa and sets of excavation units were omitted from later analyses if the data within them were considered unreliable; details are provided later.

For assessments of temporal changes in the molluskan assemblage, excavation units were grouped into temporal categories that corresponded with different archaeological time periods. The grouping was based on the recognized stratigraphic zones in combination with radiocarbon dates (see Chapters 3 and 5). Three broad temporal divisions were recognized: Early Lapita (ca. 3350–3100 BP), Late Lapita (ca. 3100–2800 BP), and post-Lapita (ca. 1200–400 BP). Within each grid unit, levels that lay at the junction of these time periods were excluded from analyses. Table 9.2 shows the allocation of grid units and levels to time periods.

Measurement of the variability in the midden molluskan assemblage within each time period (i.e., replicate samples within each time period) are needed for tests of the statistical significance of temporal changes. Since the molluskan data were collected from a large number of excavation units at site ECA (Table 9.2), this was possible. However, for data on the proportion of various taxa within each sample to be meaningful, there also need to be sufficiently large numbers of shells per sample, and some levels yielded few shells in total. Therefore, larger "shell sampling units" (SSU) were constructed by pooling sets of adjacent levels until the pooled number of shells was 50 or more (see Table 9.2). In most cases the number of shells per SSU was 100–400. These SSU each consisted of one to eight combined levels.

For Eloaua Island this provided eleven replicate Early Lapita and nine replicate Late Lapita samples from the Talepakemalai (ECA) site, and one post-Lapita SSU from the EHK site (Table 9.2). The EKE site on Boliu Island provided two SSU: one post-Lapita and one Late Lapita.

Present-day Marine Data

To assess the molluskan assemblage of the present-day shallow-water marine environment, quantitative sampling of the mollusks was conducted within a two week period in September 1988. One or more specific locations were selected for sampling within each of the major mapped habitat types (sand flats, seagrass flats, coral flats, shallow rock platforms and reef crests, subtidal basins, lagoons, and outer reef slopes; see Chapter 2).

At each location, standardized transect counts were used to measure the relative abundances of various mollusk taxa, and also to obtain unbiased samples for the measurement of age-frequency distributions. Transect counts consisted of two types at each sampling location. First, at least six replicated short transects (1 x 5 m) were established. Within each short transect all surface and buried mollusks were collected (or recorded in situ if too large or cemented to the substrate), identified, and measured. Second, at least two replicated long transects (30 x 2 m) were also laid out, in which only surface mollusks were sampled. These were designed to sample large and sparsely distributed species such as *Tridacna*, *Hippopus*, and *Lambis*.

A limited number of systematic quadrat-based searches were made in subtidal basin areas in order to sample the bivalves *Chama*, *Hyotissa*, and *Spondylus*, which were firmly attached to coral heads in these habitats. Additionally, generalized searches were made over wider areas in coral flat and seagrass flat habitats to obtain larger samples of certain species (including *Lambis* and *Anadara*) that had been under-sampled using the transect methods in the restricted time available.

The Molluskan Species Assemblage

Midden

A total of 111 species (46 bivalve and 65 gastropod) was identified from the molluskan samples; full taxonomic details of these are provided in Table S9.1. As noted earlier, this is probably an underestimate of the total number of species present. The total number of individual shells obtained from the SSU used for analyses (see Table 9.2) was 7,301 (4,146 bivalves, equivalent to 2,073 individuals; and 3,155 gastropods). The identified species were distributed across 59 genera (26 bivalve and 33 gastropod), within 39 families (18 bivalve and 21 gastropod). The number of taxa used for practical purposes in this study was 54 (29 bivalve and 25 gastropod), and these were further reduced for the analyses (see below). An extremely high biological diversity of coral reef organisms, including mollusks, is typical of that part of the Indo-Pacific region within which the Mussau Islands lie (Catterall 1998). Comparably high diversity was reported by Swadling (2017), who identified 48 gastropod and 47 bivalve species from an excavated section of the Motupore midden in southern Papua New Guinea, from 16,037 and 12,292 shells respectively. See Table S9.1 at www.dig.ucla.edu/talepakemalai.

In spite of this diversity, a limited number of taxa accounted for a large proportion of the midden shells. Two species were much more common than any other taxa (Table S9.1): *Strombus* (*Conomurex*) *luhuanus* (family Strombidae) with 2,149 individuals and *Anadara antiquata* (family Arcidae) with 1,300 individuals. A further three genera had more than 300 individuals: *Acrosterigma* (family Cardiidae, three species), *Chama* (family Chamidae, mainly one species, *C. limbula*), and *Lambis* (family Strombidae, two identified species, with *L. lambis* by far the more common). Most taxa were represented by less than 200 individuals, even though many of these taxa included several different genera.

Taxa with intermediate numbers of individuals (Table 9.3) included the families Tridacnidae (reef clams), Spondylidae (thorny oysters), genus *Hyotissa* (cockscomb oyster), Trochidae (top shells), and certain gastropod species including the large cone shells *Conus litteratus* and *C. leopardus*, and the tiger cowrie *Cypraea tigris*, which were used in the manufacture of ornaments and artifacts.

Many taxa provided less than 20 individuals. These taxa incorporate the majority of species, especially small bivalves including some within the families Cardiidae (cockles), Lucinidae, Mactridae, Myidae, Mytilidae (mussels), Ostreidae (oysters), and Pectinidae (scallops). Gastropods in this category included taxa within the families Cypraeidae (cowries), Cerithidae (creepers), and a variety of neogastropods.

Midden shells from the bivalve families Tellinidae and Veneridae contained a variety of genera and species of poorly resolved taxonomy, in which genera and species are difficult to distinguish without specialized training. Furthermore, many of these species are typically found in shallow areas of soft sand such as that near the shoreline where the shell middens were deposited (Kirch 1987a, 1988b). Hence shells accumulating from deaths of these mollusks in situ could not be distinguished from those deposited within the midden. Limited analyses were therefore made with these taxa, although it is probable that they were gathered for food at least some of the time.

Present-Day Marine Environment

Within the present-day marine environment particular mollusk species are largely restricted to certain of the shallow-water habitat types (Table 9.3), and certain species are numerically dominant within particular habitats. *Anadara*, *Acrosterigma*, and *Gafrarium* typically occur in seagrass flats, which are characterized by these together with a relatively high density of other small bivalve species. Taxa which are typical of intertidal coral flats are the horseshoe clam *Hippopus hippopus* (family Tridacnidae) and gastropods of the family Strombidae (*Lambis*, *Strombus*). The various *Tridacna* species occur commonly in a range of habitats: coral flats, reef platforms, and subtidal basins/reef slopes. Reef platforms also support a moderate density of small bivalves, and a relatively high density and diversity of gastropods including trochids, cone shells, and other neogastropods. Large bivalves in the genera *Chama*, *Spondylus*, and *Hyotissa* occur mainly in the deeper subtidal basins and reef slope habitats.

However, quantitative details of these data must be interpreted with caution since they were collected at one season only, and many marine species show seasonal variation in both density and age distribution, as well as between-year fluctuations. Furthermore, certain habitats (especially sand flats, reef slopes, and subtidal basins) were lightly and non-randomly sampled.

Prehistoric Environment

A comparison of Tables S9.1 and 9.3 reveals that the midden molluskan fauna is broadly similar to that present in the nearby present-day marine environment. The same suites of taxa (*Anadara*, tridacnids, *Chama*, strombids)

Table 9.3. Relative abundance (%) of shell taxa in the major shallow-water habitats of the present-day marine environment, in reefs near to Eloaua Island and Boliu Island, as of early October 1988. The habitat types are as mapped and described in Chapter 2. The proportion of shallow-water area covered by each habitat type is shown in the top row. See Table 9.3 for descriptions of taxa. The numbers shown are the percentages of all mollusk individuals obtained from transect or quadrat sampling within a particular habitat, rounded to nearest whole number; zero values may include cases where one or two individuals of a taxon were found. N is the total number of mollusks sampled in each habitat. The bottom section of the table shows the sampling effort (total number of sampling units of each type) within each habitat; because the sampling was restricted in both total effort and seasonal timing, these data reflect broad trends only

		Habitats					
		Sand Flat	**Seagrass Flat**	**Coral Flat**	**Platform/ Crest**	**Slope/Basin**	**All Habitats**
Mapped area (%)		**41**	**10**	**21**	**8**	**20**	**100**
Bivalves	*Anadara*	0	14	0	0	0	2
	Acrosterigma	0	1	0	0	0	0
	Gafrarium	0	1	0	0	0	0
	Hippopus	0	0	7	1	0	2
	Tridacna	0	0	6	14	9	5
	Chama	0	0	0	0	30	3
	Spondylus	0	0	1	0	5	1
	Hyotissa	0	0	0	0	55	6
	Tapes	0	0	0	0	0	0
	Pitar	0	1	0	0	0	0
	"Quidnipagus"	0	2	0	0	0	0
	Other bivalves	0	43	0	19	1	9
Gastropods	*S. luhuanus*	0	0	66	5	0	22
	Lambis	0	0	8	0	0	3
	T. niloticus	0	0	0	0	0	0
	C. "litteratus"	2	2	2	0	0	1
	C. tigris	0	2	0	0	0	0
	S. gibberulus	91	22	1	2	0	28
	S. urceus	0	0	0	3	0	0
	T. "pyramis"	0	0	0	2	0	0
	Neogastropods	5	7	7	26	0	9
	Other gastropods	2	2	4	27	0	6
Total mollusks (N)		442	222	504	262	186	1637
Sampling effort							
	Short transects	6*	20	23	15	0	64
	Long transects	0	4	19	8	0	31
	Systematic quadrat search	0	0	0	0	4	4
	Other searches**	1	3	2	0	0	6

* All located within localized *S. gibberulus* colony.

** Not included in the above counts.

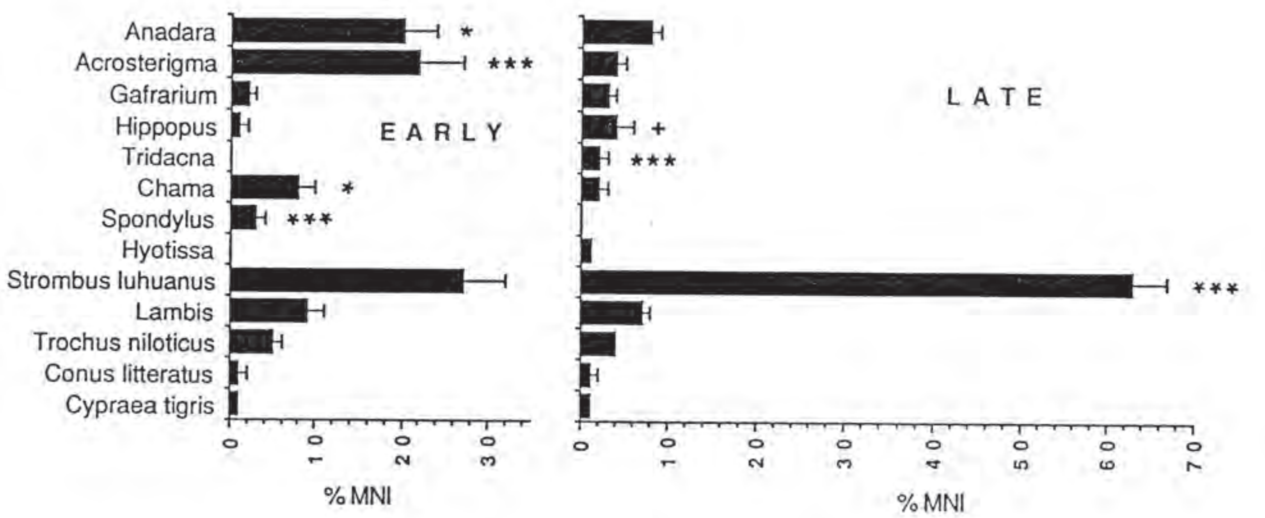


Figure 9.3. Temporal change in the relative frequencies of mollusks within selected major taxa between the Early and Late Lapita time periods at the ECA site. (Diagram by C. Catterall.)

tend to dominate both. These are all taxa typical of the shallower parts of clear-water coral reef environments. An exception is the neogastropods (including the Conidae); this venomous group is underrepresented in the middens (Table S9.1) when compared with the contemporary marine environment (Table 9.3).

Tropical gastropods that occur mainly in other types of intertidal habitat are relatively rare in both midden and marine samples. Such taxa include members of the Potamididae (mudwhelks: *Telescopium*, *Cerithidea*) and Corbiculidae (*Batissa*, *Geloina*), both of which characterize more turbid, muddy areas, and members of the Turbinidae (*Turbo* species), Trochidae, and Muricidae, all of which are common in rocky shores exposed to wave action. Both of these habitat types can currently be found in proximity to the main Mussau Island, to the north of the area on which the current study is focused. Midden samples near these areas are correspondingly different (see Chapter 2 for details). Swadling (1977a) also reported that midden assemblages in sites from southern PNG near to mangrove areas differed from sites near to coral reef flat areas, and local-scale correspondence between the molluskan assemblages of shell middens and those of nearby marine environments was noted by Kirch (1982b).

It can therefore be concluded that the marine environment at the time of midden formation in the Eloaua Island region was similar in nature to that currently present, and consisted of the range of habitat types associated with clear-water tropical coral reef ecosystems, including tidal flats (sand flats, seagrass flats, and coral flats), shallow rock platforms and reef crests, subtidal basins, lagoons, and outer reef slopes (see Chapter 2). However, the spatial arrangement, relative frequency, and microhabitat characteristics of these habitat types may have changed over time. In broad terms, the assemblage of molluskan species in the Mussau middens is dominated by a similar group of taxa to that exploited by humans in tropical shallow-water marine environments elsewhere (Catterall 1986, Harris and Weisler 2017).

Temporal Changes in the Midden Taxonomic Composition

Description of Temporal and Spatial Changes

Figure 9.3 shows the extent of temporal change in the relative frequencies of mollusks within selected major taxa between the Early and Late Lapita time periods at the ECA site. The taxa used are those that were reliably identified in all SSU, and that are sufficiently common to permit valid statistical analysis.

The two time periods were similar in overall species composition, with the red-lipped stromb *Strombus luhuanus* being the dominant species in both, and with certain other taxa (*Gafrarium*, *Tridacna*, *Spondylus*, *Hyotissa*, *Conus "litteratus,"* and *Cypraea tigris*) being relatively rare in both. However, there were also a number of statistically significant differences between the two time periods. Taxa which were significantly more dominant in the Early Lapita period were *Anadara*, *Acrosterigma*, *Chama*, and *Spondylus*, and those significantly more dominant in the Late Lapita period were *Tridacna* and *Strombus luhuanus*. Additionally, *Hippopus* strongly ($p < 0.10$) tended toward greater dominance in the Late Lapita period.

In Table 9.4 these data are compared with the limited information available for another Early Lapita site on Eloaua Island (EKE), and with two post-Lapita sites (the upper component at EKE on Boliu Is., and the EHK site on Eloaua Is.). Since these latter three are represented by only one SSU each, the data must be treated with caution, especially those for the Early Lapita period at EKE, which is based on a total shell MNI of only 68 (Table 9.4A). All sites and time periods other than this Early EKE sample are dominated by *Strombus luhuanus*.

Correlations among the sites/time periods are generally high and statistically significant (Table 9.4B), other than those involving the Early EKE sample, and this reflects the low numbers of *Strombus luhuanus* in the latter sample, which in turn is probably due to inadequate data rather than to any real difference in time or space. The best correspondance is between the three Late Lapita and post-Lapita samples, with correlation coefficients of 0.94 or more: These samples all share the increased dominance by *Strombus luhuanus* after the Early Lapita period that was also revealed in the comparison of Early and Late Lapita at the ECA site (Figure 9.3), as well as large decreases in *Acrosterigma*, smaller decreases in *Spondylus*, and increases in *Tridacna*.

What Do These Changes Mean?

It is possible to examine the pattern of temporal difference in the midden mollusks for consistency with the hypotheses of minor habitat change versus impacts of changed exploitation intensity (which could be influenced by altered human population size, dietary preferences, or other cultural factors such as gathering techniques or shell export rates, as discussed previously). The broad similarity in mollusk species composition among the archaeological deposits from the Early, Late, and post-Lapita time periods is consistent with the similarity in dominant taxa between midden samples and the present-day marine environment, further supporting the inference that major habitat changes did not occur during the long period from Early Lapita settlement to the present. Nevertheless, there may have been shifts in area or location of habitat types, which could affect the relative availability of different mollusk species.

With respect to human exploitation, consideration of the biological attributes of the species in question (Table 9.1) leads to the following predictions. Heavier gathering pressure should have a greater impact on populations of *Tridacna* and *Hippopus* than on populations of *Strombus* or *Anadara*. Since *Acrosterigma* broadly resembles *Anadara* in ecological attributes, it should also be less impacted by gathering. Insufficient biological data are available to reliably make predictions concerning *Chama* and *Spondylus*. If changes in patterns of numerical dominance are a consequence of changed exploitation pressure, then *Strombus*, *Anadara*, and *Acrosterigma* should increase concurrently, at the same time that *Tridacna* and *Hippopus* both decrease. This was clearly not the case (Figure 9.3, Table 9.4). Thus there is little support for the hypothesis of exploitation effects.

On the other hand, *Anadara* and *Acrosterigma* are both primarily species of shallow-water seagrass flats in the study region, whereas *Strombus*, *Tridacna*, and *Hippopus* are more typical of other shallow-water coral reef habitats (Table 9.3), and *Chama* and *Spondylus* are common in subtidal basin/reef slope areas. The decreased representation of *Chama* and *Spondylus* in the midden deposits from Early to Late Lapita periods may suggest a decreased area of subtidal basin habitats. At the same time, the decreased representation of *Anadara* and *Acrosterigma*, together with increased numbers of *Strombus*, are consistent with a decrease in the proportion of the reef flat area covered by seagrass, accompanied by an increase in the proportion of coral flat. Similarly, Amesbury (2007) commented on the concurrent increase in the sand flat gastropod *Strombus* (*Gibberulus*) *gibberulus* and decrease in the seagrass-associated bivalve *Anadara antiquata*, across an archeological record of some 3,000 years in the Mariana islands, and concluded that this change was driven by shifts in marine habiats over time rather than the effects of human exploitation (in that study *A.antiquata* was assumed

Table 9.4. A. Relative frequencies (% of total) of selected mollusk taxa at different excavation sites and time periods. The figures for the ECA (Eloaua Island) site correspond with the data in Figure 9.3 but are pooled over each of the 11 Early and 9 Late Lapita shell sampling units (SSU). The EKE and EHK site data are each based on a single SSU. The bottom row (Total MNI) is the total gastropods plus half the total bivalves, across all taxa listed (excluding all other taxa). B. Matrix of parametric correlation coefficients among the sites/time periods). For details of shell taxa see Table 9.3

		Early Lapita		Late Lapita	Post-Lapita	
Site		**ECA**	**EKE**	**ECA**	**EKE**	**EHK**
SSU		**11**	**1**	**9**	**1**	**1**
A. Relative frequencies						
Bivalves	*Anadara*	21	19	7	14	21
	Acrosterigma	15	33	3	7	1
	Gafrarium	2	1	3	0	0
	Hippopus	1	4	3	1	1
	Tridacna	0	1	2	2	2
	Chama	10	14	2	10	10
	Spondylus	4	21	0	0	1
	Hyotissa	0	0	0	0	0
Gastropods	*S. luhuanus*	24	1	67	55	52
	Lambis	11	4	7	9	6
	T. niloticus	7	0	3	0	0
	C. "litteratus"	3	0	1	0	0
	C. tigris	2	0	1	1	6
Total MNI		982	68	786	2144	385
B. Correlation matrix						
Early Lapita	ECA	1.00				
	EKE	0.42	1.00			
Late Lapita	ECA	0.67*	-0.16	1.00		
Post-Lapita	EKE	0.80**	-0.01	0.97***	1.00	
	EHK	0.79*	-0.04	0.94***	0.98***	1.00

* $p < 0.05$, **$p < 0.01$, ***$p < 0.001$

without clear reason to occur mainly in mangrove habitats, rather than seagrass, but seagrass is often found adjacent to mangroves at lower tidal levels).

In general, the pattern of minor but statistically significant temporal change in relative abundances of molluskan taxa in the midden deposits of the Eloaua Island region is more consistent with changes in the type and distribution of coral reef habitat (especially a decrease in seagrass and an increase in coral flats) than with an effect of changed human exploitation levels or patterns.

Temporal Changes of Population Characteristics within Certain Mollusk Species

Size Distributions

For both the archaeological samples (Early, Late, and post-Lapita), and the present-day marine samples our analyses indicated that there was large variation across taxa in typical size. A few taxa are notably large (mostly over 70 mm): *Hippopus*, *Tridacna*, *Hyotissa*, and *Lambis*. These are the only taxa in which the sampling in the present-day marine environment undertaken during this study would have provided relatively unbiased data on the size-frequency distribution. The smaller mollusks have slower early growth rates than these large species, which, together with the difficulty of sampling for individuals less than 30 mm, leads to unreliable representation of younger age classes of smaller taxa in the marine data set. These younger age classes are also unreliably represented in the midden samples, since both their sorting and screening and the behavior of shell-gatherers tend to exclude shells smaller than 20–30 mm.

Furthermore, data from taxa that consist of groups of species (see Table S9.1) must be treated with caution, as shifts in size frequencies could be due to changes in species composition. The only taxa not of this type are: *Anadara*, *Hippopus*, *Hyotissa*, *S. luhuanus*, *Lambis* (which is mainly *L. lambis*), *T. niloticus*, *C. tigris*, *S. gibberulus*, and *S. urceus*. Of these taxa, the shell length measurements in *Lambis*, *S. luhuanus*, *C. tigris*, *S. gibberulus*, and *S. urceus* may often reflect environmental conditions rather than age since these taxa have determinate growth, an issue also discussed by Giovas and others (2010). However, for *S. luhuanus*, shell lip thickness was also measured and used as a more reliable indicator of age (Table 9.5), and *Lambis* is sufficiently large that juveniles still increasing in length were gathered and shell length hence partly reflects age.

This leaves *Anadara*, *Hippopus*, *Hyotissa*, *S. luhuanus*, *T. niloticus*, and perhaps *Lambis* as being suitable for closer scrutiny and statistical testing (Table 9.5A, B). Although there are some statistically significant differences between prehistoric time periods in the proportion of larger (i.e., older) shells, some relationships are weak, and there is little consistent pattern. The data for *Anadara*, *Hippopus*, *Hyotissa*, and *S. luhuanus* all suggest that the lightest impact of gathering (the highest proportion of large individuals) occurred during the Late Lapita period. Neither *T. niloticus* nor *Lambis* show this pattern, but the *Lambis* data may only weakly reflect shell age (see above), and the *T. niloticus* data are probably of little validity due to an increased loss of large shells for artifact manufacture in the Late Lapita period (see below). Size patterns for many of the larger mollusks also point to the post-Lapita period as the time of heaviest gathering impact. The large bivalves (*Hippopus*, *Tridacna*, *Chama*, *Spondylus*, and *Hyotissa*) all show substantially decreased representation of larger size classes post-Lapita compared with Lapita and present-day marine environments, and the large *Trochus* and *Conus* species show complete disappearance at this time.

Statistical comparisons with the present-day (unexploited) marine environment are also made in Table 9.5C, for the large species (*Hippopus*, *Hyotissa*, *Lambis*) only. All show a large and statistically significant increase in the proportion of older individuals in present-day marine samples, indicating that shell-gathering in prehistoric times had a detectable influence on their age distributions. Other taxa did not show strong or consistent patterns of temporal change in age distribution within the midden deposits, and inferences about the effects of gathering on their populations are impossible due to the various complicating factors discussed above.

Data on shell size and lip thickness of *Strombus luhuanus* (Table 9.6) provide further information. In this well-studied species, immature individuals have thin shell lips while their body size grows rapidly, followed by about two years during which the shell size of mature individuals is fixed but the shell lip thickness progressively increases (Catterall and Poiner 1983; Poiner and Catterall 1988). The *S. luhuanus* shell sample from the post-Lapita period contained a larger proportion of thinner-lipped (young) individuals than those from the Early or Late Lapita periods (Table 9.6), and the greatest proportion of thicker-lipped individuals occurred during the Late Lapita. Two explanations are possible: either the stocks were most heavily exploited in the post-Lapita (and least in the Late Lapita), or thick-lipped shells were preferentially targeted for collection in the Lapita periods. Comparisons with the present-day marine sample (Table 9.7) are difficult because our field sampling would have incorporated younger individuals than were targeted by prehistoric shell-gatherers, but they

Table 9.5. Statistical tests of differences in size distributions for those species for which these data are potentially meaningful (see text). The frequencies of shells have been pooled into two size classes (above and below a selected cutoff) for each taxon and the percent shells above the cutoff is compared across pairs of time periods (N is the total sample size of shells from each taxon). All p values are derived from χ^2 tests of 2 x 2 contingency tables. Figure 9.2 illustrates the shell dimensions measured

Mollusk Taxa	***Anadara***		***Hippopus***		***Hyotissa***		***Strombus luhuanus***		***Lambis***		***Trochus niloticus***	
Size cutoff (mm)	**50**		**100**		**120**		**1 (lip)**		**120**		**50**	
	%	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**
A. Early vs. Late Lapita												
Early Lapita	62	330	43	23	100	4	94	80	20	46	56	54
Late Lapita	69	99	62	45	100	7	99	140	17	23	30	10
χ2 comparison (p)	ns ($p < 0.07$)		ns		ns		$p < 0.05$		ns		ns	
B. All Lapita vs. post-Lapita												
Lapita	63	429	56	68	100	11	97	220	19	69	52	64
Post-Lapita	70	455	11	36	33	12	94	308	45	99	—	0
χ^2 comparison (p)	$p = 0.05$		$p < 0.001$		ns		ns ($p < 0.08$)		$p < 0.001$		—	
C. All midden vs. present-day marine												
Midden	67	884	40	104	65	23	95	528	35	168	52	64
Contemporary marine	—	—	90	49	90	102	—	—	76	46	—	—
χ^2 comparison (p)	—		$p < 0.0001$		$p < 0.001$		—		$p < 0.0001$		—	

do show that the present-day *S. luhuanus* individuals are considerably smaller when adult (thick-lipped) than those occurring in all prehistoric time periods. This finding is consistent with increased competition among higher-density populations in the absence of exploitation, but may also be a product of changes in other environmental factors (Faulkner 2009; Giovas et al. 2010).

Shell Damage

The frequency of shell damage to the midden mollusks varies strikingly among shell taxa (Table 9.7). Shells were scored as "damaged" when this damage prevented measurement. Shell damage rates were high in *S. luhuanus*, *Lambis*, *T. niloticus*, *T. pyramis,* and *C. "litteratus."* Lower rates of shell damage occurred in *Anadara*, *Acrosterigma*, *Hippopus*, *Tridacna*, and *Chama*, and shells in the other taxa were rarely sufficiently damaged to prevent measurement.

Damage rates in the present-day marine shells were consistently low (Table 9.7), indicating that the damage in midden shells was a consequence of either human treatment or disturbance post-deposition. Since the upper midden layers that showed signs of disturbance through human cultivation were excluded from the analyses, and the lower layers showed remarkably little post-deposition disturbance (Kirch 1987a, 1988b), the measured rates of shell damage (Table 9.7) would have been due to human treatment prior to deposition. Remarkably high rates of shell damage occurred in *C. "litteratus"* (93% in Early Lapita samples), *S. luhuanus* (65% in Early and Late Lapita and 42% post-Lapita), *Lambis* (57–59% in Early and Late Lapita and 53% post-Lapita), and *T. niloticus* (18% and 62% in Early and Late Lapita). Taxa showing moderate (10–20%) damage rates during at least one time period were *Anadara*, *Acrosterigma*, *Hippopus*, *Tridacna*, *Chama*, *C. tigris*, and *T. pyramis*. Rates of damage to many taxa vary among the three time periods (Table 9.7).

Table 9.6. The percentages of *Strombus (Conomurex) luhuanus* shells within various combinations of shell size class and lip thickness (see Figure 9.2), from midden samples at three different archaeological time periods (Early, Late, and Post-Lapita; see Table 9.2), and in the present-day marine environment. For each time period, N is the total number of undamaged shells measured. The lip thickness categories reflect shell age; immature individuals have lips < 1 mm and are growing in size, but when an individual reaches sexual maturity it stops growing and the lip thickens from about 1 to about 4 mm during the following two years (see Poiner and Catterall 1988)

		Lip Thickness (mm x 10)						
	Shell Size (mm)	**< 10**	**10–19**	**20–29**	**30–39**	**40–49**	**≥ 50**	**All**
Early Lapita (N = 80 shells)	< 45	3	0	0	6	0	0	9
	45–49	1	1	4	16	5	0	28
	50–54	1	1	9	15	14	1	41
	55–59	1	0	4	8	5	1	19
	≥ 60	0	0	3	0	1	0	4
	all	6	3	19	45	25	3	100
Late Lapita (N = 140 shells)	< 45	1	1	2	3	1	1	9
	45–49	0	1	2	9	5	3	20
	50–54	0	1	4	21	17	6	49
	55–59	0	1	2	11	4	2	20
	≥ 60	0	0	0	1	0	1	2
	all	1	4	11	44	27	14	100
Post-Lapita (N = 308 shells)	< 45	3	1	8	5	1	0	18
	45–49	2	3	15	10	2	0	32
	50–54	1	2	10	15	3	2	32
	55–59	0	0	3	9	3	0	16
	≥ 60	0	0	0	1	0	1	2
	all	6	6	36	40	8	3	100
Present-day marine (N = 342 shells)	<45	27	0	1	8	2	0	38
	45–49	5	1	4	17	12	1	39
	50–54	1	1	1	9	8	0	20
	55–59	0	0	0	1	1	0	3
	≥60	0	0	0	0	0	0	0
	all	33	2	6	35	22	1	100

This damage could have occurred as a consequence of either flesh-extraction procedures (see Chapter 8) or artifact manufacture (see Chapter 13). *T. niloticus* (and probably *T. "pyramis"*) and *C. "litteratus"* have been identified as the source of *Trochus* shell armbands and other ornaments (Kirch 1987a, 1988b), and were probably primarily collected for this purpose. Damage to *T. niloticus* typically consisted of the excision of the first body whorl; in many cases this left the central spire still in place so that shells could still be measured, and consequently the damage rates

Table 9.7. Percentage rates of damage to shells from the midden, and from the present-day marine environment; N is the number of shells in each sample, and percentages were only calculated where N > 5

Taxon	Early Lapita		Late Lapita		Post-Lapita		Present-Day Marine	
	%	N	%	N	%	N	%	N
Anadara	10	365	7	106	14	530	0	32
Acrosterigma	10	296	8	52	15	280	0	3
Gafrarium	0	38	3	40	0	18	0	3
Hippopus	4	24	13	51	20	45	0	49
Tridacna	14	7	0	31	15	80	0	20
Chama	3	191	22	36	4	362	0	57
Spondylus	8	75	14	7	—	4	0	17
Hyotissa	0	5	0	7	8	13	0	102
Tapes	0	84	—	1	—	0	—	1
Pitar	1	72	0	38	—	0	—	4
"Tellina" (small)	1	153	—	3	—	0	—	0
Anodontia	3	34	—	3	—	0	—	0
"Quidnipagus"	1	76	0	32	—	0	—	4
S. luhuanus	65	229	65	402	42	531	0	342
Lambis	59	112	57	53	53	211	0	46
T. niloticus	18	66	62	26	—	0	—	0
C. "litteratus"	93	28	—	4	—	0	0	23
C. tigris	0	22	0	8	13	46	0	6
S. gibberulus	2	56	0	8	—	0	0	314
S. urceus	0	58	—	3	—	0	0	7
T. "pyramis"	16	117	15	13	—	0	0	6

shown are an underestimate of the proportion of shells that were worked. *T. niloticus* shows higher damage rates in the Late than Early Lapita period (concurrent with a decrease in the proportion of large individuals in the measurable sample), and a disappearance from post-Lapita samples (Table 9.7). Damage to *C. "litteratus"* consisted of the loss of most of the body whorl, and this corresponds with working for armband manufacture shown in Kirch (1987a; see also Chapter 13). This species is also absent from later samples. Damage to *Lambis* consisted of breakage or loss of the spines associated with the shell apex, leaving the shell lip and both ends of the body whorl intact (and measurable).

Damage to *S. luhuanus* mainly consisted of removal of the shell lip (75% of 633 damaged shells) along the length of the shell (see Figure 9.2), sometimes accompanied by breakage of the anterior section of the body whorl (25%). Simple shell lip removal does not facilitate meat extraction, because the adductor muscle remains firmly attached to the shell's interior. J. Allen (2017) noted the presence of similar lip damage (at an unquantified rate) among midden shells at Motupore Island in southern Papua New Guinea, and considered that the thickened reddish shell lips of *S.*

luhuanus likely provided the bulk of the raw material for small shell bead manufacture, citing historical ethnographic sources for this having been a favorite material for necklaces. In the Mussau midden samples, damage rates to *S. luhuanus* were considerably lower in the post-Lapita than during the Lapita time period (Table 9.7).

Meat removal in both *S. luhuanus* and *Lambis* is typically achieved either by simply pulling the flesh from the aperture of whole steamed shells or by breaking a hole in the dorsal surface of the body whorl, which permits the adductor muscle to be severed. Such punctures in the dorsal shell surface are common in species of *Strombus* and *Lambis* from both midden deposits and present-day samples at a wide range of localities (personal observation; see also Poiner and Catterall 1988). This type of damage was also common in the Mussau midden samples, in both *S. luhuanus* and *Lambis*, as well as in the midden deposits of Motupore Island (personal observation). It therefore seems likely that on both Mussau and Motupore, *S. luhuanus* (and possibly *Lambis*) were used for both artifact manufacture and as food.

Several of the taxa with lower damage rates, including *Tridacna*, would also have been used for both food and artifacts (see Kirch 1987a, 1988b). *Anadara*, while primarily a food species, is also used by present-day Mussau islanders for weighting fishing nets (as also noted on Motupore by Swadling [2017]), and *Acrosterigma* could have been used for the same purpose.

Effects of Collecting on Mollusks of Coral Reefs in the Mussau Environmental System

In summary, comparisons of midden samples with the present-day ungathered marine shellfish populations indicate that human exploitation did lead to detectable shifts in the population age structures of some gathered shellfish. The data on frequencies and size distributions of the larger bivalve and gastropod species suggest that the effects of human exploitation on marine mollusk stocks were probably lowest in the Late Lapita, and highest in the post-Lapita period. However, no period seems to show extremely heavy exploitation of molluskan stocks. Although the data indicate that the effects of human exploitation on marine mollusk stocks may have been lowest in the Late Lapita period, there is no evidence that any species declined in overall population density in its marine habitat as a result of prehistoric gathering during any time period at Mussau. The observed changes in species composition were not major, and are more consistent with minor habitat change than with human impact.

The inference of relatively low exploitation pressures is further supported by comparisons with midden data from southern Papua New Guinea, where comparable data on the size distributions of *Strombus luhuanus* and *Anadara antiquata* are available from theTaurama [AJA] and Motupore [AAR] midden sites (Table 9.8; see also Poiner and Catterall [1988] and Swadling [1977b]). Taurama is on the mainland, and Motupore Island is less than 1 km from the mainland; these archaeological sites were respectively described by Swadling (1976) and Allen (1977). Both are bordered by a coral reef system which is mainly of the “seagrass flat” type (Poiner and Catterall 1988; Swadling 1977a).

The current-day *S. luhuanus* population in the marine environment at Motupore Island displays high resilience to gathering, in terms of the persistence of high-density populations, although heavily exploited populations showed a shift toward domination by younger age classes (Poiner and Catterall 1988). The midden samples from Motupore and Taurama contain a relatively low percentage of adult *Strombus luhuanus* shells (49% and 60% with lip > 1 mm; Table 9.8), which indicates the extent to which exploitation pressure can influence the age distribution of gathered shells (see Poiner and Catterall 1988 for further discussion). In contrast, the Mussau midden samples consist almost entirely of adult individuals throughout the period of human occupancy (94–99%: Tables 9.5 to 9.7), indicating that heavy exploitation had not occurred.

Anadara antiquata shows a similar pattern, with a much higher proportion (67%: Table 9.8) of larger shells occurring in the Mussau samples than at Bootless Inlet (23–40%). This strongly suggests that *A. antiquata* has also been under relatively light exploitation pressure at Eloaua Island, although it is also possible that environmental differences may be responsible for intrinsically smaller stocks at Bootless Inlet.

Table 9.8. A comparison of the shell size distributions of *Strombus luhuanus* and *Anadara antiquata* between the Mussau middens and midden samples from southern PNG (Bootless Inlet: Motupore and Taurama), as an indication of the different impacts of harvesting on the prehistoric mollusk populations at the two localities

Taxon	Site	Shells Above the Size Cutoff*		Source of Data
		%	N	
Strombus luhuanus	Mussau midden	95	528	This study (Table 9.6)
	Motupore midden	49**	300	Poiner and Catterall (1988, Table 9.6)
	Taurama midden	50**	835	Swadling (1977a, Table 9.4)
Anadara antiquata	Mussau midden	67	884	This study (Table 9.6)
	Taurama midden	33**	267	Swadling (1977a, Table 9.5)

* As in Table 9.6, 1 mm (lip) for *S. luhuanus* and 50 mm for *A. antiquata*.
** Significantly different from the Mussau percentage; $p < 0.0001$, $\chi 2$ contingency test.

The relatively low human impact on molluskan stocks in the Eloaua atoll system could be a consequence of any combination of the following factors: (1) the large marine area (approximately 18 km^2 of shallow-water reef habitat and 8 km^2 of lagoon in the Eloaua Is. atoll system alone; see Chapter 2) available for human use relative to the small area of dry land (approximately 7 km^2 in the Eloaua Is. atoll system) available for human settlement; (2) a small human population in the region; or (3) a human lifestyle in which greater emphasis was placed on the use of terrestrial resources than on exploitation of the marine environment. Finally, the impacts on shellfish species collected primarily for artifact construction may arguably have been greater than those on food taxa, but this cannot be confirmed due to the loss of this shell material from the excavated samples.

Acknowledgments

We thank Mike Ritchie for help with marine sampling, cheerful company, and perseverance during late-night shell-measuring sessions in the field; Patrick Kirch, Jason Tyler, and Dana Lepofsky for company, useful discussions, and contributions to shell counts and measurements from the ECA and EKE sites; Nick Araho for providing shell data from the EHK site; Milan Solon, Ave Male, Stella Male, and many others for help in the field and generous hospitality on Eloaua Island; Marc Hero and Peter Schmidt for their contribution to sorting and analysis of the data; and Thora Whitehead of the Queensland Museum for providing formal identifications of the shell specimens. This study was supported by NSF grant BNS-8996182 to P. Kirch, and by funds from CSIRO Marine Laboratories and Griffith University.

CHAPTER 10

Macrobotanical Remains from Talepakemalai (Site ECA) and the Case for Lapita Arboriculture

Patrick Vinton Kirch

One of the major questions invigorating debates about the Lapita cultural complex in the early 1980s, when the Lapita Homeland Project was conceived and initiated, focused on the nature of its economic base and, more specifically, whether this had included horticulture. Many archaeologists, including Green (1979a) and myself (Kirch 1979), had rejected Groube's (1971) proposition that Lapita peoples were "strandloopers" who subsisted largely by exploiting rich littoral and marine resources. To the extent that Lapita was seen as being correlated with the Oceanic branch of the Austronesian language speakers, historical linguistic reconstructions of multiple words for taro, yams, bananas, and other tropical crops provided indirect evidence for Lapita horticulture (Kirch 1979, table 12.2). Yet the direct archaeological evidence for crops and their cultivation was, at the time, admittedly thin, the only macrobotanical evidence for crop plants in Lapita sites consisting of carbonized coconut endocarps.

Building upon earlier studies by Barrau (1958, 1965a, 1965b), Douglas Yen had advanced a series of hypotheses concerning the origins and development of Oceanic cultivation systems, based in large part on his own ethnobotanical fieldwork in the Solomon Islands during the 1970s (Yen 1971, 1973, 1974, 1985). Whereas most studies of Oceanic cultivation systems emphasized the dominant taro–yam complex, Yen drew attention to the wide range of tree crops and to the importance of village tree gardens (arboriculture) throughout the region extending from the Bismarck Archipelago through the Solomon Islands and Vanuatu, and attenuating in Fiji, Tonga, and Samoa. Although the taro–yam complex was thought to have been introduced to the region by Austronesian-speakers moving out of island Southeast Asia, the natural distribution of most of the tree crop genera suggested that they might have been domesticated over a broad area that included New Guinea, the Bismarcks, and the Solomons (i.e., Near

Oceania). This raised the question of whether the arboricultural complex of Melanesia and Western Polynesia was of Austronesian origins, or might alternatively have been developed within Near Oceania. The possibilities of pre-Lapita plant domestication in Near Oceania had been strengthened by Golson's discoveries of early-to-mid-Holocene cultivation in the New Guinea Highlands (Golson 1977, 1990).

With these debates as context, one of my priorities for fieldwork in Mussau in 1985 was to obtain new archaeological evidence that might bear on the question of Lapita horticulture. What I hardly anticipated was the discovery of waterlogged deposits at the Talepakemalai site containing abundant, well-preserved plant remains deriving from many of the tree crops identified by Barrau (1958) and Yen (1974) as being central to Melanesian arboriculture. When the first anaerobically preserved seeds began to appear in our sieves in 1985, I realized that Talepakemalai was going to provide substantial direct evidence for Lapita arboriculture. Major effort was concentrated in the following two field seasons on expanding the sample of plant remains, which has proved to be the largest and most diverse set of macrobotanical evidence bearing on Lapita tree crops. This chapter presents the results of that effort, building upon an earlier preliminary account (Kirch 1989).

Traditional Arboriculture in Mussau

Having conducted fieldwork together with ethnobotanist Douglas Yen in the eastern Solomon Islands on several occasions during the 1970s (Kirch and Yen 1982; Yen 1974), prior to beginning research in Mussau I was well attuned to the significance of arboriculture or tree cropping in indigenous Melanesian subsistence systems. As I began to explore Eloaua Island in 1985, it was apparent that in addition to their field cropping of taro, yams, and manioc, the Mussau people maintained extensive orchard gardens in and around their settlements, cultivating and using many of the tree crops that I was already familiar with from my prior experiences in the eastern Solomons. My interest in traditional Mussau arboriculture was heightened after we began to recover anaerobically preserved seeds and other plant remains in the Talepakemalai site. In 1986 I spent time working with Ave Male and other informants to catalog the array of tree crops still cultivated in Mussau. As we began to identify the assemblage of well-preserved plant materials coming out of the ECA sediments, it became evident that most of the taxa continue to be used in Mussau today. Indeed, the emphasis on tree cropping is arguably a part of the *longue durée* of subsistence economy in the Bismarck Archipelago.

Recognizing that a more thorough study of Mussau arboriculture would be important as a reference point for interpreting the archaeobotanical assemblage, in 1988 I invited my then graduate student Dana Lepofsky to undertake such a study. Her results were published in full elsewhere (Lepofsky 1992) and it is not necessary to repeat the details here. However, a brief overview provides some context for interpreting the archaeobotanical materials.

The inventory of tree crops cultivated in Mussau is summarized in Table 10.1, with 25 botanically identified taxa; the Mussau islanders in many cases recognize two or more named varieties of each scientific taxon. While the most important uses are typically as food, with edible nuts, seeds, or fruits, many of these trees also have secondary uses, such as leaves being woven into mats or baskets, leaves being used as wrappers for foods to be cooked in the earth oven, wood used in construction or for artifacts, or for medicinal purposes. All of these trees continue to play an important role in the subsistence economy of Eloaua Island, with the exception of the betel nut (*Areca catechu*), which was banned after the conversion of the islanders to the Seventh-Day Adventist religion in the 1930s. Prior to that time betel nut was the main stimulant plant, and was culturally of great importance, as described by Nevermann (1933).

Tree crops are spatially concentrated in what Lepofsky calls the "arboricultural zones" of the offshore islands, consisting of the coastal aprons of flat, calcareous soils that have developed on the former beach ridges, often enriched with organic materials from former habitations (Lepofsky 1992, Figure 2; see also Chapter 2, this volume). In contrast, the upraised coral limestone plateau forming the interior parts of the islets are planted in annual field crops such as taro and manioc, reverting to second growth in intervals between cultivation. The coastal arboricultural zones encompass the small hamlets, so that the dwellings and cookhouses are closely surrounded by a diversity of tree crops. Lepfosky (1992, Figure 5) recorded five profile diagrams of tree crops across transects through the arboricultural zone on Eloaua Island. In these profiles, the most dominant tree crop was coconut, followed by *Pandanus dubius*, *Pandanus tectorius*, and then bananas. Concerning tree cropping in Mussau, Lepofsky writes:

> The arboriculture zones of today are tended gardens. Tree gardeners frequently transplant cuttings or seeds of "better" varieties or new species from other tree crop zones into their own arboriculture zone. . . . The tree gardener has a mental map of the trees in the zone, and often knows where newly acquired cultivars will be planted beforehand. Most trees are fertilized throughout their growing period, and the entire zone is periodically weeded out of unwanted understory vegetation. Trees which volunteer in the arboriculture zone, and are valued for food or non-food uses, are tended along with the cultivars. Both men and women tree garden today [Lepofsky 1992:209].

Of the 25 taxa listed in Table 10.1, 14 are represented in the archaeobotanical assemblage from the ECA site. Some of the taxa that are not archaeologically represented, such as breadfruit (*Artocarpus altilis*), bananas (*Musa* sp.), and the *Syzigium* "apples," have soft, fleshy fruit not conducive to anaerobic preservation in a waterlogged sedimentary environment; their absence at ECA does not necessarily imply that the crops themselves were not part of the Lapita subsistence repertoire. Indeed, the presence of numerous *Cypraea*-shell scrapers (see Chapter 13) offers strong indirect evidence that breadfruit was present and probably important. The presence of *Syzigium* in Lapita times was confirmed through identification of wood samples (see below).

Materials and Methods

During all three field seasons at the ECA site, anaerobically preserved, non-carbonized, macrobotanical remains were recovered by wet sieving of the waterlogged sediments through 5 mm and 3 mm mesh screens. The materials consist primarily of durable seeds or seed endocarps, with woody or fibrous structures; no soft material such as the flesh of fruits, or corms and tubers, was preserved. The plant remains were placed in heavy-duty plastic bags, which kept the material in wet condition for some time after it was returned to the laboratory. All measurements on seeds and other plant parts were made while the material was still in wet condition, prior to any shrinkage due to eventual drying out. During the 1988 field season we also processed sediment samples using flotation to determine whether smaller seeds or other plant materials were present (see Chapter 3), although the results were largely negative. The large sizes of the seeds and fruit of most Oceanic tree crops are such that they were readily retained in our sieves, rendering flotation unnecessary.

Identification of the archaeobotanical remains began in earnest during the 1986 field season, through the assembling of a reference collection of modern seeds. We also interviewed Eloaua informants who recognized many of the plant remains, took us to the modern trees growing in their orchard gardens, and provided us with details regarding contemporary use for food and other purposes. Holly McEldowney, who had taken time out from her own ethnoarchaeological study of cultivation systems in Manus to join us in Mussau in 1986, assisted me in this work. In 1988 I engaged Dana Lepofsky to undertake a more in-depth ethnobotanical study of contemporary Mussau arboriculture (Lepofsky 1992). Lepofsky prepared a collection of pressed botanical specimens of Mussau plants that were deposited in the Herbarium Pacificum of the Bernice P. Bishop Museum, Honolulu, as vouchers to support our botanical identifications, and also added to our seed reference collection. In addition, eleven samples of archaeobotanical materials including several whole seeds of *Canarium indicum* were sent to Douglas Yen at the Australian National University for further analysis.

The assemblage of 7,905 macrobotanical remains from the ECA site is summarized in Table 10.2, using NISP (number of identified specimens) as the quantification method. (While some investigators have recorded plant remains by weight [e.g., Matthews and Gosden 1997], the weight of plant remains varies greatly depending upon whether they are wet or dried, and NISP in my view provides a more useful measure.) As previously noted, the Mussau materials are all non-carbonized, anaerobically preserved plant parts.

The Mussau macrobotanical remains were concentrated most heavily in a fairly narrow band between the base of the mid-Holocene beach ridge and the location of the

Table 10.1. Tree crops of the Mussau Islands

Scientific Binomial and Family	English Name	Mussau Name	Uses
Areca catechu (Arecaceae)	Betel nut	buai	nut formerly chewed as a stimulant, wood used in construction
Artocarpus altilis (Moraceae)	Breadfruit	ulu	fruit eaten, leaves used as wrappers, wood used in construction
Barringtonia procera (Barringtoniaceae)	Cutnut	alingasa	nut eaten, leaves used to wrap food cooking in earth oven
Burckella obovata (Sapotaceae)		natu	fruit eaten
Canarium indicum (Burseraceae)	Pacific almond	osaosa	nut eaten, wood used in construction
Cocos nucifera (Arecaceae)	Coconut	niu	nut eaten, leaves plaited, wood used in construction
Corynocarpus cribbianus (Corynocarpaceae)		moso	fruit eaten
Cycas rumphii (Cycadaceae)	Cycad	otou	seeds eaten after processing, leaves used to wrap food for cooking in earth oven
Diospyros peckelii (Ebenaceae)		aipa	fruit eaten, wood used for artifacts
Dracontomelon dao (Anacardiaceae)	Papuan walnut	ra	fruits rarely eaten
Inocarpus fagifer (Fabaceae)	Tahitian chestnut	iy	seed kernel eaten after baking, leaves used to wrap sago for cooking in earth oven
Musa sections *Eumusa* and *Australimusa* (Musaceae)	Banana	uri	fruit eaten, leaves used to wrap food for cooking in earth oven
Paratocarpus venemosus (Moraceae)		kaui	fruit eaten
Pandanus conoideus (Pandanaceae)	Screwpine	katai	fruit baked and juice from seeds mixed with taro
Pandanus dubius (Pandanaceae)	Screwpine	aum	drupes chewed raw or baked in earth oven, leaves used to wrap fish for baking in earth oven, leaves also plaited and used for thatch
Pandanus kaernbachii (Pandanaceae)	Screwpine	yeri	drupes chewed raw or baked in earth oven, leaves used to weave mats
Pandanus tectorius (Pandanaceae)	Screwpine	arana	drupes eaten raw, leaves used to weave mats and for thatch
Pangium edule (Flacourtiaceae)		suete	fruit eaten raw, seeds eaten after processing
Pometia pinnata (Sapindaceae)	Island lychee	taono	fruit eaten raw, seeds eaten after processing, wood used in construction
Spondias dulcis (Anacardiaceae)	Vi apple	malai	fruit eaten raw
Syzigium aqueum (Myrtaceae)		bagalime	fruit eaten raw
Syzigium malaccense (Myrtaceae)	Malay apple	oa	fruit eaten raw and highly valued
Syzigium samarangense (Myrtaceae)	Java apple	kaviu	fruit eaten raw
Terminalia catappa (Combretaceae)	Sea almond	paka	nut eaten
Terminalia whitmorei (Combretaceae)		aitabage	nut eaten, wood used for canoes

Area B stilt house. This is approximately between N120 and N150 on the W200 transect and between N110 and N140 along the W250 transect, and is the area we referred to informally as the "muck zone" during our excavations, due to the fine, silty nature of the sediments (see Chapter 3). These fine-grained sediments accumulated in a very low-energy depositional environment, entrapping wood, abundant coconut shells, and other plant remains discarded either off of the stilt houses or as trash deposited at the foot of the beach. Some plant remains were also encountered in the deepest (fully waterlogged) deposits farther to the north along these transects, including at Area C, but their density was not as great as within the "muck zone" deposits.

During the 1988 field season, I thought that it might be informative to quantify the modern beach drift vegetation that can be found along the Mussau beaches in order to compare this with the archaeological assemblage from site ECA. I did this in part because my then University of Washington colleague, Robert Dunnell, had questioned whether the ECA archaeobotanical materials might simply be non-cultural drift materials rather than actual food refuse. Subsequent to our fieldwork, Matthews and Gosden (1997) have also addressed the taphonomic issues of discriminating between culturally deposited plant remains and natural drift material at the Arawe Islands Lapita sites.

Modern drift vegetation between the low and high tide marks was counted in three sample quadrants (each measuring 4 m^2): (1) at the sand spit on the southern tip of Enusagila Island, a location distant from any contemporary habitations, and thus most likely to be representative of natural drift; (2) Eloaua 1, a silty, low-energy beach in front of the Male hamlet; and, (3) Eloaua 2, a second low-energy beach in front of the Aite hamlet. Both Eloaua 1 and 2 are adjacent to contemporary habitations, and therefore could be expected to incorporate at least some culturally deposited material. The quantified drift material is reported in Table 10.3. The numerous tree crops present in the ECA assemblage (Table 10.2), when compared with the general lack of such tree crops in the modern drift samples (Table 10.3), strongly reinforce our interpretation that the archaeobotanical materials from ECA were indeed deposited as food refuse, and do not represent natural or non-cultural drift. It is also noteworthy that the modern drift samples are dominated by the seeds of *Calophyllum inophyllum* and *Casuarina equisetifolia*, two trees that grow along the beach ridges of Eloaua and other Mussau islets. Moreover, partial endocarps of coconut (*C. nucifera*), which are plentiful in the ECA assemblage, were present only in the Eloaua 1 and 2 samples, adjacent to habitations.

The Talepakemalai Archaeobotanical Assemblage

The 7,905 NISP macrobotanical remains from site ECA were sorted into 25 taxonomic categories, for the most part to the species level, as reported in Table 10.2. A residual category of 1,136 "unidentified seeds" consisted mostly of very small seeds not referable to any of the known arboricultural plants, presumably deriving from various elements of the natural vegetation. Selected examples of the identified taxa are illustrated in Figure 10.1; the drawings were made directly from ECA specimens excavated during the 1986 field season, while the material was still in wet condition. Three decades later, the macrobotanical remains from ECA have all become thoroughly dessicated, resulting in some shrinkage or deformation of fibrous structures.

Figure 10.2, a rank-order frequency plot of the identified taxa, shows that *Canarium indicum* heavily dominates the assemblage, followed by coconut (*Cocos nucifera*). Next in rank order are *Pangium edule*, *Spondias dulcis*, *Dracontomelon dao*, *Inocarpus fagifer*, and *Pandanus* spp., all important tree crops with edible fruits or seeds. The remaining taxa all have NISP frequencies of less than 100. The following paragraphs discuss each of the taxa including notes on their economic value; the presentation is in alphabetical order.[1]

Aleurites moluccana (Euphorbiaceae)

The candlenut, a large tree bearing hard-shelled nuts with oily kernels, has a pan-Oceanic distribution, but we did not observe it growing on Eloaua or the other offshore islets. At site ECA, candlenut is represented by four well-preserved whole endocarps. As the seeds readily float, these may simply represent non-cultural drift. Certainly, the very low frequency of candlenuts at ECA indicates that even if present on the island in the past, candlenuts were not regularly used.

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[1] The following section incorporates some material previously published in Kirch (1989).

Table 10.2. Macrobotanical remains (NISP) from Site ECA

Taxon	Part	W200 Transect, Area B	W250 Transect	Area C	Other Units	Totals
Aleurites moluccana	Endocarp	1	2		1	4
Atuna racemosa	Endocarp		2	6		8
Bruguiera rhizphora	Hypocotyl skin	9				9
Burckella obovata	Endocarp	10	2		9	21
Calophyllum inophyllum	Endocarp				1	1
Canarium indicum	Endocarp	1,557	785	50	165	2,557
Canarium sp. "wild"	Endocarp	6	3			9
Casuarina equisetifolia	Seed	24	31		3	58
Cocos nucifera	Endocarp	224	1,158	246	7	1,635
Cordia subcordata	Seed	76			19	95
Corynocarpus cribbianus	Endocarp	5	10	9		24
Cycas rumphii	Seed case			1	5	6
Diospyros sp.	Seed		1			1
Dracontomelon dao	Stone	193	226	1	58	478
Ficus sp.	Seed	20				20
Inocarpus fagifer	Fibrous pericarp	255	24	30	45	354
Nypa fruticans	Syncarp	7				7
Pandanus dubius	Syncarp drupe	1				1
Pandanus tectorius	Syncarp drupe		56	79	1	136
Pandanus spp.	Syncarp drupe	10	11	25	14	60
Pangium edule	Woody pericarp	404	160	35	79	678
Piper sp.	Stem		5	1		6
Pometia pinnata	Seed cap	4			1	5
Spondias dulcis	Endocarp	229	230	73	81	613
Terminalia catappa	Seed	3	1			4
Unidentified seeds		857	29		250	1,136
Totals		3,895	2,736	556	739	7,926

Atuna racemosa (Chrysobalanaceae)

Known locally as "putty nut," *Atuna racemosa* is often referenced in older botanical literature by the synonyms *Parinarium laurinum* or *Cyclandrophora laurina* (e.g., Peekel 1984:202). Peekel (1984:203) reports that the large seed of this tree, common in the primary and foreshore forests, "is grated and the putty-like mash pressed into cracks in canoes" as caulking. Eight fragments of *A. racemosa* seed endocarps were recovered from the W250 transect and Area C (Table 10.2). These fragments cannot have drifted to the site, and thus we interpreted them as artifacts deriving from cultural use.

Table 10.3. Modern shoreline drift samples

Taxon or Material	Plant Part	Enusagila Island	Eloaua 1	Eloaua 2
Barringtonia asiatica	Fruit	1		1
Bruguiera sp.	Hypocotyl	2		1
Calophyllum inophyllum	Seed	32	3	35
Casuarina equisetifolia	Seed	1	46	19
Cocos nucifera	Immature fruit	2		
Cocos nucifera	Husk	6		
Cocos nucifera	Partial endocarp		9	1
Guettarda speciosa	Seed	2		
Manihot esculenta	Tuber		2	
Nypa sp.	Fruit			1
Pandanus sp.	Drupe		2	1
Terminalia catappa	Seed	1		1
Wooden sticks			8	
Wooden chips (cut)				4

Bruguiera rhizphora (Rhizophoraceae)

The *Bruguiera* mangroves form dense thickets around certain coastal sectors of the offshore islets and also the shoreline of the main island of Mussau. The species is represented at ECA by nine fragments of hypocotyl skin. The Mussau people regard the mangrove hypocotyl as a famine food. However, the hypocotyls also float and occur as elements in modern shoreline drift (Table 10.3). Whether the presence of *Bruguiera* in site ECA indicates cultural use is therefore not certain; I am inclined to think that its presence in the site is due to natural drift.

Burckella obovata (Sapotaceae)

This large tree (up to 30 m crown) bears light-green fleshy fruit (7–10 cm long) that can be eaten either raw or roasted. Peekel (1984:431) observed that the tree is "common in the gardens of the natives and their surroundings" throughout the Bismarck Archipelago, while in the Santa Cruz Islands of the eastern Solomons, Yen (1974:274) found *B. obovata* to be a "conspicuous cultigen." The Eloaua people call the tree and its fruit *natu*, and it is common in the arboricultural zone and around the houses. At ECA the plant is represented by 21 specimens, all whole or partial endocarps. While by no means one of the dominant taxa, *Burckella obovata* is sufficiently well represented in the ECA site to be regarded as a component of the Lapita arboricultural complex.

Calophyllum inophyllum (Guttiferae)

This large coastal tree of widespread distribution throughout Oceania (Merrill 1945:28) does not bear edible fruit; however, its hard timber is prized for construction, including canoe hulls. The tree is common along the Eloaua Island shoreline today, and therefore it is somewhat surprising that only a single seed was recovered at ECA. Numerous seeds of *C. inophyllum* were present in the Enusagila and Eloaua 2 samples of modern drift (Table 10.3). The low frequency of seeds in the ECA assemblage may suggest that *C. inophyllum* was not a major component of the shoreline vegetation in Lapita times, but that it later became dominant as a result of gradual and continuing protection and tending of volunteer seedlings by islanders who valued the excellent

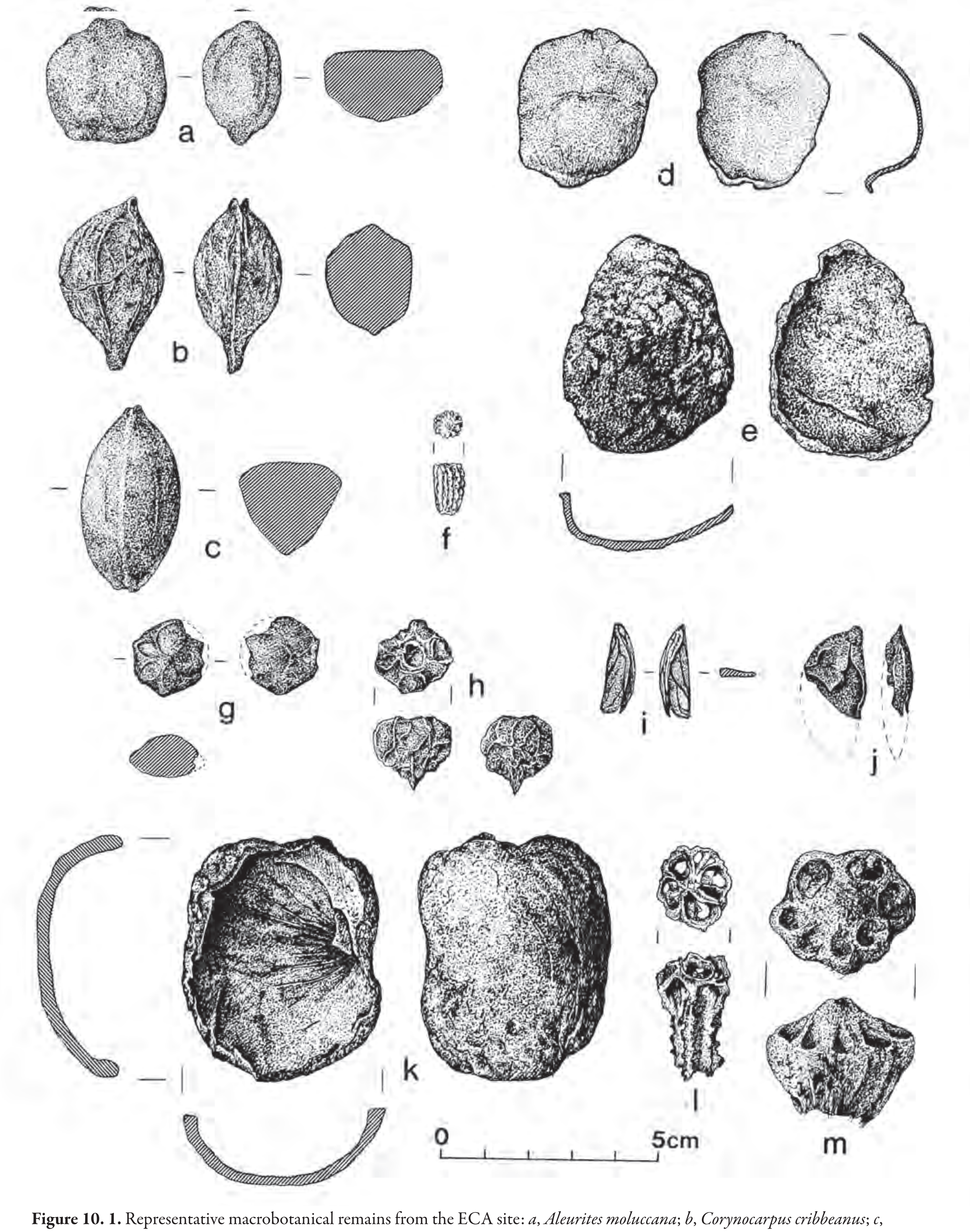


Figure 10. 1. Representative macrobotanical remains from the ECA site: *a*, *Aleurites moluccana*; *b*, *Corynocarpus cribbeanus*; *c*, *Canarium indicum*; *d*, *Cycas rumphii*; *e*, *Pangium edule*; *f*, *Casuarina equisetifolia*; *g*, *Dracontomelon dao*; *h*, *Cordia subcordata*; *i*, *Diospyros* sp.; *j*, *Burckella obovata*; *k*, *Inocarpus fagifer*; *l*, *Spondias dulcis*; *m*, *Pandanus* sp.

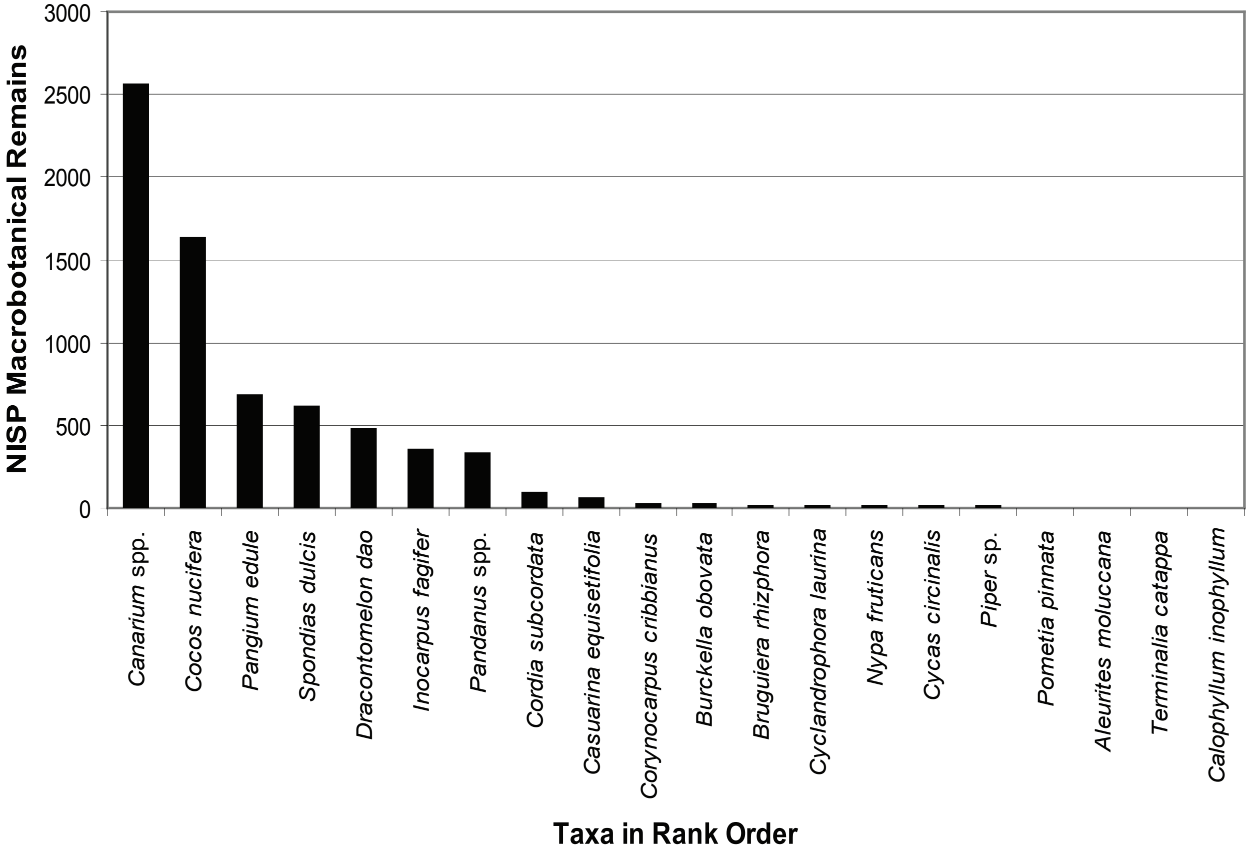


Figure 10.2. Rank-order plot of macrobotanical remains from the ECA site (rank order based on NISP).

timber. On the Polynesian Outlier of Tikopia, Kirch and Yen (1982:28–30) observed that *C. inophyllum* seeds were intentionally planted along the coastal beach ridges in order to harness the tree's natural ability to stabilize the sandy ridges and resist erosion.

Canarium indicum (Burseraceae)

Canarium indicum, sometimes referred to as the Pacific almond, Java almond, or Galip nut, is a stately tree rising to 25–40 m in height, bearing abundant drupes with a relatively thin flesh (mesocarp) covering a woody nut (endocarp) encasing an edible kernel. In cross section, the nut typically has three locules or cells, two of which are sterile (empty) while one enlarged locule contains the edible kernel. The kernels can be eaten raw but are often roasted or smoked, after which they can be stored for several months if kept dry. The nuts are typically opened by holding the nut in a vertical position with one pointed end on a hard surface such as an anvil stone, and hitting the other pointed end with a hammerstone. This causes one of the plates of the three-sided nut to break free, exposing the kernel.

Peekel (1984:281) says that *Canarium indicum* nuts were highly valued in the Bismarcks, and that several different varieties were recognized. We did not observe any trees on Eloaua, but they grow on the main island of Mussau and informants said that traditionally baskets of nuts were traded to the smaller islet communities (Lepofsky 1992:195).

Leenhouts (1955) monographed the genus *Canarium* in the Pacific, and in addition to *C. indicum* described two other cultivated species occurring within the Bismarcks–Solomons region: *C. harveyi* and *C. salomonense*. The species *C. harveyi* has the largest nuts, with Yen (1974) reporting that in the Santa Cruz Islands it was the object of intense selection for gigantism. The nuts of *C. salomonense* are similar in size and shape to those of *C. indicum*, with botanical distinctions between the species being based on floral characters such as the morphology of the stipules (which are not preserved in our archaeological samples). Moreover, as Yen (1996) demonstrates based on his extensive study of *Canarium* in Melanesia, the nuts of *C. indicum* exhibit considerable variation in size, external shape, and internal morphology of the locules (1996:Figures 5a, 5b).

The hard-shelled endocarps of *Canarium indicum*, with a total NISP of 2,557, were the most frequent of any plant taxon at ECA (Table 10.2, Figure 10.2). While a number of whole nuts were recovered, most of the material is fragmentary, with many fragments of the outer wall of the seed-bearing locule as well as partial nuts retaining one or both ends. The fragments typically have sharp, angular edges lacking signs of weathering. This kind of fragmentation conforms with the practice of cracking the nuts open with a hammerstone, leaving no doubt that the *C. indicum* nuts at ECA were purposefully opened in order to extract the edible kernels.

Because of the difficulty in discriminating among the nuts of *Canarium indicum*, *C. harveyi*, and *C. salomonense*, we sent selected materials to Douglas Yen at the Australian National University for expert identification. A sample from the W220N140 excavation unit showed that nuts ranged in length from 3.2 to 5.2 cm and in width from 2.0 to 3.2 cm (Yen, personal communication, 28 Oct 1987). All of the material was identified as *C. indicum*. After the 1988 excavation season, an additional six whole nuts (from units along the W250 transect) were also sent to Yen, who again determined all of them to be *Canarium indicum*.

The abundance of *Canarium indicum* remains at ECA, along with the clear indications of intentional smashing of the nut to extract the kernel, leave no doubt that *C. indicum* was a significant component within the Lapita arboricultural complex in Mussau. Notably, Matthews and Gosden (1997) also report finding substantial numbers of *C. indicum* nut shells in the Arawe Island Lapita sites.

Casuarina equisetifolia (Casuarinaceae)

The ironwood tree, named for its particularly dense hardwood, is widely used in Pacific Island cultures for house posts, spears, clubs, and other kinds of artifacts (Merrill 1945:28); it has no edible fruit. On Eloaua today the tree is not planted, but volunteers are protected and encouraged, and *C. equisetifolia* is a dominant component of the village shoreline vegetation. At ECA, the ironwood is represented by 58 NISP of its distinctive small, oval, woody fruit (superficially resembling a conifer cone) about 10–15 mm long, consisting of numerous carpels each containing a single seed. These fruit do not appear to float well; in our modern drift samples they were abundant only at the Eloaua 1 and 2 quadrants where *C. casuarina* trees were present in the nearby vicinity (Table 10.3). This suggests that ironwood trees were likely to have been a component of the shoreline vegetation during the period that the ECA site was occupied.

Cocos nucifera (Arecaceae)

Of all the trees comprising the Melanesian arboricultural complex, none is more important than the coconut, with virtually every part of this large palm having one or more economic uses. The nut (technically, a drupe) not only provides nutritious meat and refreshing liquid, but cream expressed from the meat and oil further rendered from the cream by stone boiling are important emollients in Oceanic cuisine. The husk (fibrous exocarp) provides the raw material for making sennit cordage, while the dried "shells" (endocarps) provide a hot-burning fuel for igniting earth ovens. The fronds are used extensively to plait various kinds of baskets, mats, and other artifacts; the trunk can be used in construction or for carving wooden objects.

The origin and later history of domestication of *Cocos nucifera* remain somewhat obscure, although this surely occurred within the Indo-Pacific region. Harries and Clement (2014) present an intriguing hypothesis that *C. nucifera* evolved as a component of tropical coral atoll ecosystems. Recent finds of anaerobically preserved endocarps of a wild form of coconut with a small cavity (diameter ca. 7 cm) dated to around 4000 BP on Mo'orea in the Society Islands (Kahn et al. 2014) demonstrate that coconuts had dispersed by natural means as far eastward as central Polynesia, by the mid-Holocene if not earlier.

While populations of small-fruited, 'wild" coconuts were thus likely to have been widely distributed across the southwestern Pacific prior to the Lapita dispersal, the coconut remains from the ECA site are distinctly *not* of a wild variety. Not only were coconut endocarps the second most abundant plant taxon in the ECA site deposits (NISP = 1,635), but the morphology of the larger endocarps (many of them half cups), with diameters of 12–14 cm, indicates that they are most likely a form of the domesticated "niuvai" type described by Harries (1978). Two specimens from ECA were sent to Hugh Harries, who confirmed that they represent a domesticated variety (personal communication, March 17, 1991). This leaves little doubt that the Lapita occupants of Eloaua possessed one or more domesticated cultivars of *C. nucifera*. The abundance of coconut remains at ECA further indicates that these palms were numerous and that their fruit was extensively used.

Cordia subcordata (Boraginaceae)

Cordia subcordata is a medium-sized tree (up to 10 m height) commonly found in the coastal zones of Pacific islands, producing abundant spherical fruits (2–3 cm diameter) with a corky exocarp. The fruits are not edible; however, the excellent hardwood is prized for house posts and for carving bowls and other artifacts. The Mussau islanders call the tree, which is abundant along the Eloaua shoreline, *niuniu*. Curiously, although the seeds readily float, no *C. subcordata* seeds appeared in any of the three drift vegetation quadrants (Table 10.3).

The hard, angular endocarps of *Cordia subcordata*, with one end distinctly pointed, were well represented at ECA (NISP = 95), suggesting that the trees were probably abundant along the Eloaua coastline during the Lapita period. This interpretation is confirmed by the presence of 12 specimens of wood (including worked wood with indications of adzing) from site ECA, identified by C. Orliac as being *C. subcordata* (see below).

Corynocarpus cribbianus (Corynocarpaceae)

This tree, with a large, globose, fleshy fruit (4–5 cm diameter), is not common in Melanesian arboricultural systems; Peekel (1984), for example, does not mention it, nor does Barrau (1958). Yen (1974:265–266) found that the trees were often situated "close to former village sites" on Santa Cruz Island in the eastern Solomons. During my fieldwork on Eloaua I observed only a single tree in a village garden. Lepofsky (1992:197) reports that the fruit, called *moso*, "is either eaten raw, after removing the skin, or baked in the earth oven." The distinctive hard endocarps of *C. cribbianus* were easily identified and, while not abundant (NISP = 24), were nonetheless represented in different parts of the ECA site (Table 10.2). There is no evidence that these fruit float, and therefore their presence at ECA can be taken as evidence that the tree was a part of the Lapita arboricultural complex.

Cycas rumphii (Cycadaceae)

In an earlier article on ECA plant remains from the 1985 and 1986 field seasons, this cycad was referred to as *Cycas circinalis*, the name used by Peekel (1984:35). Some sources regard *C. circinalis* and *C. rumphii* as synonyms, but more recent taxonomic and biogeographic work has resulted in *C. circinalis* being confined to the Indian subcontinent, with *C. rumphii* having a distribution in eastern Indonesia and into the New Guinea–Bismarcks region (Lindstrom et al. 2009). We observed *C. rumphii* plants in the Eloaua arboricultural zone, but the islanders rarely eat them today. Some older informants were able to describe the necessary process of extracting and incising the kernel, followed by overnight saltwater soaking to leach out the toxic hydrocyanic acid (Merrill 1945:187), and final baking in the earth oven. Barrau (1965a:285–287) regarded cycads as among the oldest food plants used by Pacific islanders. Lepofsky (1992:197) reports that on Eloaua during her stay cycad leaves were used to wrap food to be baked in the earth oven. Six fragments of *C. rumphii* seed cases were recovered from the ECA excavations. There is no indication that the seeds float, and they are therefore unlikely to be drift material, but the low numbers of cycad seeds in the site suggest that it was not a major food item.

Diospyros sp. (Ebenaceae)

One whole fruit from excavation Unit W250N130 (level 11), measuring 1.5 cm in diameter, was identified by Douglas Yen (personal communication, June 26, 1989) as being of the genus *Diospyros*. The species *Diospyros peekelii* grows on Eloaua today, and Lepofsky was told that it was "an important food of the ancestors," although "the fruits are not highly regarded today" (1992:197). Peekel (1984:432–433) says that the trees are abundant in native gardens in the Bismarcks, although he characterizes the fruit as "tasteless." Orliac identified one of the wooden posts at Area B as made of *Diospyros* sp. wood (see below), further confirming the presence of a *Diospyros* on Eloaua during the period of Lapita occupation. Whether this species was *D. peekelii* will require further sampling to confirm.

Dracontomelon dao (Anacardiaceae)

Known as the Pacific walnut, this very tall tree (height up to 55 m) produces an edible, globose drupe (2–4 cm diameter). Peekel (1984:323) says that the fruit has a "sour, rather tart taste" and that "the native New Irelanders reject it." We initially thought that the tree was absent on Eloaua, but in 1988 Lepofsky located a single tree; the villagers reported that other trees had recently been cut down (1992:195). The Eloaua people do not eat the fruit today, although they claimed that they were eaten in the past.

The current lack of interest in *Dracontomelon dao* fruits among the Eloaua people contrasts markedly with the archaeobotanical situation, for the distinctive hard, lens-shaped, five-loculed stone of this fruit is highly represented at ECA (NISP = 478). The fruit does not float, and there can be little doubt that the presence of so many seeds at ECA is the result of cultural use and discard. Matthews and Gosden (1997:Table 1) also report the presence of *D. dao* seeds at the Arawe Islands Lapita sites.

Ficus sp. (Moraceae)

Douglas Yen (personal communication, June 26, 1989) identified 20 small, compressed-globose seeds from Area B at ECA as belonging to the fig genus *Ficus*. The genus is widespread throughout the Indo-Pacific region; Peekel (1984) reported at least 16 species in the Bismarck Archipelago, with a number of the species having cultural uses. These small seeds are unlikely to be natural drift, but without further identification to species it is not possible to infer how the plant might have been used at the Talepakemalai site. Further confirmation of the presence of at least one species of fig on Eloaua during Lapita times comes from Orliac's identification of a wooden stake in excavation Unit W250N170 as *Ficus* sp. (see below).

Inocarpus fagifer (Fabaceae)

The Tahitian chestnut, a large tree with a strongly buttressed and fluted lower trunk, bears clusters of ovoid fruit (each fruit measuring up to 13 cm long). The kidney-shaped seed, protected by a think, fibrous skin, must be cooked (usually baked in an earth oven) before it can be eaten, but has a taste not unlike that of a chestnut (with individual seeds weighing up to 50 g). *Inocarpus fagifer* is an important component of Oceanic arboricultural systems, and its geographic range extends from the Bismarcks as far east as the Marquesas and Austral Islands (Brown 1935:118–119). The Mussau people call it *iy* and regularly consume the cooked kernels.

The fibrous pericarps of *Inocarpus inocarpus* were abundant at ECA (NISP = 354); the fact that these were all half sections of the fruit attests to their having been opened for extraction of the edible kernel. There is little question, then, that the Tahitian chestnut was an important component of the Lapita diet at ECA.

Nypa fruticans (Arecaceae)

The nipa or mangrove palm was not observed on Eloaua Island today, but is a component of the mangrove forests on nearby Mussau Island. Peekel (1984:66) reports that the long, stiff fronds "provide excellent material for atap matting." *Nypa fruticans* is represented at site ECA by seven syncarp fragments; whether these reflect cultural use and discard, or whether they are the result of drift from nearby mangrove forests on Mussau Island, is uncertain.

Pandanus dubius, P. tectorius, and *Pandanus* spp. (Pandanaceae)

The diverse genus *Pandanus* includes some 750 recognized species distributed across the Old World tropics. Most are wild but several species are cultivated on Pacific islands, both for their edible drupes and for their flax-like leaves that can be dried and woven or plaited into mats, baskets, and other artifacts. *Pandanus* leaves are also widely used for thatching. Lepofsky (1992:201) identified five species of *Pandanus* that are cultivated on Eloaua Island: *P. dubius*, *P. conoideus*, *P. engelerianus*, *P. kaernbachii*, and *P. tectorius*. *Pandanus dubius*, with an especially large syncarp (aggregate fruit), is widely cultivated and consumed. The leaves of *P. kaernbachii* are used to make mats. *Pandanus tectorius*, with trees scattered across the interior limestone plateau, is an important snack food for people working in the gardens.

Pandanus drupes were quite abundant at ECA, but only a single drupe could confidently be identified as *P. dubius*. The drupes of *P. tectorius* were common (NISP = 136); one of these still had the impressions left by two incisor teeth that had stripped the fleshy meat off of the fibrous base of the drupe. Another 60 drupes were simply identified as *Pandanus* spp. without attribution to species.

Pangium edule (Salicaceae)

This tall tree (height 25–60 m) produces large fleshy fruit (sometimes compared to a football, which they resemble in shape and size), each fruit containing numerous seeds. The seeds are edible, but must first be processed to remove the toxic hydrocyanic acid (as with *Cycas*; see Merrill 1945:154, 187). Peekel (1984:384–385) says that the tree is common in the Bismarck Archipelago. In addition to eating the seeds after processing, the large woody pericarps were fashioned into rattles that were attached to belts for dancing (Nevermann 1933:62, Figure 20). On Eloaua, Lepofsky reports that "although almost exclusively eaten by the older generation today, the fruits and seeds were traditionally prized foodstuffs" (1992:197–198).

The distinctive, wrinkled, woody pericarps of *Pangium edule* were plentiful in the ECA site (NISP = 678), with this taxon being the third-ranked in the ECA assemblage (Figure 10.2). Only two were whole, indicating that the seeds had been opened for extraction of the kernel. There is little doubt that *Pangium edule* was an important component of the Lapita arboricultural complex.

Piper sp. (Piperaceae)

From three different excavation units along the W250 transect (N130, N140, and N181) we recovered six fragments of the distinctive woody stems of a large *Piper* sp., or kava plant, with their characteristic swollen nodes (Figure 10.3). The stem diameters range from 13–20 mm. The only *Piper* species with comparably large stems are the two varieties of *Piper methysticum*, *P. methysticum* var. *wichmanii* and *P. methysticum* var. *methysticum*. These were formerly regarded as two separate species, but Siméoni and Lebot (2014:24–25) now regard the former as the wild, and the latter as the cultivated, varieties of the same species. Most likely, the ECA *Piper* stems are of *P. methysticum* var. *wichmanii*, as the cultivated variety is thought to have been domesticated within the Vanuatu Archipelago, probably later in the Lapita period (Lebot and Levesque 1989). The kava stems from ECA are significant, for they indicate that the early Lapita occupants of the Bismarck Archipelago may have been already experimenting with the kava plant (presumably in a still wild, but possibly cultivated, form), thereby possibly discovering the psychoactive properties that would eventually make it one of the most important ritual and ceremonial plants in Oceania. Ross and others (2008:396) state that a Proto-Oceanic word **kawaRi* can be reconstructed, with a probable meaning of "potent roots," or "roots with special properties," including *Piper wichmanii*.

It is worth noting here the complete absence of the betel palm (*Areca catechu*) in the ECA site deposits. Were *A. catechu* present in Lapita times, its dense, fibrous husk should have preserved in the site's waterlogged deposits. Ethnohistorically, the consumption of betel was extremely important in the Mussau culture (Nevermann 1933), and kava was not known to be used. This suggests that the use of *Areca catechu* developed in Mussau in the post-Lapita period. One cannot help but recall Rivers's hypothesis that kava use may have first originated in the Bismarck Archipelago, and was associated with an early group of migrants into Melanesia (what he called the "kava people"), and that the use of the betel nut was a later development (Rivers 1914:2:243–257).

Figure 10.3. Stem fragments of *Piper* sp. from site ECA.

Pometia pinnata (Sapindaceae)

This large tree, sometimes called the island lychee, produces clusters of globose, edible fruit (3.5 cm diameter) with white, sweet, and aromatic flesh. Peekel (1984:335) reported the tree to be widespread throughout the Bismarcks, and highly valued. Yen (1974:266–268) indicates that *P. pinnata* is important in the arboricultural complex of the Santa Cruz Islands; it also occurs as far eastward as Fiji (Parham 1972:247) and Tonga (Yuncker 1959:173–174). Indeed, the Oceanic distribution of this species coincides remarkably with the area of Lapita dispersal. Lepofsky (1992:202) says that *P. pinnata* trees are "prominent in the arboricultural zones and forest near the villages" of Eloaua. In contrast with the evident important of this species in Eloaua today, we recovered just five seeds in the ECA excavations (Table 10.2), sufficient only to demonstrate that it was a part of the Lapita arboricultural complex, if only a minor one.

Spondias dulcis (Anacardiaceae)

The vi apple, a large tree with spreading crown, has a distribution ranging across most of the tropical Pacific, as far east as the Marquesas (Brown 1935:154). There is some dispute about whether *S. dulcis* was widely cultivated in Melanesia or merely a component of the natural forest, but in Polynesia, according to Yen (1974:265), "it was undoubtedly a cultigen, one of the few large succulent fruits among the indigenous economic plants." The fruit, which are up to 10 cm long, have a flesh that is crisp like an apple when still green, becoming increasingly acidic as the fruit ripens. Lepofsky reports that on Eloaua, *S. dulcis* fruits are "a favorite of children and pregnant women" (1992:195).

The distinctive endocarps of *Spondias dulcis* (Figure 10.1) were abundant in the ECA site (NISP = 613), making this the third-ranked macrobotanical taxon (Figure 10.2). The seeds do not float, and it seems evident that the vi apple was an important component of the Lapita arboricultural complex at Eloaua.

Terminalia catappa (Combretaceae)

Sometimes called the sea almond or tropical almond, *Terminalia catappa* is a common element of the coastal strand vegetation throughout the tropical Pacific (Merrill 1945:29), its seeds being naturally dispersed by floating. Although it disperses well and germinates easily in beach sands, the tree is also widely planted and cultivated in Melanesia and Polynesia (Barrau 1958:54). *Terminalia catappa* is common on Eloaua today, with the fruit being a "prized between-meal snack" (Lepofsky 1992:195). However, seeds of *T. catappa* were rare in the ECA deposits (NISP = 4). Given the fact that these seeds readily float, we cannot be certain whether this tree was actually a minor part of the Lapita arboricultural complex or simply part of the natural strand vegetation.

Metric Analyses of Key Taxa

The large series of well-preserved drupes and endocarps of four taxa at site ECA (*Canarium indicum*, *Dracontomelon dao*, *Pandanus tectorius*, and *Spondias dulcis*) offered an opportunity to conduct metric and statistical analysis of the size and shape of these specimens, in order to (1) compare them with modern reference materials, and (2) assess whether there was evidence for statistically significant size or shape changes over time. The results of this study, including details of the metrics and statistical analyses, were presented in full by Lepofsky and others (1998), and thus only the key findings are summarized here. Archaeological specimens of these four taxa from site ECA were divided into subgroups of Early, Middle, and Late, based on their stratigraphic associations along the W200 and W250 transects, in order to assess whether there was temporal change in seed size or shape over time. Analyses included univariate size comparisons (of seed length and width), univariate shape comparisons (using length/width ratios), and bivariate comparisons of size and shape (using Gaussian confidence intervals on bivariate centroids).

For *Canarium indicum*, the analyses demonstrated that the seeds became longer—but not consistently wider—over the time period that the ECA site was occupied. Modern reference seeds, however, were both longer and wider than the archaeological material. "Thus, there appears to be a trend among *Canarium* nuts towards increasing size and changing shape over time" (Lepofsky et al. 1998:1012). In the case of the *Dracontomelon dao* seeds, modern reference seeds from Manus Island and a single Late Period specimen from ECA are larger in both dimensions than the Early and Middle archaeological materials. For *Pandanus tectorius*, all three analyses showed no statistically significant changes in size or shape over time. For *Spondias dulcis*, the results indicate a "clear trend among the archaeological seeds, but not between the archaeological and modern reference material" (1998:1012). Lepofsky, Kirch, and Lertzman summarized the results of this study as follows:

> The results of our three analyses indicate clear changes in fruit size and shape over time for all tree crops except *Pandanus*. *Canarium* and *Dracontemelon* demonstrate changing shape and increasingly [sic] size among the archaeological and reference specimens, whereas only the *Spondias* archaeological specimens show such directional change in morphology. In *Canarium*, the changing morphology of the endocarp reflects selection for a larger edible kernel. . . . Both *Dracontomelon* and *Spondias*, unlike many other drupes which are selected for specific qualities of flesh, also exhibit a trend towards increasing size and changing shape of the endocarp [Lepofsky et al. 1998:1012].

The progression to larger seed sizes in three of these taxa is strongly suggestive of a process of cultural selection for larger fruits and nuts in the Bismarck Archipelago over the course of the last three thousand years.

Anaerobically Preserved Wood

In addition to the thousands of seeds and other macrobotanical material described above, the waterlogged deposits at Talepakemalai contained a substantial amount of preserved (non-carbonized) wood. After the 1986 field season, a selection of 22 wood samples from Area B was sent to C. Orliac at the Laboratoire d'Ethnologie Préhistorique (CNRS, U.A. 276) in Paris. Together with her colleague A. Plu at the Muséum National d'Histoire Naturelle (MNHN), Orliac endeavored to identify these specimens, although they were somewhat hampered by the lack of comparative reference materials. Nonetheless, with reference to materials in the MNHN, they were able to make preliminary determinations on a number of specimens, with the following taxa tentatively identified: *Cordia* cf. *subcordata*, *Calophyllum* cf. *inophyllum*, *Psychotria* cf. *tahitiensis*, *Terminalia* cf. *glabrata*, and *Diospyros* sp. (Orliac and Plu 1988a).

Following the 1988 field season, an additional selection of 33 preserved wood specimens, from both the W200 and W250 transects, Area C, and other excavation units, were again sent to Orliac and Plu. These specimens included the bases of several wooden posts or stakes, worked wood (showing cut marks from adze blades), and unmodified wood. In addition, I sent Orliac and Plu a collection of 40 modern wood samples that Lepofsky and I had collected on Eloaua in 1988. In collecting these wood samples, we had also prepared pressed herbarium voucher specimens that were sent to the Herbarium Pacificum at the Bernice P. Bishop Museum in Honolulu. Unfortunately, only 21 of these vouchers could be identified by the Herbarium staff, because many of the vouchers were sterile specimens. However, the 21 identified woods, together with reference to the collections at the MNHN in Paris, permitted the identification of 23 of the 33 specimens from the second lot (Orliac and Plu 1988b). Following standard wood identification procedures, the archaeological woods were sectioned with razor blades to expose the transverse, tangential longitudinal, and longitudinal radial sections. These sections were then examined under stereo, episcopic, and scanning electron microscopes, and comparison made with the reference materials. Results of the identification of the 33 samples submitted in 1988 are summarized in Table 10.4.

The largest number of identified wood specimens (N = 12) are of the coastal tree *Cordia subcordata*, also well represented by seeds (see above). Figure 10.4 is a scanning electronic microscope image of a tangential section through one of the ECA specimens of *C. subcordata* at 70X magnification. Many of these *C. subcordata* specimens are of wood chips or other pieces of wood showing adze cut marks. The wood of this tree is prized in many island societies for carving bowls or other objects, and it seems evident that the Lapita occupants at Talepakemalai were similarly fashioning artifacts from *C. subcordata*. The second most frequent wood is that of a *Syzigium* sp. (N = 6), possibly *S. malaccense*, which bears edible fruit. Figure 10.5 is a scanning electronic microscope image of a transversal section through one of the ECA specimens of *Syzigium* sp. at 70X magnification. The *Syzigium* wood was used for posts or stakes, but there are no adzed specimens. Two specimens, including one post, are of *Intsia bijuga*, a tree prized throughout the southwestern Pacific for its timber. The oily wood is resistant to water and

Table 10.4. Wood samples from Talepakemalai (Site ECA). Identifications by C. Orliac (Laboratoire d'Ethnologie Préhistorique, CNRS, Paris) and A. Plu (Laboratoire d'Ethnobiologie-Biogéographie, Muséum National d'Histoire Naturelle, Paris)

Unit/Level	Dimensions (cm)	Family	Genus and Species	Comments
W199N120/10	10 x 3	Boraginaceae	*Cordia subcordata*	Adzed wood chip
W199N120/11	5 fragments	Boraginaceae	*Cordia subcordata*	Adzed wood chip
W199N120/12	13 fragments	Boraginaceae	*Cordia subcordata*	Cut wood
W199N120/17		Boraginaceae	*Cordia subcordata*	
W199N120/9	6 x 3.5	Undetermined		Worked wood chip
W200N110	5.5 x 8.5 x 7	Cesalpiniaceae	*Instia bijuga*	
W200N120/10	5 x 1.8	Undetermined		
W200N120/8	6 x 2.5	Boraginaceae	*Cordia subcordata*	Worked wood chip
W200N120/9	6 x 2	Boraginaceae	*Cordia subcordata*	Small adze chip
W200N120/10	5.5 x 1	Boraginaceae	*Cordia subcordata*	Adzed wood chip
W200N160/8	4 x 6.5 x 6.5	Myrtaceae	*Syzigium* sp.	
W200N180/4	4.5 x 9 x 5	Myrtaceae	*Syzigium* sp.	
W220N140/6	4 x 1.5	Boraginaceae	*Cordia subcordata*	
W220N140/7	6.5 x 3	Myrtaceae	*Syzigium* sp.	
W240N140/6	5.5 x 3 x 9	Undetermined		
W240N140/7	4 x 3	Bark?		Possible worked wood
W240N140/7	3 x 7	Bark?		Worked wood
W249N158/3		Undetermined		
W250N110/A	12 x 2	Myrtaceae ?		Pointed stick with adzed cut at end
W250N110	4.5 x 5.5	Myrtaceae		Post 1
W250N110	7.5 x 6 x 3.5	Myrtaceae	*Syzigium* sp.	Post 3
W250N110/13	6 x 2	Boraginaceae	*Cordia subcordata*	Adzed wood chip
W250N120/9	6 x 6	Undetermined		Post 2
W250N120/1	9 x 7.5 x 3	Myrtaceae	*Syzigium* sp.	Post
W250N130/13	2.5 x 1.5	Boraginaceae	*Cordia subcordata*	Wood with multiple adze cuts
W250N140/6	2.5 x 5 x 6.2	Rubiaceae	*Neonauclea* sp. ?	
W250N150/8	9.5 x 4	Boraginaceae	*Cordia subcordata*	
W250N170/3	4 x 6 x 10	Moraceae	*Ficus* sp.	Adzed base of wooden stake
W250N170/6	4.5 x 3.3	Boraginaceae	*Cordia subcordata*	Adzed wood chip
W250N181/6	8 x 5 x 6	Undetermined		Post
W250N181/7		Myrtaceae	*Syzigium* sp.	Post 2
W250N188	2.5 x 5 x 3.5	Ebenaceae	*Diospyros* sp.	Post
W250N191	6.5 x 13 x 6.5	Cesalpiniaceae	*Intsia bijuga*	Post

Figure 10.4. Scanning electron microscope image of a specimen of *Cordia subcordata* wood from the ECA site (magnification X70; photo by C. Orliac).

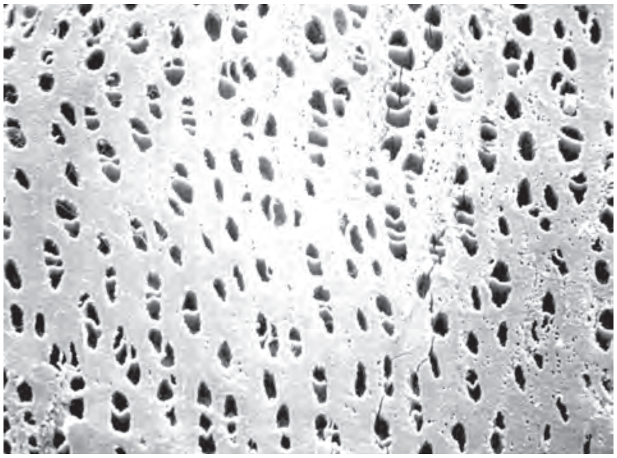


Figure 10.5. Scanning electron microscope image of a specimen of *Syzigium* sp. wood from the ECA site (magnification X70; photo by C. Orliac).

termites; thus it is not surprising that this wood was selected for use as stilts to support the Mussau houses. In addition to the above, there is one specimen each of a *Ficus* sp., a *Diospyros* sp., and a *Neonauclea* sp.

Conclusions

The unprecedented preservation in anaerobic, waterlogged deposits at site ECA of thousands of seeds and other plant parts provides significant direct evidence that Lapita people who occupied Eloaua Island over several centuries from the late second millennium to early first millennium BC practiced sophisticated arboriculture, and that the consumption of a range of tree crops was an integral part of their subsistence economy. It should be stressed, however, that taphonomic factors have undoubtedly affected the nature of this macrobotanical assemblage, with only woody or fibrous, highly resistant plant parts being preserved. The absence of soft tissues such as the parenchyma of tubers or the flesh of fruits such as bananas or breadfruit does not indicate that crops with these kinds of edible fruit or tubers were lacking at Talepakemalai. Indeed, other lines of evidence strongly suggest that taro, yams, breadfruit, and bananas were also part of the Lapita horticultural complex (see Chapter 13).

The 22 taxa represented at site ECA (Table 10.2) can be divided into the following four groups, based on the evidence for their being cultivated, culturally used, naturally present (but not cultivated), or deposited as natural drift:

> Group 1, Taxa with unequivocal or very strong evidence of cultivation and/or cultural use: *Atuna racemosa*, *Burckella obovata*, *Canarium indicum*, *Cocos nucifera*, *Corynocarpus cribbianus*, *Cycas rumphii*, *Dracontomelon dao*, *Inocarpus fagifer*, *Pandanus dubius*, *Pandanus tectorius*, *Pangium edule*, *Piper* sp., *Pometia pinnata*, *Spondias dulcis*.
>
> Group 2, Taxa present on Eloaua but not necessarily cultivated: *Casuarina equisetifolia*, *Cordia subcordata*, *Diospyros* sp., *Ficus* sp.
>
> Group 3, Taxa possibility used culturally but for which natural deposition (drift) is also likely: *Bruguiera rhizophora*, *Nypa fruticans*, *Terminalia catappa*.
>
> Group 4, Taxa likely to have been deposited as a result of natural drift: *Aleurites moluccana*, *Calophyllum inophyllum*.

Group 1 includes 14 taxa for which there is high confidence that these were cultivated and deposited in the site as a result of cultural use. The plants in this group include many that are key elements in ethnobotanically documented Melanesian arboriculture (Barrau 1958; Yen 1974), indicating that this distinctive tree crop complex can be traced back at least to the Lapita cultural complex. The deeper history of the domestication of many of these species is, of course, an issue that will need to be pursued with future ethnobotanical and archaeobotanical research in both Near Oceania and island Southeast Asia.

CHAPTER 11

Ceramic Assemblages of the Mussau Islands

Patrick Vinton Kirch and Scarlett Chiu

Pottery has always been the *sine qua non* of Lapita archaeology. The evident similarities between the highly distinctive dentate-stamped ceramics from the eponymous site of Lapita at Koné, New Caledonia, and those previously excavated by McKern (1929) in Tonga and by Meyer (1909, 1910) at Watom near New Britain provided the clue that Gifford needed to first recognize the existence of a ceramic horizon extending across much of the southwestern Pacific (Gifford and Shutler 1956). Golson (1971) soon defined Lapita as a "ceramic series," arguing that its extension across the southwestern Pacific spoke to "some early community of culture" linking the ancestral cultures of Melanesia with those of Western Polynesia. Although Green (1979a) extended the definition of the Lapita "cultural complex" beyond ceramics—to include other aspects of material culture, settlement patterns, economy, and trade—he also expanded upon and elaborated Golson's concept of Lapita pottery as a "ceramic series." Drawing upon detailed analyses of both vessel form and decorative motifs, Green wrote:

> The restricted number of rules needed to generate the Lapita style from its elements, and the demonstration of a substantial corpus of early motifs spread from Watom to Samoa, are the most convincing evidence available that the style reflects a unified system known to the makers of the pots everywhere. The likelihood that we are dealing culturally with a series of closely related communities is therefore great. Yet each center or region also has its own unique motifs and developmental sequence [Green 1979a:40].

In the four decades since Green outlined these fundamental characteristics of the Lapita ceramic series, our knowledge of the ceramic complex and its variation through time and space have expanded considerably.

Most Lapita scholars recognize a geographic subdivision of the Lapita ceramic series into four main regions: *Far Western Lapita*, focused on the Bismarck Archipelago; *Western Lapita*, centered on the Santa Cruz Islands and

Vanuatu; *Southern Lapita*, encompassing the Loyalty Island and New Caledonia; and *Eastern Lapita*, spanning Fiji to Tonga and Samoa (Kirch 1997; Sand 1997, 2010). Within each region temporal sequences are evident, so one needs to distinguish between early and subsequent phases. It is, of course, this three-dimensional variation over both space and time that renders Lapita a ceramic *series*, combining aspects of both *horizon* and *tradition*, in the framework of classic Americanist culture history.

The Lapita pottery assemblages of Mussau fall within the Far Western subgroup, and indeed the early finds of Egloff (1975; Bafmatuk et al. 1980) from Eloaua, along with those from Watom, Ambitle, and Talasea, were essential to Anson's initial definition of a distinctive Far Western Lapita province (Anson 1983, 1986). A decade later, Summerhayes (1996, 2000a) incorporated the results of Lapita Homeland Project excavations in West New Britain to further refine the nature of Far Western Lapita and the exchange interactions between the Lapita communities of the Bismarcks. In addition to the Mussau finds, important ceramic assemblages have now been recovered from sites distributed around the arc of the Bismarck Archipelago, including those at the Arawe Islands (southwestern New Britain), Boduna (Willaumez Peninsula of New Britain), the Duke of York Islands, Watom, Kamgot (Anir Is.), and Emirau (see the site list in Summerhayes 2010:92–93). In spite of these finds, there has been a dearth of descriptive analyses of the ceramic assemblages from these Far Western Lapita sites, including such essential details as scale drawings and photographs of reconstructed vessels and illustrations of the full range of decorative motifs. In our view, such detailed accounts are essential in providing the foundation for comparative analyses, and it is for this reason that we have endeavored to provide a full account of the Mussau pottery assemblages in the present chapter.

Analytical Approach and Methods

After washing and drying, sherds from all excavations were first examined and sorted in the field into categories of plain body sherds and of "diagnostic" sherds, the latter including rims, carinations, bases, sherds with any form of decoration or any other unusual characteristic. Due to the prohibitive expense of shipping large quantities of sherds to the laboratory, only selected lots of plain body sherds were retained (representative lots were deposited in the Papua New Guinea National Museum). The remainder of the plain body sherds were discarded in Mussau. All diagnostic sherds were sent to the laboratory in Seattle (and later moved to Berkeley) for further study.

Kirch's initial approach to the analysis of the Mussau ceramics was that of a *sherd-based attribute analysis*, in which systematic observations of individual sherds were entered into a database, with each sherd providing a single record. The attributes selected for recording were based on Kirch's prior experience with ceramic assemblages from Niuatoputapu (Kirch 1988a) and Tikopia (Kirch and Yen 1982), also following methods advocated by Shepard (1963), Rye (1981), and Bennett (1974). In addition to basic provenience data (site, excavation unit, level), the following attributes with their possible attribute states were recorded:

Sherd Type: 1, Body sherd; 2, Rim/neck, with lip intact; 3, Rim/neck, lip missing; 4, Carination; 5, Base; 6, Rim/neck + carination; 7, Rim/neck + body; 8, Rim/neck + body + base; 9, Pedestal or ring foot.

Vessel Form: 0, indeterminate; 1, simple bowl; 2, carinated bowl; 3, bowl attached to pedestal; 4, bowl, either 1 or 2 (above); 5, flat-bottom dish (flaring sides); 6, large carinated jar; 7, narrow-necked jar; 8, cylinder stand; 9, "drum"; 10, large jar, otherwise indeterminate; 11, lid.

Temper Type: temper was recorded as a four-digit numeric field, with most to least frequent temper grains noted in rank order: 0, indeterminate; 1, calcareous sand; 2, black sand (dark minerals, e.g., pyroxene); 3, translucent sand (light minerals, e.g., quartz); 4, shell fragments (not rounded); 5, olivine sand; 6, pumice fragments.

Firing Core: 0, indeterminate; 1, pronounced; 2, present but not pronounced; 3, absent (wholly oxidized).

Main Motif Decorative Technique: This was recorded as a five-digit numeric field, with each category indicated by 0 for absent, 1 for present. Category 1: fine dentate stamping; Category 2: coarse dentate stamping; Category 3: Incising; Category 4: Carving or cutouts; Category 5: Shell impressed.

Lip Edge Decorative Technique: This was recorded as a six-digit numeric field, with each category indicated by 0 for absent, 1 for present. Category 1: fine dentate stamping; Category 2: coarse dentate stamping; Category 3: Incising; Category 4: Carving or cutouts; Category 5: Notching (tool notched); Category 6: Crenate (finger pinched).

Inner Vessel Edge Decorative Technique (numeric, 4 chars): Recorded as a four-digit numeric field, with each category indicated by 0 for absent, 1 for present. Category 1: fine dentate stamping; Category 2: coarse dentate stamping; Category3: Incising; Category 4: Carving or cutouts.

Raised Bands (presence/absence): I, indeterminate; Y, present; N, absent.

Lime-Infilling (presence/absence): I, indeterminate; Y, present; N, absent.

Exterior Surface Treatment: 0, indeterminate; 1, eroded; 2, burnished or smoothed; 3, red-slipped.

Rim Form: 0, indeterminate; 1, vertical; 2, everted; 3, inverted; 4, sharply out-turned (90° angle).

Lip Form: 0, indeterminate; 1, flat; 2, outward beveled; 3, inward beveled; 4, rounded; 5, double-beveled; 6, expanded; 7, grooved; pointed.

Rim Diameter: recorded in centimeters, to nearest cm.

Lip Thickness: recorded in millimeters, to nearest mm.

Vessel Wall Thickness: recorded in millimeters, to nearest mm.

Lip Edge Motif: Recorded using the catalog numbers in Anson (1983).

Exterior Defining Motif: Recorded using the Anson catalog number of the motif defining the upper part of the main body decoration (zone marker).

Main Exterior Motif: Recorded using the Anson catalog number of the motif; 999 if not present in the Anson catalog.

In the initial years of laboratory analysis following the completion of fieldwork in 1988, a total of 2,297 sherds from sites ECA (924 sherds), ECB (830 sherds), and EHB (523 sherds) were analyzed according to this protocol. The data were at first recorded using Borlan's Paradox database system, and were later migrated to Microsoft Excel and Access platforms.

In 2010, Kirch invited Chiu—who was then engaged in establishing the Lapita Pottery Online Database (LPOD) at the Academia Sinica in Taiwan—to collaborate on the analysis of the Mussau pottery. The core of the LPOD involves a standardized recording procedure for Lapita assemblages throughout the southwestern Pacific, with the goal of ultimately allowing for systematic comparisons between site assemblages (http://lapita.rchss.sinica.edu.tw/web/). Beginning in the summer of 2010, and for several subsequent summers up through 2015, Chiu and her assistants used the LODP system in Kirch's Berkeley laboratory to record 6,976 sherds from sites ECA, ECB, EHB, and EKQ. This effort included not only the recording of an expanded suite of attributes, but also photographing of all sherds. These data and photographs have been incorporated into the LPOD.

During initial analysis, Kirch recognized that many sherds from ECA in particular could be refitted, and began to rejoin sherds to form partially reconstructed vessels. Chiu and her assistants picked up where this effort had left off, so that by 2017 a substantial number of vessels had been reconstructed, at least sufficiently to determine vessel diameter and hence to prepare drawings showing the reconstructed vessel forms with their decorative motifs. This work allowed Kirch to prepare a Mussau Ceramic Catalog of 269 such reconstructed vessels, which he compiled during the 2017–2018 academic year. The catalog is available online in the Supplementary Materials to this volume. Please see www.dig.ucla.edu/talepakemalai. The catalog allowed for a second, complementary approach to the ceramic analysis, in which the reconstructed vessels rather than individual sherds form the basis for determining frequency trends. In reporting on the various Mussau ceramic assemblages in this chapter, we have drawn upon both the sherd-based and the vessel-based data sets as appropriate.

The recording of Lapita pottery decoration, which can be quite complex as it involves combinations of multiple motifs, has posed a challenge since the initial efforts of Mead and others (1975) to document the relatively simple Lapita pottery of Fiji. In spite of efforts to extend the Mead system to Western and Far Western Lapita assemblages (Donovan 1973; Sharp 1988), following Anson (1983) most researchers have adopted simple numbered lists or indexes of motifs. For the LPOD project, Chiu compares the motifs on a specimen against all other motif lists and associated graphics in order to determine the uniqueness of the motif in question. Whenever possible, a drawn motif is also compared against the original sherd that contains such a motif to verify not only the accuracy of the line drawing, but also what techniques were employed to execute it. Rather than lumping motifs made of different orientations of a given design element into a single motif ID, or combing two or even three bands of motifs that are separated with lines of void spaces into one motif, in the LPOD these cases are assigned a new motif identification number and treated separately.

Once a new decorative motif has been recognized, a unique motif ID number is assigned. Usually the initials of the excavator are used to create new motif IDs for that particular assemblage (thus motifs uniquely identified in the Mussau assemblage are numbered PK1 to PK*n*). When a motif is too fragmented to reconstruct its original pattern, it is assigned an ID starting with "TFG" (Too Fragmented), in order to separate it from the more complete motifs that may contain grammatical information. Attributes such as what techniques were used to create it, what design elements and design units were used to compose it, what construction rules had been applied to generate it, what larger motif "theme" or family it belongs to, and where it appears on a ceramic vessel, are all coded in the LPOD. We have used the motif ID numbers as recorded in the LPOD in our descriptions in the Mussau Ceramic Catalog, available online in the Supplementary Materials. A total of 472 new motifs have been identified in the Mussau ceramic assemblage.

Whether a motif may be assigned to a particular motif "theme" depends on whether it appears on the central decorative panel on the surface of a vessel (Chiu and Sand 2005; Sand 2007, 1996). If so, the next step is to determine whether it is an alloform of a more general decorative pattern shared with similarly constructed motifs. In all, 32 motif themes have been recognized so far in the LPOD, and some of these themes can be further divided into subcategories. For example, the face motif theme is further divided into "undetermined," "triangular face," "long-nose face with headdress," "simple face," "odd face," and "double face," a total of six subcategories. Each of these subcategories has its particular construction grammar while maintaining the basic shared underlying concept of a face in its various designs. Different subcategories of a given motif theme seem to have acquired rather different emphases among island groups; for example, long-nose face motifs are far more popular in the Reefs/Santa Cruz Lapita ceramic assemblages, while simple faces are the most abundant subcategory in the New Caledonian Lapita sites (Chiu 2007). Similar observations hold for other motif themes as well (Chiu 2015).

Overview of the Mussau Ceramic Assemblages

Over the course of our three field seasons, ceramic assemblages were recovered from nine excavated sites (Table 11.1), with a total of 71,216 sherds, of which 43,040 (60.4%) are from the Talepakemalai or ECA site. Aside from ECA, significant assemblages were recovered from the two smaller Lapita sites of ECB and EHB, from the EKE site on Boliu Island, and from the EKQ rockshelter on the northwestern side of Mussau Island. Small quantities of sherds were also found at three small rockshelters on Eloaua Island (sites EHM, EKO, and EKP), and at the open site of Sinakasae (EKU) on Mussau Island.

The majority of this ceramic material—some 88.7% by count—consists of plain body sherds (Table 11.1). Given the large numbers and sheer weight of plain body sherds, it was not possible transport all of these back to the laboratory. Therefore, after counting and weighing in the field, some sets of body sherds were discarded, while other sets were deposited in the National Museum in Port Moresby. Only selected, representative lots of plain body sherds were returned to the lab for further study.

Diagnostic sherds, making up 11.3% of the total collected, are defined as those exhibiting rims, carinations, bases, decoration, or any other features that are useful in defining characteristics of the ceramic assemblages. All diagnostic sherds were returned to the laboratory. Sherds bearing some form of decoration, a subset of the diagnostic sherds, make up 8.8% of the total collection.

Variation in Mussau Ceramic Tempers

It has long been recognized that the addition by Lapita potters of non-plastic inclusions, or temper, to their clay mixes can provide important information relating to where individual pots were likely to have been made, and to the

Table 11.1. Summary of ceramics from Mussau excavated sites

Site	Total Sherds	Plain Body Sherds		Diagnostic Sherds		Decorated Sherds	
		N	%	N	%	N	%
ECA	43,040	38,456	89.3	4,584	10.6	3,267	7.5
ECB	8,159	7,265	89.0	894	10.9	487	5.7
EHB	7,470	6,925	92.7	545	7.3	486	6.5
EHM	2	2	100	0	0	0	0
EKE	1,761	1,742	98.9	19	1.1	15	0.8
EKO	219	193	88.1	26	11.9	11	5.0
EKP	63	63	100	0	0	0	0
EKQ	10,447	9,721	93.0	726	6.9	576	5.5
EKU	55	46	83.6	9	16.4	4	7.3
Totals	71,216	64,413	90.4	6,803	9.5	4,846	6.8

exchange or trade of ceramics between island communities. The late William Dickinson, in particular, over a long career analyzed temper suites from Pacific archaeological ceramics, with often significant results (Dickinson 2006; Dickinson and Shutler 1979, 2000). Less attention has been paid to the analysis of variation in clay composition in Oceanic pottery. In the Mussau project, we explored both approaches to the characterization of variability in the Lapita ceramic assemblages.

During the sherd-based analysis of assemblages from the ECA, ECB, and EHB Lapita sites, a total of 1,098 sherds were examined in hand specimen (using a low-power binocular microscope) and coded for temper composition using a simple rank-order system. Scanning an exposed edge of a sherd, temper grains were identified according to the following categories: 1, calcareous sand grains; 2, dark mineral grains, such as pyroxene; 3, light or translucent mineral grains, such as feldspar or quartz; 4, marine shell fragments; 5, olivine mineral grains; and 6, pumice fragments. Up to four different constituents were then recorded, in rank order according to their relative abundance. Thus, a code of 1000 would indicate exclusively calcareous grains, while a code of 2130 would indicate a mix with dark minerals, calcareous sand, and light minerals in that descending order of abundance.

Table 11.2 summarizes the results of this initial stage of analysis of temper variation in sherds from the three principal Lapita sites. The greatest number of discrete temper combinations—some 20 different mixes—occurs at Area B in site ECA, with somewhat less variation at sites ECB and EHB. At ECA and ECB, sherds with exclusively calcareous temper make up 45% of the assemblages, while at EHB this rises to 79%. Less abundant at all sites are temper mixes in which calcareous grains dominate, but occur together with various combinations of other terrigenous grains such as pyroxene or feldspar. Sherds lacking any calcareous grains, in which dark minerals are dominant, make up nearly 17% of the assemblage at ECA, Area B, 10% at ECB, and just 2% at EHB. Other temper combinations are present in low frequencies at ECA and ECB, but are entirely lacking at the early EHB site.

This initial characterization of temper variation in the Mussau Lapita pottery—while admittedly coarse-grained—nonetheless provides some key insights. First, of the three site assemblages, the ceramics at ECA Area B have the greatest variability in temper mixes. Second, sherds with exclusively calcareous sand temper make up a large part of these assemblages, especially at EHB. Given that Eloaua and Emananus are exclusively coralline islands, we cannot rule out the possibility that some of the pottery present

Table 11.2. Temper composition of Mussau Lapita pottery

Attribute	ECA, Area B	ECB	EHB
N sherds analyzed for temper	208	376	514
N temper combinations present	20	13	11
Calcareous temper only (%)	45.2	45.5	79.4
Calcareous temper dominant with other terrigenous grains present (%)	35.6	43.3	18.5
Dark mineral grains dominant (%)	16.8	10.6	2.1
Other temper mixes (%)	2.4	0.3	0

in these sites was locally manufactured, although the clay would have had to be imported from other sources, as clays are lacking on both islets. However, importation of pottery with exclusively calcareous temper is also likely. Third, sherds with terrigenous grains (dark and light minerals, and olivine) are unlikely to have come from pots manufactured on either Eloaua or Emananus, unless both the clay and temper were transported to these coral islands from elsewhere.

In order to characterize the Mussau tempers in greater detail, Kirch initially sent twelve sherds recovered from the 1985 test pits to William Dickinson for thin-sectioning and petrographic analysis. When Dickinson was able to visit Kirch's laboratory following the 1988 excavations, they selected for petrographic analysis an additional 49 sherds, primarily from the Area B extension at site ECA (33 sherds), but also from Area C at ECA (10 sherds) and from the EHB site (6 sherds). These sherds were carefully selected to ensure that the range of decoration (fine dentate, coarse dentate, incising) at ECA and EHB was represented. During this visit, Dickinson examined *all* of the diagnostic sherds from the Area B extension in hand specimen, concentrating in his selection of sherds for further petrographic analysis on those with evident non-calcareous tempers.

Dickinson's report on his petrographic analysis of the 61 sherds from Mussau is provided in Chapter 13. As summarized here in Table 11.3, ten discrete temper groups were defined, of which group A consists of sherds with exclusively calcareous sand grains, while the nine other groups consist of various combinations of terrigenous grains. Five of the temper groups appear exclusively at ECA (groups C, D, E, F, and K), and one group (J) appears only in Area C at ECA. The other four groups (A, B, G, and H) occur at both the ECA and EHB sites. As suggested by our initial hand-specimen characterization of temper variation (Table 11.2), the greatest variability in non-calcareous tempers is found in Area B at site ECA, with Area C at ECA and site EHB having less variation. In Chapter 13, Dickinson discusses the possible source areas for the different temper groups, which include the Admiralty Islands (Manus), New Ireland and its offshore islands (the Lihir group), New Britain, and even the New Guinea mainland. The fundamental take-home message of Dickinson's analysis, however, is that Lapita ceramics in Mussau without doubt included *a significant number of vessels that were imported from several different source areas around the Bismarck Archipelago*. This reinforces the idea that Mussau was an important aggregation node for several different Lapita communities dispersed around the Bismarcks region.

Elemental Microanalysis of Mussau Ceramic Clay Composition

During the intensive laboratory analysis of the Mussau collections following the 1986 field season (see Chapter 1), Terry Hunt conducted an energy-dispersive X-ray microanalysis of the clay composition in a sample of 172 sherds selected from sites ECA (Areas A and B), ECB, EHB, EKQ, and EKU. The aim was to complement the hand-specimen temper analysis with a parallel analysis of the variation in chemical composition of the clays making up the Mussau pottery fabrics. This analysis built upon

Table 11.3. Distribution of Dickinson temper groups by site

Dickinson Temper Groups	ECA, Initial Test Pits	ECA, Area B	ECA, Area C	EHB	Total for Type
A. Calcareous		3	3	2	8
B. Calcareous with rare terrigenous grains		9	3	2	14
C. Hybrid placer, rich in opaque iron oxides	3	7			10
D. Opaque-rich placer	1	2			3
E. Hornblendic-feldspathic, pyroxene-free volcanic	3	1			4
F. Hornblendic-feldspathic, pyroxene-bearing volcanic	2	3			5
G. Pyroxenic volcanic	1	6	1	1	9
H. Hybrid non-placer		1	1	1	3
J. Quartzone-feldspathic volcanic			2		2
K. Feldspathic-pyroxenic volcanic	2	1			3
Total sherds examined per site	12	33	10	6	61

the pioneering work of Anson (1983), who had pioneered the application of X-ray microanalysis to Lapita ceramics.

The full methodological details and results of Hunt's study are presented in his unpublished doctoral dissertation (Hunt 1989), with only the principal highlights summarized here. Hunt's analysis was conducted with a JEOL model JSM-840A scanning electron microscope (SEM) fitted with a Tracor Northern energy-dispersive X-ray detector housed in the Department of Botany at the University of Washington. Sherds selected for microanalysis were vacuum-impregnated with casting resin, cut into 5 mm thick sections, and polished with fine wet silicon carbide cloth. The thick sections were then mounted on pure carbon or aluminum SEM stubs, and left uncoated. During the microanalysis procedure, specimens were viewed on the SEM's CRT screen to ensure that the point selected for analysis consisted only of clay matrix lacking any inclusions or other anomalies. X-ray data were collected for a minimum of 100 seconds, with most samples being characterized more than once to ensure replicable compositional data. The following twelve major and minor elements were within the detection limits of this machine system, and were selected for analysis: Na, Mg, Al, Si, P, Cl, K, Ca, Ti, Cr, Mn, and Fe.

In addition to the 172 sherds recovered from our excavations, Hunt analyzed three geological clay samples: one from Mussau Island and two from the Admiralty Islands (Manus). The Mussau clay was collected by Kirch in 1986, who was shown this source by villagers from Tanaliu Village, who use the clay for body paint and for medicinal purposes. The Admiralty Island clays, one each from the small islands of Mbuke and Hus, were obtained courtesy of Margaret Tuckson, who had collected these potting clays in the field (May and Tuckson 1982). Ceramic tiles prepared from these three clay samples were fired at 500° C for 15 minutes. Thick-sections of the fired tiles were prepared as for the sherds, and analyzed in the same manner as the archaeological samples. Although the three clays are similar, with a high ratio of silicon to aluminum, cluster and discriminant function analyses demonstrated that the clays were "sufficiently distinct to be reliably separated using a variety of quantitative methods" (Hunt 1989:178).

The energy-dispersive X-ray data for the 175 ceramic sherds and for the three source clay specimens were analyzed using two agglomerative hierarchical clustering procedures, complete (furthest neighbor) linkage and average (between groups) linkage, using the SPSS-X statistical package (version 3.0). The results of these clustering procedures were plotted as dendrograms, yielding clusters of sherds (and for three clusters, incorporating the clay tiles). Only clusters that grouped identical sets of specimens in both clustering procedures were considered to be valid. The result was 16 cluster solutions containing a total of 150 specimens; the remaining 25 sherds that did not fall into identical groups using both clustering procedures were regarded as unreliable and discarded from the analysis. Three of the clusters included one each of the source clays (group 7, the Mussau clay; group 8, the Mbuke clay; and group 10, the Hus clay) along with one or more archaeological samples. Hunt interpreted the archaeological sherds clustering with their respective source clays as having originated from those sources. The remaining 13 clusters represent different clay compositional groups at present unmatched to known clay sources. These unmatched clusters could potentially derive from other locations on Mussau Island, in the Admiralty Islands, or elsewhere in the Bismarck–New Guinea region.

A summary of the clay compositional microanalysis results is presented in Table 11.4, showing the frequency of analyzed sherds by cluster and site. Site ECB and Area B at site ECA have the greatest number of clay compositional groups represented, with 12 and 11 clusters respectively. The EHB site has nine clusters represented, EKQ eight clusters, and Area A at ECA just six clusters. The EKU site, which is post-Lapita in age, has just three clusters present. Cluster 7, which includes the Mussau clay source, is present only at sites ECB and EKQ; the presence of this clay source at EKQ is not surprising, given the proximity of the EKQ rockshelter to the Mussau clay source. Cluster 8, containing the Mbuke clay source, is represented at ECA Area A, ECB, and EKQ. The Hus clay source, falling into cluster 10, includes only one archaeological sherd, from the post-Lapita EKU site.

One especially significant result of the energy-dispersive X-ray microanalysis is to highlight the diversity of clay sources in sherds containing only calcareous sand temper. Of the sherds analyzed by Hunt, 116 contained only calcareous sand temper (temper code 1000), yet 14 of the 16 clay compositional groups were represented within this subsample (Hunt 1989:Figure 7.3). Thus, while based on temper alone one might be tempted to ascribe a local origin to the calcareous-sand tempered ceramics, this is clearly not justified on the basis of the clay compositional analysis. Indeed, there is substantial variation within the calcareous-sand tempered pottery, and multiple origins are indicated.

It is also noteworthy that none of the known clay sources is represented at Area B of site ECA; Hunt thus concluded that "the proportion of the ECA Area B pottery assemblage of exotic origin is estimated to be as high as 100%" (1989:200). Comparison of clay compositional clusters with decorative technique is also informative: "When the clay compositional results are compared to the results of the simple chi-squared tests of temper-decoration associations, it appears that while all pottery [of Area B, ECA] is exotic, decorated pottery appears to come from production sources which used non-calcareous (i.e., volcanic sand mixtures) temper sands more often than those using calcareous sand alone" (Hunt 1989:201).

To sum up, macro-scale characterization of temper, petrographic analysis of temper, and energy-dispersive X-ray analysis of clay composition all reveal a high degree of variation in the Mussau ceramic assemblages. Even though a large fraction of the Mussau Lapita pottery is tempered with calcareous sands, it is evident from the clay compositional analysis that most of these ceramics are not of local origin. Both the petrographic analysis of temper and the compositional analysis of the clays indicate that as many as ten to twelve different source areas or production centers are represented by the ceramic assemblages at sites such as ECB and ECA Area B. This significant variation reinforces the interpretation of the Mussau Lapita sites as not simply local communities that produced and used their own pottery, but rather as aggregation nodes where multiple communities or representatives of those communities gathered to exchange and use pottery together.

Manufacture and Surface Treatment

All of the Mussau pottery consists of earthenware made from a variety of clay and temper mixes. The most common temper constituent was calcareous sand, but various volcanic and other terrigenous sands are also well represented (Tables 11. 2 and 11.3). Slab-building was the dominant method of vessel forming, as indicated by occasional incomplete slab joins visible in vessel wall sections. Bases were sometimes thickened with the additional of a second slab. There is no evidence for the use of a wheel. The paddle-and-anvil method of vessel wall thinning, in which an anvil

Table 11.4. Results of energy-dispersive X-ray microanalysis of Mussau ceramics (modified from Hunt 1989:Figure 7.1)

Compositional Cluster	Source Clay	ECA Area A	ECA Area B	ECB	EHB	EKQ	EKU	Total
1		6	1	4		7	1	19
2		1	10	1	1			13
3		1	4	2	6	1		14
4				3	1	1		5
5		3	3	3	1	5		15
6			10	2	3			15
7	1 (Mussau)			3		3		7
8	1 (Mbuke)	1		1		6		9
9						3		3
10	1 (Hus)						1	2
11		2	8	3	2			15
12			1		1	1	1	4
13			6	5	5			16
14			1	1				2
15			6	1	3			10
16			1					1
Unassigned sherds		4	5	4	6	5	1	25
Total specimens	3	18	56	33	29	32	4	175
N clusters represented		6	11	12	9	8	3	

(typically a rounded cobble) is held against the inner wall of the vessel while the outer wall is beaten with a wooden paddle, is evidenced by anvil impressions on the interior surfaces of a number of sherds deriving from jars (vessel form II, see below). The paddle-and-anvil method is well evidenced ethnographically in Oceania (May and Tuckson 1982; Palmer et al. 1968).

After vessel forming, the exterior and sometimes interior surfaces (especially of unrestricted bowls and of flat-bottom dishes) were finished in several different ways. Based on a sample of 213 reconstructed vessels that have non-eroded surfaces, the most common finishing technique (68.5%) was simple wiping and smoothing of the surface. In some cases the wiping was done with a coarse material, possibly barkcloth, leaving fine parallel striations. In about a quarter of the vessels (26.3%), the surfaces were burnished, removing the wiping striations and leaving a uniformly smooth, hard surface. This burnishing was most likely done by rubbing a smooth pebble over the surface. Burnishing appears most often on unrestricted bowls and jars, although it was also done to the surfaces of some flat-bottom dishes. The application of a thin red or reddish-orange slip is also evidenced, on 5.2% of the reconstructed vessels.

In general, the Mussau earthenwares are quite low fired; we have no evidence of kilns, and firing was presumably carried out with simple open pyres. Ethnographically, firing practices in Oceania sometimes make use of a bed of hot-burning coconut shells, with other fuel such as wood and coconut fronds then placed on and around the pots to be fired (Palmer et al. 1968). During the analysis of

Table 11.5. Frequency of firing cores in diagnostic sherds at sites ECA (Area B), ECB, and EHB

Firing Core Type	Site ECA		Site ECB		Site EHB	
	N	%	N	%	N	%
Pronounced unoxidized core	77	25.2	255	35.4	84	25.8
Unoxidized core present	131	49.9	236	32.7	129	39.7
Fully oxidized sherd	97	31.8	230	31.9	112	34.5
Totals	305		721		325	

diagnostic sherd assemblages from sites ECA (Area B), ECB, and EHB, the nature of firing cores was recorded whenever the sherd section permitted, and the results are tabulated in Table 11.5. Some kind of inoxidized core, indicative of low temperature or incomplete firing, is present on roughly two-thirds of all sherds, with fully oxidized or completely fired pots accounting for just one-third of the sherds examined.

Ceramic Vessel Classification

Despite considerable variation in size and in details of rim and lip form, in terms of general vessel form or shape, the Mussau ceramics fall into six broad categories: I, bowls; II, jars; III, flat-bottom dishes; IV, bowls supported on pedestals or ring feet; V, cylinder stands; and VI, lids. The differences in shape between these categories must also imply significant functional differences. These broad shape categories—and important subcategories within the bowls and jars—can be formally defined using the shape criteria originally proposed by Shepard (1965:Figure 22), as in Kirch's classification of Lapita vessel forms on Niuatoputapu (Kirch 1988a:Table 22). Table 11.6 provides such a formal classification of Mussau vessel forms. Following the terminology of Dunnell (1971), this is a true classification of the kind known as a *taxonomy*, and not an ad hoc *grouping*. Thus the vessel shape classes have been delineated according to a formal set of ideational criteria, and not on the basis of a similarity exercise.

Vessel class I, bowls, is divided into three subclasses. Class IA consists of restricted bowls in which the rim is incurved, so that the rim diameter is smaller than the maximum vessel diameter. Class IB, unrestricted bowls (rim diameter is equal to maximum vessel diameter), is divided into two additional subclasses: IB1, in which there is no break in the curved contour of the vessel; and IB2, in which there is a carination in the side of the bowl, creating a composite vessel contour.

Vessel class II, jars (restricted vessels in which vessel height is greater than the diameter of the neck or opening), has three subclasses. Class IIA consists of jars with globular bodies, restricted necks, and everted rims; in the Mussau assemblages these are further distinguished by having plain bodies with decoration limited to the rim lips. Class IIB consists of jars with a distinct carination angle midway along the contour of the body; these are typically decorated with either dentate stamping or incising, with the decoration restricted to that part of the body above the carination. Class IIC consists of jars with restricted necks but variable rim form, typically decorated, and for which it is not possible to discern whether a carination was present or not.

Vessel class III consists of unrestricted vessels with rim diameter equal to the maximum vessel diameter, rim diameter exceeding vessel height, and a flat base. The sides of the vessel are everted, with a sharp carination angle between the everted rim and the base. We refer to these vessels as flat-bottom dishes.

Vessel class IV consists of vessels—apparently exclusively unrestricted bowls—supported upon a pedestal or ring foot. The upper part consisting of the bowl is referred to as subclass IVA, and the pedestal part—which is almost always found detached—as subclass IVB. Unfortunately, most of these vessels have broken apart at the juncture of the bowl and ring foot, so that we have just a few examples where the upper bowl still exhibits its attachment to the pedestal, and can be classified as of Class IVA. Most of the class IV vessels are therefore base or body portions of the pedestal, classified as IVB. It should be evident from this discussion that some bowls assigned to vessel class

Table 11.6. Formal classification of Mussau vessel forms

Shape Criteria	Vessel Form
1. Unrestricted vessels	
A. Simple vessel contours	IB1, simple bowls
B. Composite vessel contours	
a. Carinated sides, round bases	IB2, carinated bowls
b. Everted sides, flat bases	III, flat-bottom dishes
2. Restricted vessels	
A. Simple vessel contours	
a. Rounded bases	IA, restricted bowls
b. Open bases	V, cylinder stands
c. Inverted shallow bowl shape	VI, lids
B. Composite vessel contours	
a. Carinated body, everted rim	IIB, carinated jars
b. Pedestal supporting bowl	IV, pedestaled bowls
C. Inflected vessel contours	
a. Globular body, everted rim	IIA, globular jars
b. Restricted neck, body form not determined, rim form varies	IIC, jars

IB1 were probably originally attached to pedestals, and should therefore properly be assigned to class IVA, but it is impossible to make this determination.

Vessel class V ceramics are, strictly speaking, not true "vessels" because they are open at both the rim and the base, and therefore are not containers. These are referred to as "cylinder stands"; their function seems to have been as pedestals to support certain flat-bottom dishes, without being physically joined to them.

Finally, vessel class VI consists of what we interpret as lids, probably placed over certain bowls, flat-bottom dishes, or perhaps jars. These lids can be difficult to distinguish from the rims of class IVB pedestals; they are, in any case, quite rare.

In addition to these six formal vessel classes, the Mussau vessel catalog includes one instance of a large ceramic "ring," undecorated, with thick vessel walls and a diameter of 50 cm. For reasons described further below, we interpret this object as a ceramic drum.

Table 11.7 provides the frequency distribution of vessel classes by site (and for ECA by site area), based on the catalog of 265 reconstructed vessels. The most frequently represented vessel classes are: IB1, simple unrestricted bowls; IIA, plain globular jars with everted rims; IIB, carinated jars; IIC, other jars; III, flat-bottom dishes; and IVB, pedestal bases. All vessel classes and subclasses are represented in the assemblage excavated at Area B in site ECA. Further details on the stratigraphic distribution of vessel forms will be presented below when the assemblages from individual sites and areas are discussed.

Decorative Techniques and Motifs

Although Lapita pottery is defined fundamentally by the presence of the distinctive dentate-stamped mode of decoration, other kinds of decoration also appear on Lapita ceramics, in particular incising. Table 11.8 enumerates the frequency of several major modes of decoration by vessel classes, based on the 265 reconstructed vessels in the Mussau ceramic catalog.

Table 11.7. Distribution of vessel forms by site, based on the catalog of reconstructed vessels

Vessel Class	Site ECA					Site ECB	Site EHB	Site EKE	Site EKQ	Totals
	Area A	Area B	Area C	W250 Transect	Other					
IA		2			2			1		5
IB1		35		2	10	8				55
IB2	1	3			2	1			1	8
IIA	3	26		2	11	8			2	52
IIB		22			2	1				25
IIC		23	1	1	4					29
III		50		1	6					57
IVA		2			1					3
IVB		11		3	4		2			20
V		5			2					7
VI		2					1			3
Drum		1								1
Totals	4	182	1	9	44	18	3	1	3	265

Table 11.8. Frequency of decorative techniques by vessel form (all Mussau reconstructed vessels)

Vessel Form	Fine Dentate Stamping	Coarse Dentate Stamping	Incising	Carving or Cutouts	Lime In-fill	Appliqué (Nubbins and Bands)	Lip Notching	Plainware
IA	4				1			1
IB1	44	7		16	24			3
IB2	3	4	1	2	3	1		1
IIA	1		2				20	42
IIB	7	1	17		5	3		
IIC	8	5	14		3	1	1	1
III	20	35	3	19	28	8	4	
IVA	3			2	3			
IVB	12	7		14	12			
V	5	2		4	2	3		
VI	3				1			
Totals	110	61	37	57	82	16	25	48

Dentate stamping, made by impressing the leather-hard clay with comb-like stamps containing straight rows or curved arcs of multiple tines, varies in the size of the impressions left by the tines. We have characterized the dentate stamping on Mussau pottery as being either "fine" or "coarse" depending on the size and spacing of the tine impressions. Fine dentate stamping has individual tine impressions in the size range of 0.5–1.5 mm, whereas coarse dentate stamping has impressions in the range of 1.5–3 mm. Fine dentate stamping also tends to be neat and orderly, with the stamp impressions closely packed or spaced, and evenly executed; the effort involved in this detailed work is quite remarkable (Figure 11.1). In contrast, coarse dentate stamping is often more open, with greater spacing between stamps. While some coarse dentate stamping is neat and orderly, other examples appear to be crudely or sloppily executed (Figure 11.2).

Incised decoration was made by freehand drawing with a stylus or other sharp tool, pulling the edge of the tool through the leather-hard clay surface. Incised lines are typically about 1–3 mm thick and equally deep, although occasional lines may be slightly thicker and deeper. Incised designs tend to be much more open than dentate-stamped designs, and include both rectilinear and curvilinear geometric patterns. There is one clear example of an incised anthropomorphic face. Some incised designs were carefully executed, with regular spacing intervals between lines, while others seem to have been very rapidly and rather crudely scratched into the vessel surface.

Figure 11.1. An example of fine dentate stamping, vessel ECA-V-044. (Photo by Lapita Pottery Online Database team.)

Figure 11.2. An example of coarse dentate stamping, vessel ECA-V-004 with a zigzag motif. This vessel also has triangular cutouts along the base; such cutouts were originally filled in with white lime. (Photo by Lapita Pottery Online Database team.)

An additional mode of decoration, usually combined with dentate stamping, is the carving of the vessel surface by removing a part of the clay, probably with the sharp edge of a narrow stick, or perhaps with a slice of bamboo. Carving sometimes involved curvilinear grooves (similar in appearance to incising, but deeper and wider). Carving was frequently employed on the rim lips of certain vessels (especially those of class IB1 bowls and class III flat-bottom dishes), where repeated small triangular spaces (referred to as "cutouts") were carved out around the lip and integrated with dentate stamping. When filled in with lime, these carved spaces and the stamped designs can form a remarkably intricate design.

The impressions left by dentate stamping and carving (and less frequently by incising) were often filled in with a white lime paste, the lime consisting of calcium carbonate made by burning or slaking marine shell and/or calcareous sand. This white lime makes the designs stand out sharply in contrast against the reddish or sometimes black surface of the pottery. Lime infilling is apparent on 82 of the reconstructed vessels, and was probably present on many others but has eroded or dissolved away.

Table 11.9. Distribution of selected motif categories by vessel form classes, for all Mussau reconstructed vessels

Motif Category	Vessel Forms							
	IA	IB	IIA	IIB	IIC	III	IV	V
Zigzag	1	24		2		18	1	1
Labyrinth		2		1		5		
Bone	1	5				3	1	
Tongue		10		1	1		6	
Nubbins (breasts?)		1		2		9		1
Long-nosed face with headdress					2			1
Broad-nosed face					2	2		1
Long-beaked bird							4	1
Long-beaked bird rim motif		12				8		
Triangular incised				9				
Curvilinear incised			1	2	2			
Cross-hatched incised			1	1	2			

Yet another mode of decoration is that of appliqué nubbins and of raised horizontal bands. The nubbins most frequently occur on the everted rims of class III flat-bottom dishes, where they usually appear in pairs encircled by zone marking, and may be representative of female breasts. The raised bands appear on vessel class V, cylinder stands.

A final decorative technique is the notching of rim lips, by impressing the sharp edge of a stick or other tool into the clay at regularly spaced intervals, either along the outer lip edge or along both the inner and outer edges. Occasionally rim notching was done by pinching with the fingers, creating a crenate lip. Lip notching is especially prevalent on the rims of vessel class IIA, globular jars.

The particular motifs utilized to decorate vessels also vary considerably across vessel form classes. More will be said about specific motifs and their application to vessels below, when each vessel class is considered in detail. In general terms, however, Table 11.9 summarizes the distribution of certain major categories of motif, both dentate-stamped and incised, across vessel form classes. The names applied to motif classes are in part based on Chiu (2015).

The most frequently appearing motif category, the zigzag design (with 47 instances), appears primarily on vessel classes IB and III. The labyrinth pattern, although less common overall, also is found primarily on IB and III class vessels. The "tongue" motif mostly occurs on vessel class IB bowls, but is also found on vessel class IV, pedestals. Nubbins, typically in pairs and possibly representing breasts, are mostly found on the everted rims of vessel class III flat-bottom dishes. Human face motifs are restricted to vessel class II jars and to vessel class III flat-bottom dishes. The long-beaked bird motif (to be described in greater detail below) appears on vessel class IV pedestals, and in a simplified, stylized form on the rim lips of many vessel class IB1 bowls. Triangular incised motifs are found exclusively on vessel class IIB carinated jars, and other incised curvilinear and cross-hatched motifs are restricted to jar forms IIA, IIB, and IIC.

Reconstructed Vessels of the Mussau Ceramic Catalog

As described above under Methods, a total of 265 vessels have been "reconstructed" from the Mussau ceramic assemblages—not necessarily physically reconstructed in their entirety, but enough so that their diameters and often much of their shape and surfaces can be determined. Each of these vessels is individually described in the ceramic catalog available online in the Supplementary Materials to this volume. The reconstructed vessels are illustrated in Figures 11.66 to 11.118 at the end of this chapter. In aggregate, this corpus of vessels comprises the largest collection of pottery known from any Lapita site, and should prove to be an invaluable resource for future research on inter-site and cross-regional comparisons of Lapita pottery and the exchange interactions these represent. In this section, we summarize the corpus of reconstructed vessels by vessel form classes.

Vessel Class IA, Restricted Bowls

Vessel Numbers: ECA-V-026, -039, -125, -203, EKE-V-001

Description: These bowls all have incurving rims, defining them as restricted bowls. None have complete bases, but we presume that they were rounded. Of those with extant rim lips, two are rounded and two are flat. In all cases the temper includes various combinations of volcanic or terrigenous grains.

Dimensions: These are small bowls, with rim diameters ranging from 20 to 28 cm, and relatively thin walls. The small bowl ECA-V-026 has especially thin and delicate walls just 4.7 mm thick.

Decoration: One vessel (ECA-V-039) is plain, while the other four all have fine dentate-stamped designs on the exterior. Vessel ECA-V-026 is an especially fine example, with lime-infilled fine dentate stamping (Figure 11.3); the black color of this vessel is probably the result of the anoxic environment in which it was buried (the so-called "muck zone"; see Chapter 3). The lips of two vessels have a row of stamped circles (motif A417) running along their edges.

Figure 11.3. A small, delicate bowl of vessel class IA, from site ECA (ECA-V-026). (Photo by Lapita Pottery Online Database team.)

Probable Function. None of these vessels exhibit any signs of having been used for cooking, such as fire-blackening on the exterior or carbonaceous residues on the interior. They could have been used to serve foodstuffs or as drinking vessels.

Vessel Class IB1, Simple Unrestricted Bowls

Vessel Numbers: ECA-V-007, -025, -027, -032, -035, -036, -038, -042, -043, -054, -055, -057, -058, -065, -069, -070, -072, -081, -096, -113, -114, -122, -127, -134, -136, -144, -148, -153, -155, -158, -165, -169, -172, -174, -181, -192, -206, -212, -213, -215, -216, -217, -223, -227, -244, -245, ECB-V-001, -004, -008, -009, -010, -011, -013, -015.

Description: This large group of 55 vessels consists of unrestricted bowls with simple contours; most have upturned rims (49 cases), although a few rims are classified as everted (6). The majority (35) have tempers of mixed calcareous and terrigenous sands, while 20 have non-calcareous temper. In most cases, the surfaces—both exterior and interior—have been carefully smoothed (10), smoothed and burnished (18), or highly burnished (19); eight vessels have eroded surfaces. The majority of these bowls were very well made, seemingly by potters with a high degree of technical skill. The rim lips are typically flat (26), or flat with a groove running around the middle of the lip (18); seven have rounded lips. Almost all of these bowls are decorated, but three are plain. One of the undecorated bowls is very small and crudely made (ECA-V-038), a unique vessel that is the size of a small cup, with a rim diameter of 9 cm (Figure 11.4). It seems likely that many of these IB1 vessels were originally attached to pedestal bases, but unfortunately it is not possible to match them with their base pedestals, which are separately classified as vessel class IVB.

Dimensions: Leaving aside the very small cuplike vessel ECA-V-038, rim diameters of the IB1 bowls range from 18 to 60 cm, as shown in Figure 11.5, a histogram plot of rim diameters. There is a bimodal distribution of bowl diameters, with one mode at 26–30 cm and a second mode at 46–50 cm. Vessel walls are fairly thick and robust, with a mean thickness of 9.2 ± 2.8 mm.

Decoration: Excluding the three exceptions noted above, all of these vessels are decorated, in general quite elaborately. The majority of these bowls (45) are decorated

Figure 11.4. Unusual small, plain bowl or cup of vessel class IB1 (ECA-V-038). (Photo by Lapita Pottery Online Database team.)

on the exterior with fine—often very fine—dentate stamping; there are just seven examples of coarse dentate stamping (Figure 11.6). Triangular cutouts occur on 16 of the rims, typically in combination with fine dentate stamping, many involving the "long-beaked bird" motif (or highly stylized variants of this). None of the bowls is decorated with incising.

Variants of the zigzag motif family are the most common main motifs, appearing on 25 of the bowls. A fine example is ECA-V-025, shown in Figures 11.7 and 11.8; note that the rim of this vessel has a typical groove accompanied by the stylized long-beaked bird motif. Also occurring are the tongue (10), bone (3), and labyrinth motifs (2). Vessel ECA-V-057 has a well-executed long-nose face with headdress, alternating with the zigzag motif (Figures 11.9 and 11.10); ECA-V-025 bears a fragment of such a face, again with the zigzag pattern (Figure 11.7). ECA-V-134 and -216 have motifs that are probably highly stylized, repetitive faces, while the horizontal row of ovals on ECA-V-217 likely represent eyes. Another very finely executed IB1 type bowl is ECB-V-001 from the ECB site (Figure 11.11).

Figure 11.6. An unrestricted bowl of vessel class IB1 decorated with coarse dentate stamping (ECA-V-032). (Photo by Lapita Pottery Online Database team.)

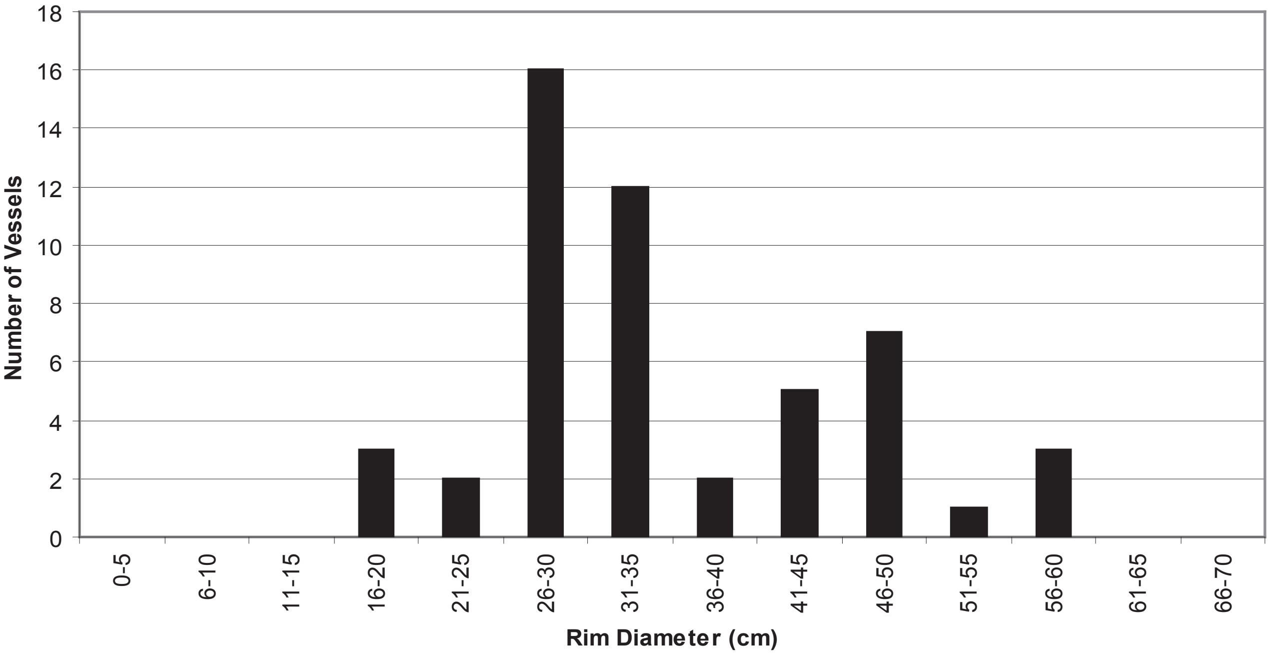


Figure 11.5. Histogram of rim diameters for vessel class IB1, unrestricted bowls.

Figure 11.7. Vessel ECA-V-025 of class IB1 is an excellent example of the zigzag motif, executed in fine dentate stamping. (Photo by Lapita Pottery Online Database team.)

Figure 11.8. The rim of vessel ECA-V-025 has a medial groove, with a row of stamped circles to the exterior, and along the interior rim a stylized version of the long-beaked bird motif. Small stamped circles represent the birds' eyes, with two birds facing each other. (Photo by Lapita Pottery Online Database team.)

Figure 11.9. Vessel ECA-V-057, executed in fine dentate stamping, combines the zigzag motif with a long-nosed face motif. (Photo by Lapita Pottery Online Database team.)

Figure 11.10. The rim of vessel ECA-V-057 again exhibits the long-beaked bird motif, with sets of opposing birds (eyes represented by small stamped circles) with downward slanting beaks, the beak tips just touching. (Photo by Lapita Pottery Online Database team.)

Figure 11.11. An unrestricted bowl of vessel class IB1 from site ECB (ECB-V-001) is decorated with very fine dentate stamping. The step or shelf around the rim may have been intended for fitting a lid to the bowl. (Photo by Lapita Pottery Online Database team.)

Of particular interest is the appearance on the lips of several bowls (ECA-V-007, -011, -027, -057, -134, ECB-011, -013) of the "long-beaked bird" motif, in which two birds face each other, their heads depicted by stamped circles and their downward oriented beaks by elongated pointed triangles (see Figures 11.8 and 11.10). These dentate-stamped birds are offset by triangular cutouts that were filled in with white lime. To the uninitiated, this striking motif might not first be recognized as birds, but when it is seen in the context of the fully developed long-beaked bird motif as seen on two pedestal bases (see Vessel Form IVB, below), there can be little doubt that this is what is being depicted. Six other bowl rims have what are probably more simplified, stylized versions of the same motif.

Probable Function: Leaving aside the small cup and the two plainware bowls, this large set of 52 bowls stands out for the high degree of technical skill exhibited in both manufacture and decoration, as well as in the elaborate nature of the fine dentate-stamped motifs. Many of these bowls were probably originally supported on pedestal bases. There is no evidence that these finely made ceramics, in which a great deal of time and effort has been invested, were used for cooking or other utilitarian purposes. Rather, everything points to their having played some socially significant role, as objects of exchange probably used in ceremonial or ritual contexts, quite likely including feasting. They could well have been used for the presentation of foodstuffs. However, they could equally have been used to hold and display other kinds of valuables, including even human crania (based on the association of ceramic vessels and human crania at the Teouma site in Vanuatu [Bedford et al. 2006; Valentin et al. 2011]). Thirty-five of these vessels were recovered from Area B or the Area B extension at ECA, and another nine from W200 transect units very close to Area B. There are many reasons to believe that the stilt house at Area B has a special function, and the association of so many of the IB1 vessels with this structure lends further support for these vessels having had a special significance. We should also note that some human skeletal remains were also found at Area B (including part of a cranium), so the idea that these elaborate vessels might have held ancestral remains within a special cult house has some traction.

Vessel Class IB2, Carinated Unrestricted Bowls

Vessel Numbers: ECA-V-012, -051, -079, -086, -132, -197; ECB-V-012; EKQ-V-003

Description: This set of eight unrestricted bowls differs from the IB1 vessel form in having a composite contour with a carination; many of these bowls were probably attached to pedestal bases. Their tempers are all various mixes of calcareous and terrigenous sands. The surfaces are mostly wiped and smoothed, although one is burnished (ECA-V-086) and one has a red slip (EKQ-V-003). The rims are everted, with rim lips mostly flat although two have rounded lips.

Figure 11.12. An example of a vessel of class IB2 from site ECA (ECA-V-012). (Photo by Lapita Pottery Online Database team.)

Dimensions: Rim diameters range from 16 to 42 cm.

Decoration: All of these bowls are decorated, with the exception of ECA-V-079, which is a plainware bowl. The main decorative techniques are fine dentate stamping (3) and coarse dentate stamping (4). Cutouts are present on the rim lips of two vessels, and nubbins on one. An example, vessel ECA-V-012, is shown in Figure 11.12.

Probable Function: As with the IB1 vessel form, the IB2 bowls were probably intended for display or prestation, either of foodstuffs or other materials, including possibly human skeletal remains. There is no evidence for their use for cooking.

Vessel Class IIA, Globular Jars

Vessel Numbers: ECA-V-048, -050, -066, -067, -074, -076, -077, -078, -089, -091, -094, -112, -137, -143, -145, -147, -154, -159, -160, -161, -166, -167, -168, -176, -182, -184, -186, -189, -193, -194, -195, -199, -200, -205, -214, -218, -222, -224, -236, -237, -238, -242; ECB-V-002, -003, -005, -014, -016, -017, -018; EKQ-V-001, -002

Description: This subcategory of jars, with 51 reconstructed vessels, is defined as restricted vessels with a relatively narrow neck, and having an inflected vessel contour characterized by a globular body, with everted rims. Temper is typically a mix of calcareous sand with some terrigenous grains (38), although there are six vessels in which the temper is entirely terrigenous. A number of the vessels exhibit anvil impressions on their interior surfaces, indicating vessel wall thinning with the paddle-and-anvil method. The rims are all everted, some quite strongly, others less so. There is a strong preference for flat rim lips (28), although rounded lips are also present (10). The majority of vessels have exterior surfaces that were simply wiped (10) or wiped and lightly smoothed (32) but still leaving traces of being wiped. Some of the wiped vessels have striations indicating wiping with a coarse material. Only four vessels have burnished surfaces, while three show evidence of red slip.

Dimensions: A histogram plot of rim diameters is provided in Figure 11.13. Rim diameters range from 18 to 60 cm, with a strong mode at 26–30 cm. Vessel wall thickness is 7.9 ± 2.4 mm.

Decoration: The bodies of all IIA vessels are plain, with decoration limited to simple notching of the rim (20), usually along both the inner and outer edges of the lip. An example is shown in Figure 11.14, with vessel ECA-V-050, which is plain except for simple notching along the flat lip.

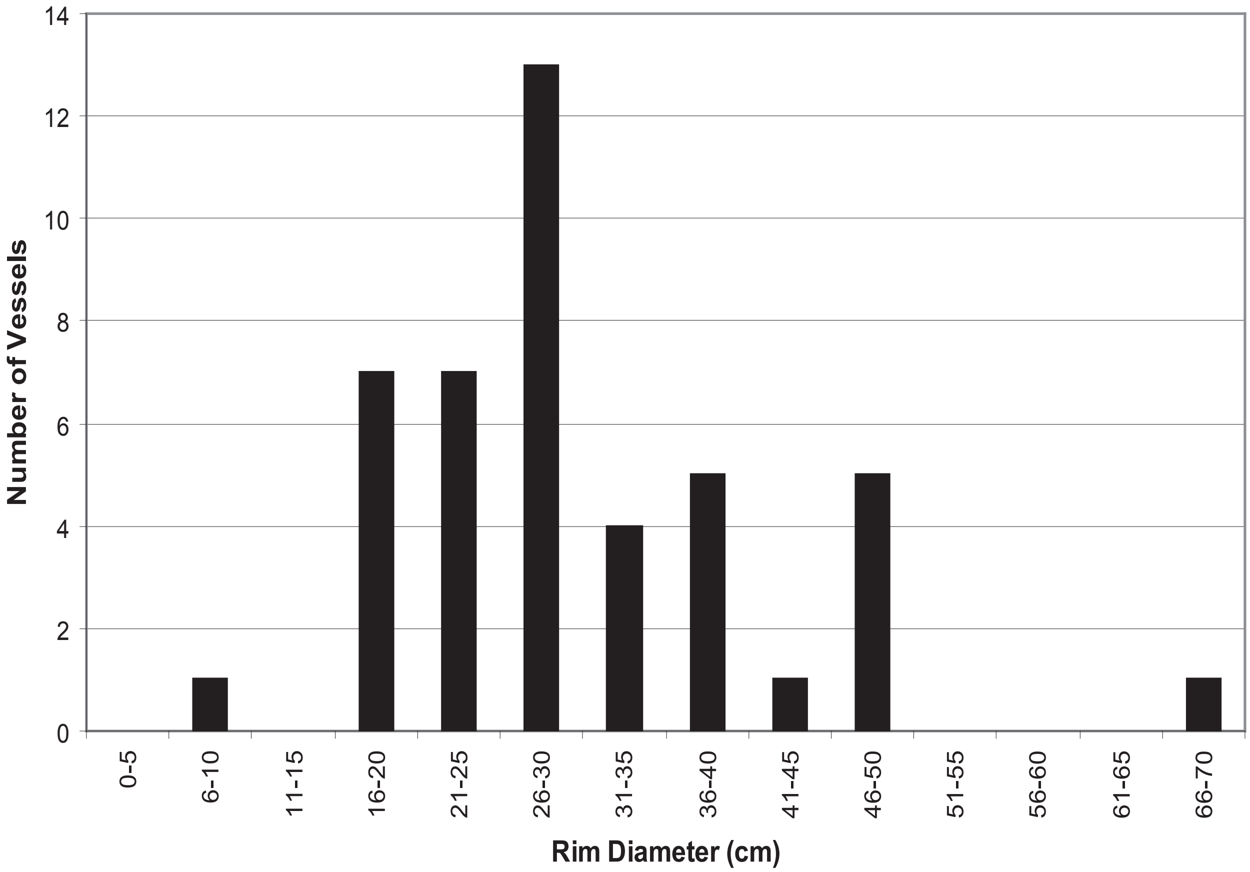


Figure 11.13. Histogram of rim diameters for vessel class IIA, globular jars.

Figure 11.14. Vessel ECA-V-050, an example of a class IIA globular jar with everted rim; the lip is decorated with simple notching. (Photo by Lapita Pottery Online Database team.)

Probable Function: In contrast with some other vessel forms such as IB1 bowls, the IIA jars appear to have had a utilitarian function, as suggested by their general lack of decoration or even of effort to burnish or smooth their exterior surfaces. Their globular form with restricted necks would have been well suited to the storage of either liquids (including water) or dry materials such as sago flour. There is no evidence—such as exterior fire blackening or interior residues—to suggest that these vessels were used in cooking.

Vessel Class IIB, Carinated Jars

Vessel Numbers: ECA-V-018, -031, -071, -083, -084, -085, -088, -102, -103, -105, -108, -111, -115, -117, -119, -121, -139, -141, -151, -156, -157, -178, -207, -210; ECB-V-007

Description: These jars with a restricted neck and height greater than the rim diameter have a composite contour, characterized by a sharp carination running horizontally around the middle of the body. Two (ECA-V-018 and -031) have reconstructed profiles extending from the rim lip to the carination, but the remainder lack both rims and bases, and so are known only from their carinated portions. Twenty-three of these 25 vessels come from Area B and the Area B extension at site ECA.

All of these vessels have temper mixes of both calcareous sand and terrigenous mineral grains. Most surfaces are either wiped and smoothed (N = 8), or burnished (N = 7). Where present, the rims are everted with either flat or rounded lips.

Dimensions: The two vessels with intact rims have rim diameters of 46 and 47 cm. Vessel diameters at the carination range from 25 to 62 cm, with a mode at 50 cm (N = 5).

Decoration: One of these vessels is undecorated, six are decorated with fine dentate stamping, one with coarse dentate stamping, and 17 with incising. The decoration is also restricted to the space above the carination. Nubbins occur just above the carinations on three vessels, one with fine dentate stamping (in this case paired double nubbins), one with coarse dentate stamping, and one with incising. The incised designs include curvilinear motifs, nested triangles, and other geometric combinations. Two of the more intact examples of class IIB carinated jars are illustrated in Figures 11.15 and 11.16.

Probable Function: We can only speculate regarding the possible functions of these large carinated vessels. There are no evident residues or other signs that they were used for cooking, but the vessels could have been used to store any manner of wet or dry substances. The orifice diameters are even large enough to have accommodated a human cranium.

Figure 11.15. A large carinated jar of vessel class IIB (ECA-V-018), decorated with an open, curvilinear incised motif above the carination. (Photo by Lapita Pottery Online Database team.)

Figure 11.16. A large carinated jar of vessel class IIB (ECA-V-031), decorated with an incised curvilinear motif. (Photo by Lapita Pottery Online Database team.)

Vessel Class IIC, Jars with Undetermined Body Form

Vessel Numbers: ECA-V-033, -037, -045, -059, -060, -101, -107, -109, -126, -135, -138, -140, -150, -171, -175, -177, -185, -187, -191, -196, -202, -204, -209, -221, -230, -234, -235, -239, -241

Description: The 29 vessels in this vessel class are all restricted neck jars, represented by the rims and neck portions of the vessels. We believe that the majority originally had carinated bodies, and indeed many of the class IIB carinated bodies probably belong to these upper portions, but we are unable to match them definitively and thus have kept them as a separate class. All of these vessels come from site ECA, and 23 from Area B or the Area B extension.

Most of the vessels exhibit temper consisting of a mix of calcareous and terrigenous grains, although two have exclusively terrigenous temper. In terms of surface treatment, the majority have been wiped or wiped and smoothed (N = 17), while seven have been burnished (five are too eroded to determine surface treatment).

Everted rims dominate this vessel class (N = 25), with three notable exceptions. In two cases (ECA-V-037 and -230) a double or compound rim is present, with a vertical rim and a horizontal rim extending 90° out a short distance below the vertical rim. In one other case (ECA-V-060), a pronounced horizontal rim extends at a 90° angle from the nearly vertical neck. Rim lips include rounded (N = 16) and flat (N = 11) forms.

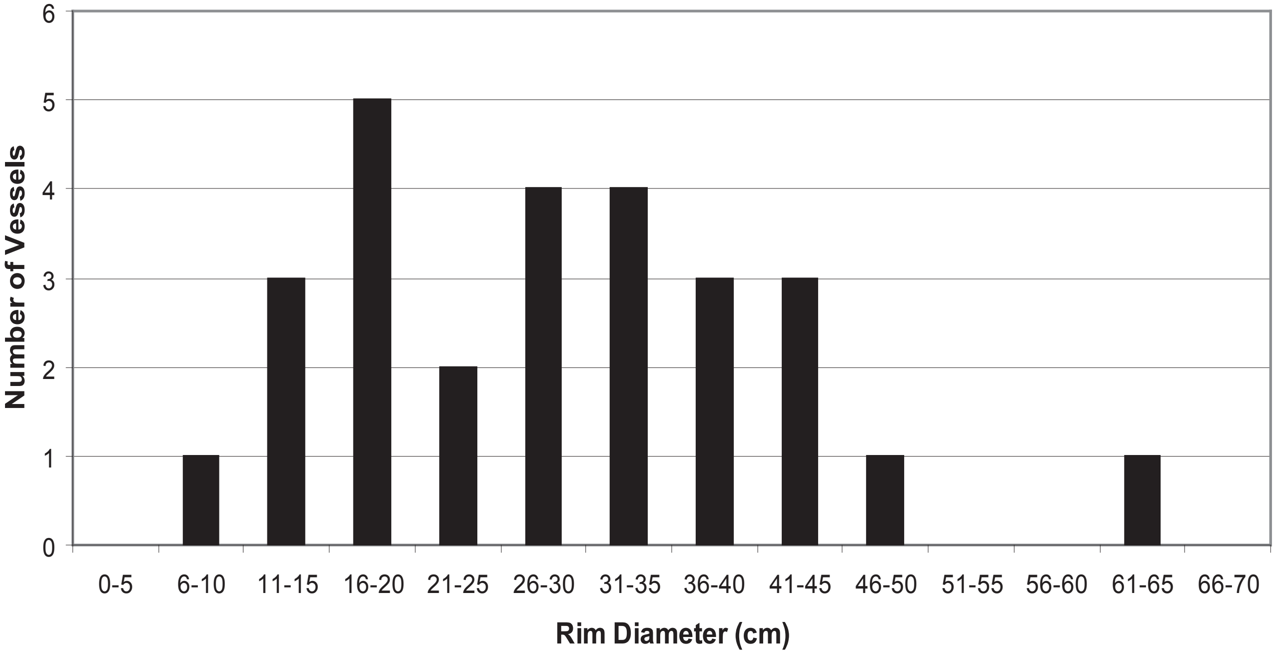


Figure 11.17. Histogram of rim diameters for vessel class IIC, jars with undetermined body form.

Dimensions: There is a substantial range in the rim diameters of these IIC jars, from 10 to 62 cm, although as seen in the histogram presented in Figure 11.17 the majority of vessels fall between 20 and 45 cm in rim diameter.

Decoration: Class IIC vessels are equally divided between those decorated with dentate stamping (N = 13) and with incising (N = 14), with one vessel decorated with bivalve-shell rocker stamping (ECA-V-185) and one plainware vessel. Of the dentate-stamped vessels, eight have fine dentate stamps and five coarse dentate stamps.

Several IIC jars with quite elaborate motifs are worthy of special comment. Among the dentate-stamped vessels, ECA-V-037, with a double or compound rim, has very fine dentate stamping with an intricate labyrinth motif, as seen in Figure 11.18. Especially striking is ECA-V-045, from the neck portion of what was almost certainly a large carinated jar, with a very finely executed anthropomorphic face (Figures 11.19 and 11.20). This is in the classic "long-nose" style, the eyes depicted with stamped ovals, and a "headdress" of stamped triangles, possibly representing feathers. The zone markers defining the sides of the face sweep down and turn back up to become arms, with four digits at the ends indicated by stamped triangles. To either side of the face, on what may be the cheeks, are identical small, two-headed creatures with an oval body and four limbs, each with three digits or toes. Vessel ECA-V-059 depicts the triangular form of the long-nosed face, again with some form of headdress, the whole motif framed in an elaborate curvilinear tableau of stamped designs and zone marking.

Figure 11.18. Vessel ECA-V-037 with a flaring rim and labyrinth motif. (Photo by Lapita Pottery Online Database team.)

Figure 11.19. Vessel ECA-V-045, part of a large class IIC jar, with a finely executed anthropomorphic face design. (Photo by Lapita Pottery Online Database team.)

Figure 11.20. Drawing of the anthropomorphic face design on vessel ECA-V-045, with the unique double-headed, three-toed zoomorphs to either side of the nose. (Drawing by Margaret Davidson.)

Figure 11.21. Vessel ECA-V-060, with a flaring rim and decoration that is a variant of the "house" motif. (Photo by Lapita Pottery Online Database team.)

Vessel ECA-V-060, with a flaring horizontal rim, is another example of artistic finesse in dentate stamping (Figure 11.21). Here there is an elaborated curvilinear triangle, possibly representing a gabled or peaked house, with just the hint of a face within this (indicated by two stamped ovals that may be eyes). To the sides of the "house" are intricate labyrinth motifs.

Among the class IIC vessels decorated with incised motifs, several are also noteworthy. Vessel ECA-V-033 has a striking geometric motif that might possibly be a highly stylized face (Figure 11.22). The motif on ECA-V-107, although fragmentary, almost certainly portrays two stylized faces, each with upturned arms; this may be an attempt—with incising—to represent the same kind of face depicted with elaborate stamping on vessel ECA-V-045. Vessel ECA-V-109 may also be depicting the end of such an upturned arm. A different sort of incised design appears on ECA-V-126, with a cruciform motif set within concentric circles.

Figure 11.22. Vessel ECA-V-033 exhibits a crudely executed, incised motif that may be a highly stylized face. (Photo by Lapita Pottery Online Database team.)

Probable Function: Many of these class IIC vessels were quite large and elaborately decorated; they seem unlikely to have served utilitarian functions. Some, like ECA-V-045 and ECA-V-060, have very complex decorative motifs. Their use in ceremonial activities, ritualized exchanges, and/or for the storage of sacred or highly valued items seems most likely.

Vessel Class III, Flat-bottom Dishes

Vessel Numbers: ECA-V-001, -002, -003, -004, -005, -006, -008, -009, -010, -011, -013, -014, -016, -017, -020, -021, -022, -023, -029, -040, -041, -046, -049, -053, -056, -061, -062, -063, -064, -080, -082, -090, -092, -093, -095, -099, -100, -106, -110, -123, -124, -128, -129, -130, -133, -149, -162, -163, -164, -173, -198, -208, -219, -220, -225, -226, -229

Description: With 57 vessels, this class— defined as unrestricted vessels with flat bases and everted rims—is the largest of the Mussau vessel forms. All of the reconstructed vessels are from site ECA, and 50 of them are from Area B or the Area B extension, where they are especially prevalent in stratigraphic zones C1 and B2.

Most of the class III dishes have mixed calcareous and terrigenous tempers, but four vessels have exclusively non-calcareous tempers. The surfaces are most commonly wiped and smoothed (N = 19), or simply wiped (N = 8), but some have been burnished (N = 11), probably with a smooth stone; many have eroded surfaces (N = 18) due to their deposition in the shallow reef flat environment. All have everted rims, this being a defining characteristic of the class. Lips, where intact, are dominantly flat (N = 37), although a few rounded examples are present (N = 5). Four of the flat lips also have a groove running around the lip, and two have raised nubbins on the lip.

Dimensions: Class III rim diameters range from 18 to 60 cm, with a unimodal distribution, as seen in Figure 11.23. Vessel wall thickness ranges from 4.8 to 16.5 mm, with a mean thickness of 7.9 ± 2.4 mm.

Decoration: The largest number of class III vessels are decorated with coarse dentate stamping (N = 35), followed by fine dentate stamping (N = 19). One especially elaborate vessel (ECA-V-005) combines fine dentate stamping with incising (Figure 11.24). Vessel ECA-V-006 is a good example of a flat-bottom dish decorated with coarse dentate stamping

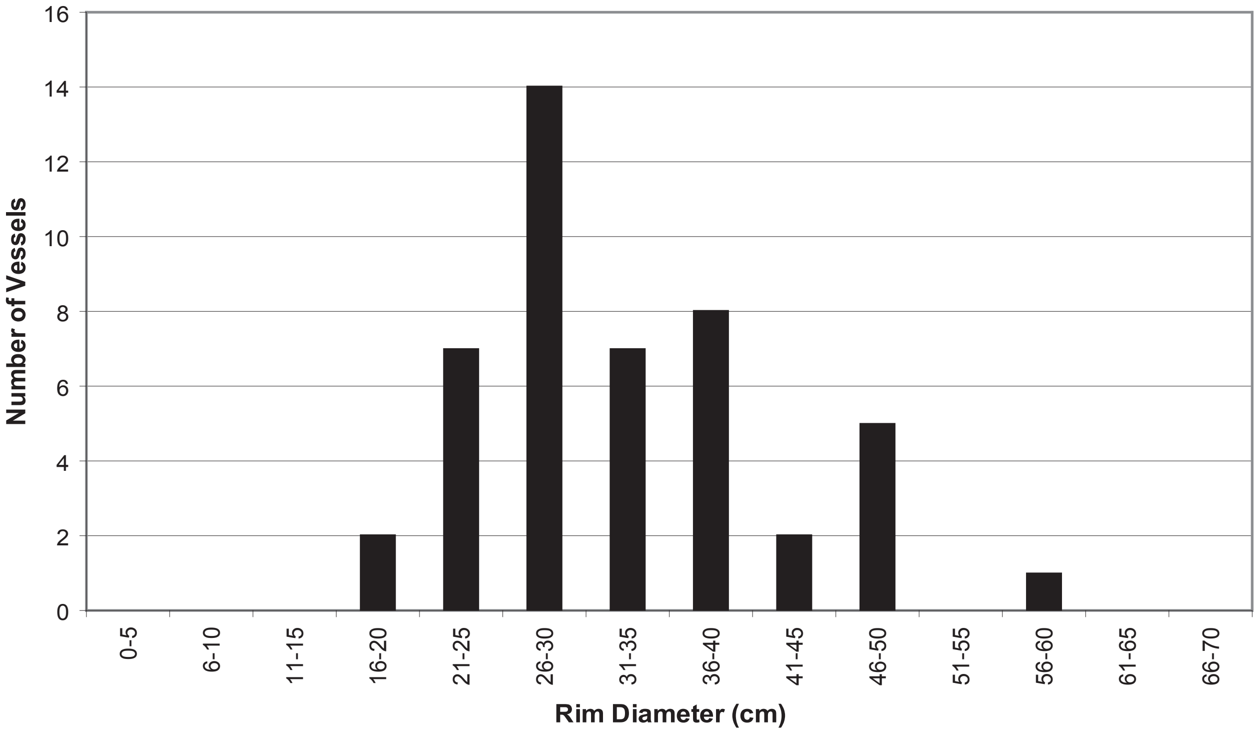


Figure 11.23. Histogram of rim diameters for vessel class III, flat-bottom dishes.

Figure 11.24. A flat-bottom dish of vessel class III, ECA-V-005 is decorated with a unique combination of very fine, precise incising and fine dentate stamping. (Photo by Lapita Pottery Online Database team.)

Figure 11.25. Vessel ECA-V-006, a flat-bottom dish, exhibits the zigzag motif most commonly found on this vessel class. (Photo by Lapita Pottery Online Database team.)

Figure 11.26. The rim lip of vessel ECA-V-006 combines dentate stamping with cutouts, in what may be a highly stylized variant of the long-beaked bird motif. (Photo by Lapita Pottery Online Database team.)

Figure 11.27. Vessel ECA-V-009 is decorated with a rare "botanical" motif. (Photo by Lapita Pottery Online Database team.)

Figure 11.28. Raised nubbins, shown here on the exterior of vessel ECA-V-010, often occur in pairs encircled by dentate stamping, and may represent female breasts. (Photo by Lapita Pottery Online Database team.)

utilizing the popular zigzag motif (Figure 11.25). The rim of ECA-V-006 is decorated with a combination of stamping and cutouts in what may be a highly stylized version of the long-beaked bird motif (Figure 11.26). Vessel ECA-V-009 is another example of a flat-bottom dish decorated with coarse dentate stamping utilizing a rare "botanical" motif (Figure 11.27). Two vessels are decorated with incising, and one is plain. Raised, appliqué nubbins appear on the exteriors of seven vessels, in addition to the two with nubbins on the lips (Figure 11.28). Cutouts are incorporated into either the lip motifs or along the bases of 18 vessels.

The most common major motif on the exteriors of class III vessels is some variant of the zigzag design (N = 18). Raised nubbins, sometimes in pairs, appear on seven vessels. Other major design groups represented are the bone (N = 3), labyrinth (N = 5), and windmill (N = 4). Vessel ECA-V-040 is a good example of the windmill motif (Figure 11.29), while vessel ECA-V-061 is an example of the labyrinth motif (Figure 11.30). Anthropomorphic faces appear on five vessels; one of these (ECA-V-046) is a classic long-nose face that repeats with intervening geometric patterns (Figure 11.31). Vessel ECA-V-053 combines the common zigzag motif with curvilinear elements that may have been part of a face motif (Figure 11.32). Vessel ECA-V-056 has a crudely executed incised design that appears to represent a face, and possibly also a house (Figures 11.33 and 11.34). The long-beaked bird motif appears along the lip or base of two vessels, and in six other cases the motif seems to be a simplified version of the long-beaked bird.

Figure 11.29. The "windmill" motif, executed here in coarse dentate stamping, is exhibited on the exterior of vessel ECA-V-040. (Photo by Lapita Pottery Online Database team.)

Figure 11.30. The labyrinth motif appears on the exterior of vessel ECA-V-061. (Photo by Lapita Pottery Online Database team.)

Figure 11.31. A repeating anthropomorphic face motif occurs on vessel ECA-V-046. (Photo by Lapita Pottery Online Database team.)

Figure 11.32. Vessel ECA-V-053 has a zigzag motif integrated with curvilinear elements that may have been part of a face motif. Cutouts and dentate-stamped elements along the base may be highly stylized variants of the long-beaked bird motif. (Photo by Lapita Pottery Online Database team.)

Figure 11.33. The interior of flat-bottom vessel ECA-V-056, decorated with crude incising. (Photo by Lapita Pottery Online Database team.)

Figure 11.34. The exterior of flat-bottom vessel ECA-V-056 has a crudely executed, incised motif probably representing a face and also a "house" motif. (Photo by Lapita Pottery Online Database team.)

Probable Function: The flat-bottom dishes appear to be designed for the display or presentation of some kind(s) of objects or possibly foodstuffs. They could well have been used for serving foods of various kinds, cooked or raw, at feasts.

Vessel Class IVA, Pedestal Bowls

Vessel Numbers: ECA-V-034, -044, -052.

Description: This small group of three vessels would otherwise be classified as unrestricted bowls, except that in these instances the vessel contours show unambiguous evidence of their having been attached to pedestal bases. They have everted or upturned rims with flat lips or, in one case, a grooved lip. The surfaces are wiped and smoothed, or in one case burnished.

Dimensions: These vessels have rim diameters of 28, 30, and 38 cm.

Decoration: All three vessels are decorated with fine dentate stamping. ECA-V-034 has a simple variant of the zigzag motif as the main decoration (Figure 11.35). ECA-V-044 is quite elaborately decorated on both the inside and outside surfaces, which is quite unusual, with both "bone" and "tongue" motifs. ECA-V-052, the burnished vessel, has a finely executed motif that may represent a very stylized set of repeating faces; along the lip is a variant of the long-beaked bird motif (Figure 11.36).

Probable Function: The function of these bowls was probably similar or identical to those in vessel class IB1, and indeed many of the IB1 bowls were probably attached to pedestals. The display or presentation of valuables, or of foodstuff at feasts, are possible functions.

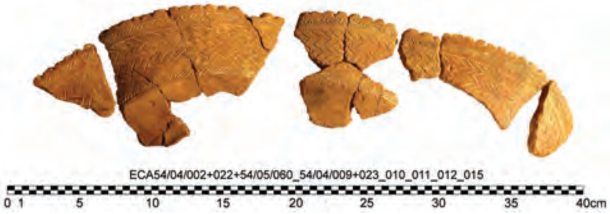


Figure 11.35. Vessel ECA-V-034, of class IVA, is decorated with a simple, open zigzag motif. (Photo by Lapita Pottery Online Database team.)

Figure 11.36. Vessel ECA-V-052 has a well-burnished exterior decorated with a simple geometric motif that may be a highly stylized version of a long-nose face; it exhibits a trace of its attachment to a pedestal base. (Photo by Lapita Pottery Online Database team.)

Vessel Class IVB, Pedestal Bases

Vessel Numbers: ECA-V-015, -019, -028, -030, -068, -131, -146, -152, -170, -179, -180, -183, -190, -231, -232, -233, -240, -243; EHB-V-001, -003

Description: These 20 vessels, 18 from site ECA and two from site EHB, are the bases of pedestals or ring feet that originally supported bowls—especially of class IB1—or possibly in some instances of class III flat-bottom dishes. They are characterized by distinctive base rim profiles, with thickened, flat lips lacking any decoration on the lip edge or interior of the lip. All except one are tempered with some mix of calcareous and terrigenous grains; one vessel lacks calcareous grains. The majority have wiped and smoothed surfaces (N = 12), although three are burnished, and six are too eroded to determine surface treatment.

Dimensions: Base diameters range from 10 to 35 cm.

Decoration: These pedestal bases are most frequently decorated with fine dentate stamping (N = 12), although coarse dentate stamping is also represented (N = 7); there are no incised pedestal bases. Cutouts or carving are present on 14 vessels; in a number of cases the cutouts extend completely through the vessel wall, as seen in both Figures 11.37 and 11.38.

Vessel ECA-V-015 deserves special mention, for this finely made pedestal with elaborate fine dentate stamping combined with carving (all lime infilled) presents the fullest representation of the long-beaked bird motif (Figures 11.39 and 11.40). As can be seen in close examination of Figures 11.40 and 11.41, the two birds, each with a long, slender beak and elaborate crest, face each other, seeming to bow down one to the other. Below the main bird motifs is a row of repeating birds, their pointed beaks touching. Below this is a carefully executed band, running along the base of the pedestal, which appears to be a series of highly stylized triangular faces, the eyes represented by small stamped circles, in alternating up and down positions. This vessel is truly one of the masterpieces of Lapita ceramic art. It is unfortunate that we do not have the upper, bowl portion of this vessel, although it very likely is one of the finely executed examples of vessel class IB1 (such as ECA-V-025 or -057), or possibly of class 1B2.

Figure 11.39. ECA-V-015 is a large pedestal base exhibiting very fine craftsmanship, with decoration that includes fine dentate stamping and lime infilled carving. (Photo by Lapita Pottery Online Database team.)

Figure 11.37. Vessel ECA-V-019 is part of a ring foot or pedestal with cutouts extending through the pedestal wall. (Photo by Lapita Pottery Online Database team.)

Figure 11.38. This pedestal or ring foot (ECA-V-028) is decorated with unusually crude stamped, lime-infilled motifs and has cutouts extending through the pedestal wall. (Photo by Lapita Pottery Online Database team.)

Figure 11.40. This lateral view of part of the ECA-V-015 pedestal base shows the extremely fine dentate stamping combined with lime-infilled carving. Seen here is the right-hand individual in a pair of long-beaked birds, above a band of alternating, stylized long-beaked birds, and with a basal band of alternating, highly stylized faces. Compare with Figure 11.41 to identify individual motifs. (Photo by Lapita Pottery Online Database team.)

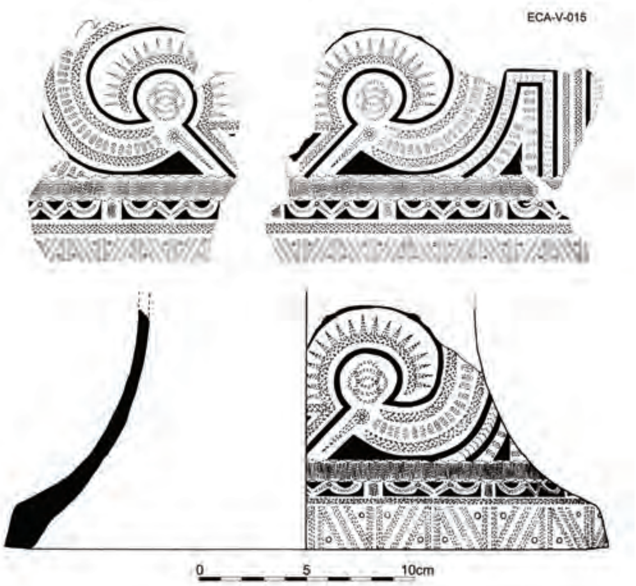


Figure 11.41. Line drawing of vessel ECA-V-015, with the twin long-beaked bird motif. (Drawing by Lapita Pottery Online Database team.)

Figure 11.42. Vessel ECA-V-030 displays what is probably a fragment of a long-beaked bird motif, with stylized bird motifs along the base, alternating with the lime-infilled cutouts. (Photo by Lapita Pottery Online Database team.)

A second instance of a long-beaked bird motif on a pedestal body is ECA-V-179. Here we have only fragments of the motif, and the design is not nearly so exquisitely executed as in ECA-V-015. Nonetheless, the two birds are clearly evident. Moreover, the pattern running along the base is suggestive of a highly stylized version of the long-beaked birds. Vessel ECA-V-030, of which only a relatively small fragment exists, may also have depicted a long-beaked bird scene, and has a long-beaked bird motif similar to that of ECA-V-015 running along the base of the pedestal (Figure 11.42).

Probable Function: These pedestals supported bowls (or in some cases possibly flat-bottom dishes), whose likely function was, as hypothesized for vessel classes IB1 and IB2, the display of valued objects, possibly even human crania, and/or of special foodstuffs at feasts (see above).

Vessel Class V, Cylinder Stands

Vessel Numbers: ECA-V-047, -073, -116, -120, -188, -211, -228

Description: Strictly speaking, a cylinder stand is not a "vessel" in that it is open at top and bottom—hence cannot hold anything. It was the recovery of vessel ECA-V-047 in Area B, with its intact rim, that led to the discovery of this ceramic form. The other examples are more fragmentary, and placed into this class largely due to their vertical profiles, and to the presence of pronounced ribbing or raised horizontal bands, also evidenced on ECA-V-047 and seemingly characteristic of cylinder stands.

In the single case with the lip present (ECA-V-047), this is flat and not decorated, presumably because it was intended to support a flat-bottom dish. The surfaces are wiped and smoothed, but in two cases there is red slip.

Dimensions: Vessel ECA-V-047 has a rim diameter of 16 cm. The other examples have body diameters ranging from 8 to 21 cm.

Decoration: Five of these cylinder stands are decorated with fine dentate stamping, two with coarse dentate stamping. Three have raised horizontal bands, and four make use of carving or cutouts in their designs. One also has a raised nubbin.

Cylinder stand ECA-V-047, of which a good-sized portion exists, is another stunning example of Lapita ceramic art (Figures 11.43, 11.44, 11.45). The extant upper portion of the cylinder is dominated by a complex anthropomorphic face motif (Figure 11.43), and is separated from the lower portion by two horizontal raised bands (Figure 11.44). Only a fragment of the lower portion remains, but it exhibits deep, lime infilled vertical cutouts. The complex and finely executed motif on the upper portion (Figure 11.45) has a long-nose face with headdress (feathers?) encompassed within a complex design executed mostly with zone marking, which appears also to be a more stylized face, the eyes indicated by a kind of starburst. There

Figure 11.43. View of the left-hand side of vessel ECA-V-047, a large cylinder stand with two raised bands. (Photo by Lapita Pottery Online Database team.)

Figure 11.44. The upper portion of vessel ECA-V-047 with dentate-stamped long-nose face motif, set within a larger, more stylized face motif. Both faces appear to be surmounted by headdresses. (Photo by Lapita Pottery Online Database team.)

Figure 11.45. The right-hand side of vessel ECA-4-047, showing the raised bands and extant lower portion with vertical, lime infilled cutouts. (Photo by Lapita Pottery Online Database team.)

is also a second headdress, and thus we have a face within a face. Vessel ECA-V-211, of which unfortunately only a small fragment exists, is also noteworthy in that it includes a clear example of the long-beaked bird motif, with the twin birds facing each other (Figure 11.46).

Probable Function: The immediate function of a cylinder stand was evidently to support a flat-bottom dish, in a manner analogous to a pedestal supporting an unrestricted bowl. The function of the flat-bottom dishes—and hence the larger function of the cylinder stands—was presumably the ceremonial display of some kinds of valued objects for foodstuffs, as suggested above for vessel class III.

Figure 11.46. Vessel ECA-V-211, a fragment of a cylinder stand with two horizontal raised bands. Above the upper band two simplified long-beaked birds are portrayed, facing each other with beak tips touching. (Photo by Lapita Pottery Online Database team.)

Vessel Class VI, Lids

Vessel Numbers: ECA-V-097, -118; EHB-002

Description: Two rim sherds from site ECA and one from EHB have been provisionally classified as lids, based on their relatively flat profiles that appear to differentiate them from ring-foot bases.

Dimensions: The three putative lids have reconstructed diameters of 18, 20, and 26 cm, respectively.

Decoration: All three sherds are decorated with fine dentate stamping on their upper sides.

Probable Function: If our interpretation of these specimens as lids is correct, they would have been used to cover unrestricted bowls with relatively small diameters.

Figure 11.47. The large ceramic drum, ECA-V-024; note the intact top and bottom rims. (Photo by Lapita Pottery Online Database team.)

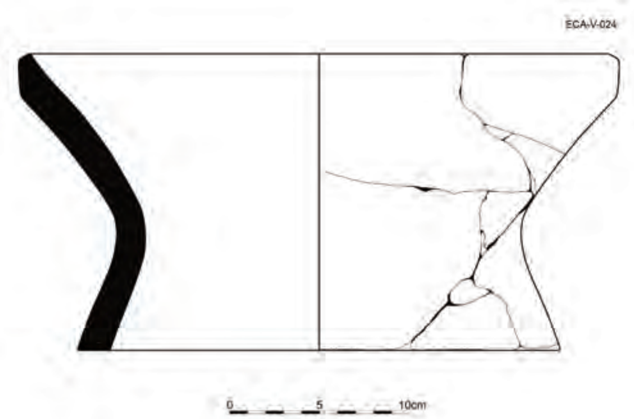


Figure 11.48. Reconstruction of the ceramic drum, ECA-V-024. (Drawing by Lapita Pottery Online Database team.)

Ceramic Drum

In Zone C3 of Area B at site ECA we recovered several matching sherds of a massive, thick-walled ceramic "ring" with a concave profile and strongly everted rim (Figures 11.47 and 11.48). Although the object is not a vessel we assigned vessel number ECA-V-024 to it in the ceramic catalog. With a rim diameter of 50 cm, it is much too large to have served as a pot stand. The most probable interpretation of this object is as a ceramic drum. The concave profile would have permitted a membrane (such as shark skin) to be stretched over the rim and secured around the "waist." We would envision the drum being played by placing it on the ground and then beating the membrane either with the hands or with a baton.

The Ceramic Assemblages of Talepakemalai (ECA)

The ceramic assemblage of Talepakemalai is the largest and most diverse of the ceramics excavated by our project in Mussau (Table 11.1). It is also the only Lapita site in Mussau with good stratification in some areas, providing key evidence for ceramic change through time (rock-shelter site EKQ is also stratified, but the deposits there are primarily post-Lapita in age, and in Unit 2 there is evidence of mixing in the lower deposits; see Chapter 5). Table 11.10 shows the distribution of 4,584 diagnostic sherds from ECA according to major sectors of the site. The largest sample comes from Area B (including the 1988 Area B extension), with 73% of the entire ECA assemblage. Of the 241 reconstructed vessels from ECA, 182 also come from Area B.

The Area B and B-extension Assemblages

A collection of 375 diagnostic sherds from the Area B extension excavation block of 4 m^2, being very well controlled stratigraphically, was used for an attribute-based analysis of ceramic variation, with results summarized in Table 11.11. A number of significant temporal trends are evident.

Figure 11.49 plots the frequency distribution of major vessel form categories by stratigraphic zone, expressed as percentages of diagnostic sherds in order to adjust for different sample sizes. In the earliest phase, stratigraphic

Table 11.10. Distribution of diagnostic ceramic sherds analyzed from the Talepakemalai (ECA) site

Sherd Type	Area A	Area B + B ext	Area C	W200 Transect	W250 Transect	Other Units	Surface	Totals
Unknown		3						3
Body sherd	11	972	50	126	95	53		1,307
Rim/neck, lip intact	40	816	78	150	102	66		1,252
Rim/neck, lip missing	19	691	18	80	48	50		906
Lip		10	2					12
Carination	3	242		18	19	9		291
Base	2	94	1	3	3	3	1	107
Rim/neck + carination	4	76		16	3	1		100
Rim/neck + body	3	74	1	4	5	5		92
Rim/neck + body + base		51		4	3	3		61
Pedestal or ring foot	2	75	1	29	12	8		127
Lid		9		1	1	2		13
Handle		1						1
Doubled rim		9			2	2		13
Appliqué nipple		12						12
Rim/neck + carination + body + base		2						2
Lip + rim/neck + body	1	181	2	25	9	11		229
Lip + rim/neck + body + base		31		3	1	1		36
Lip + rim/neck + body + base + pedestal		3		1			1	5
Lip + rim/neck + carination	1	5		1				7
Double rim + lip		7				1		8
Totals	86	3,364	153	461	303	215	2	4,584

Table 11.11. Frequency distribution of diagnostic sherd attributes by stratigraphic zone in the Area B extension, site ECA

Category	Attribute	C3	C2	C1	B2	B1	A
N diagnostic sherds		15	137	45	20	113	45
Vessel form	I, Bowls	3	16	10	1	3	1
	II, Jars, unspecified	1	10	10	5	9	3
	IIA, Globular Jars		28	4	4	6	3
	IIB, Carinated Jars		1			11	5
	III, Flat-bottom dishes		1	3	3	20	10
	IV, Pedestal vessels	4	13	2			4
	V, Cylinder stands		2	1		4	2
	VI, Lids						
	Drums		2				
Primary decorative technique	Fine dentate stamping	7	80	24	6	16	9
	Coarse dentate stamping	3	11	5	3	31	16
	Incising					39	13
	Carving or cutouts	4	7	2		4	
Lip decoration	Fine dentate stamping	2	12	9	2	2	2
	Coarse dentate stamping			1	2	11	4
	Incising				2	2	1
	Carving or cutouts	1	6	8	2	4	2
	Notching	1	30	12	9	4	3
	Finger-pinched, crenate		1				
Other traits	Lime infill	11	71	23	7	18	2
	Red slip		16	8	2	14	6

zone C3, pedestal-foot vessels and bowls (some of which were undoubtedly supported on pedestals) are the most frequent vessel types, with only a few jar forms being present. Pedestal-foot vessels then decline steadily in numbers through succeeding zones C2 through B1. Jar forms rise steadily in frequency to become dominant in zone B2, although they then decline somewhat in zone B1. Flat-bottom dishes do not become important until zone C1, and then increase steadily in their frequency. (Because Zone A is a palimpsest with sherds mixed by gardening and land crab activity, the frequency of sherds within zone A is not considered.)

Other significant temporal trends at Area B are evident in the main modes of decoration employed (Figure 11.50). In zones C3 through C1, fine dentate stamping predominates, but then rapidly declines in zones B2 and B1, at the same time that coarse dentate stamping increases in frequency. Carving and cutouts are most frequent in zone C3, and present only in low frequency in the higher zones. Most striking is the stratigraphic distribution of incising as a main decorative technique—this is entirely absent in zones C3 through C1, but makes up nearly 35% of sherds with decoration in zone B1.

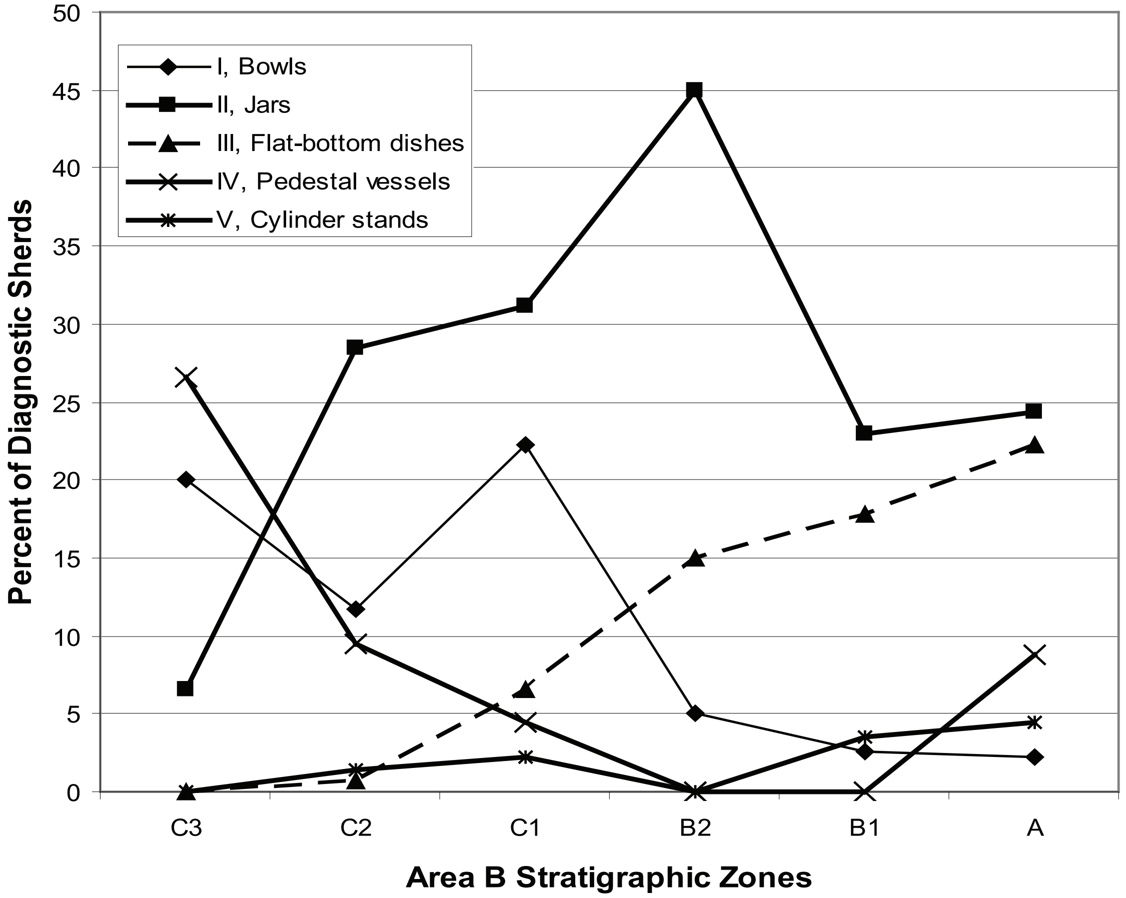


Figure 11.49. The frequency distribution of major vessel classes by stratigraphic zone within the Area B extension, based on individual sherd attributes.

Parallel trends are evident in the frequency of decorative techniques employed on rim lips (Figure 11.51). The use of fine dentate stamping fluctuates in zones C3 to C1, but declines steadily in zones B2 and B1, matched by increases in coarse dentate stamping. The trend for carving or cutouts closely parallels that of fine dentate stamping—indeed, the two are typically combined in lip decorations. Most striking is the steep increase in lip notching from zones C3 through B2, which is strongly correlated with the increase in frequency of jar form vessels.

The trends evident in Figures 11.49 through 11.51 are based on the attribute analysis of diagnostic sherds from the Area B extension excavation, but we can also explore temporal trends through the analysis of the corpus of reconstructed vessels at both Area B and Area B extension. Table 11.12 itemizes the frequency of reconstructed vessel forms by stratigraphic zones at Area B (including the Area B extension), while Figure 11.52 summarizes trends in major vessel categories expressed as percent of reconstructed vessels for each zone. The trends seen in the analysis of diagnostic sherds from the Area B extension are reinforced by the trends in the reconstructed vessels, with a steady decline through time in both bowls and pedestal-foot vessels (most if not all of which were themselves topped by bowls), matched by rapid increases in flat-bottom dishes and in jar forms.

The main decorative techniques employed on the reconstructed vessels from Area B and the Area B extension are enumerated in Table 11.13; the trends are graphically depicted in Figure 11.53 as percentages of vessels

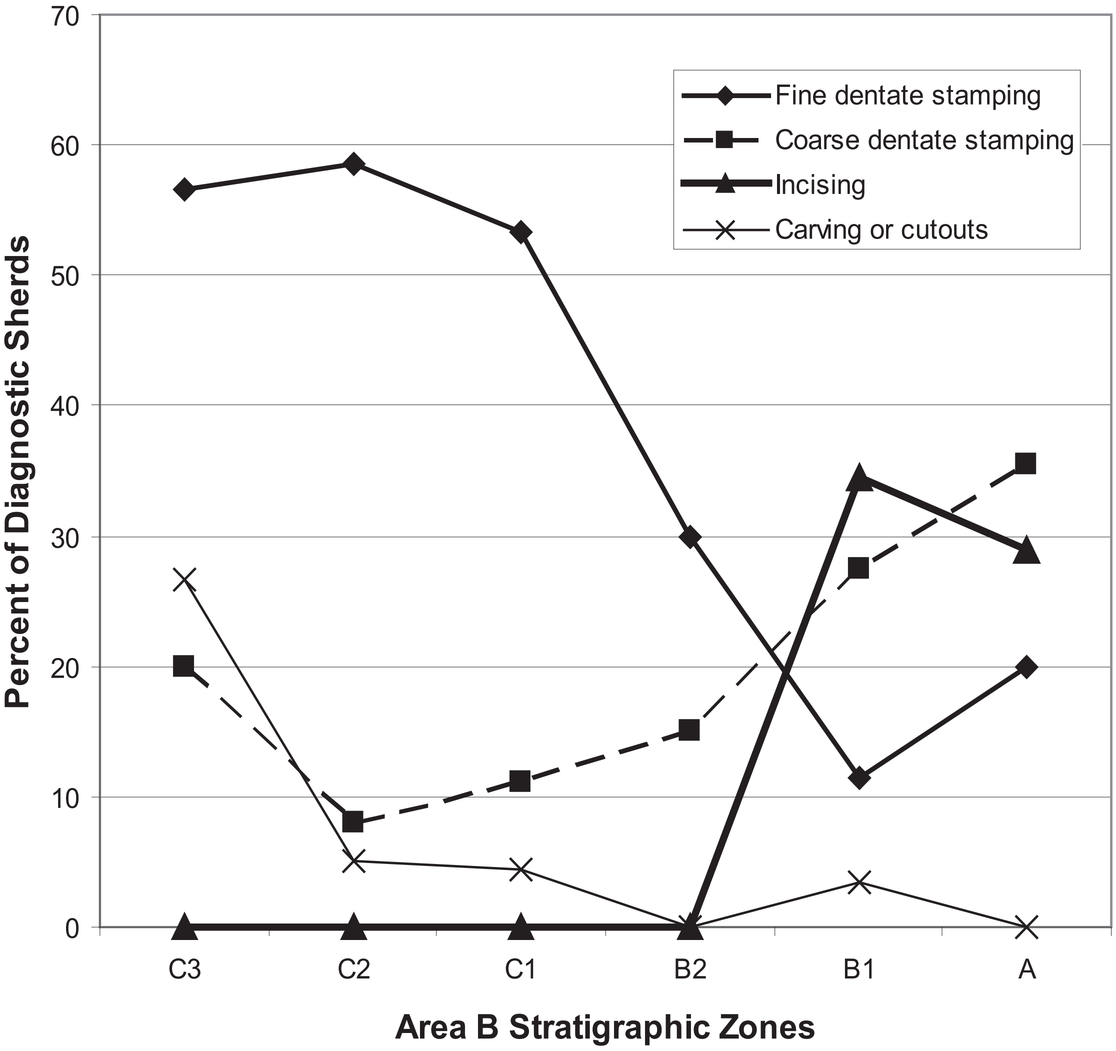


Figure 11.50. Distribution of major decorative techniques by stratigraphic zone within the Area B extension, based on individual sherd attributes.

decorated with each technique. As with the sherd-based analysis, a steady decline in the use of fine dentate stamping from zone C3 through zone B1 is evident, matched by a significant increase in coarse dentate stamping. The use of incising also increases, especially from zone C2 to zone C1.

Along with temporal shifts in the main decorative techniques used on vessels in the Area B and Area B extension assemblages, there are trends in the frequency of the particular motifs present on individual vessels. Table 11.14 summarizes the distribution of some of the major motif categories on these vessels. Variants of the zigzag motif are most frequent in zones C3 through C1, reflecting their frequent appearance on bowls of vessel form IB1. The zigzag motif also appears on vessel class III, flat-bottom dishes, and so continues into zones B2 and B1 on this vessel class. The "bone" motif is found only in zones C1 through B1, while the "tongue" motif occurs only in zones C3 through C1. Nubbins, occurring mostly on the sides of flat-bottom dishes, appear in the later zones C1 through B1, as does the "broad-nosed face" motif. The "long-nosed face with headdress" motif is found only in the earliest zones C3 and C2, where it occurs on IB1 bowls and cylinder stands. Finally, the "long-beaked bird" motif on rim lips is also limited to early zones C3 through C1, occurring primarily on class IB1 vessels.

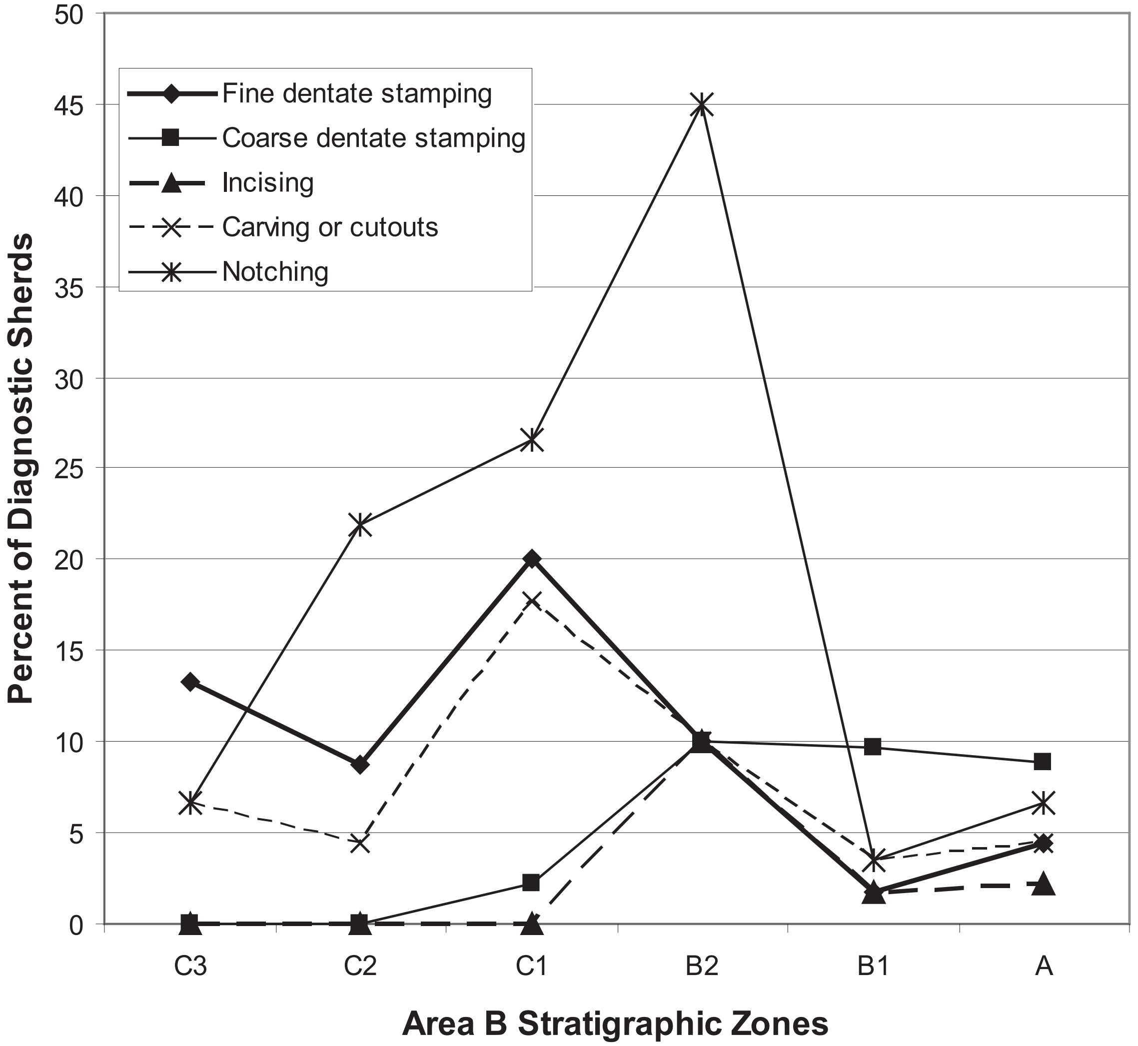


Figure 11.51. Distribution of decorative techniques employed on vessel rim lips, by stratigraphic zone within the Area B extension, based on individual sherd attributes.

The Area A Assemblage

Area A is situated on the paleobeach terrace just south of the shoreline during the early Lapita period, close to the 1978 National Museum of Papua New Guinea excavation (Bafmatuk et al. 1980). The 6 m^2 block excavation at Area A yielded an assemblage of 1,629 sherds, notable for its uniformity, restricted range of vessel forms, and general lack of decoration. Of this total, 65 are rims, 9 are carinated body sherds, and 3 are rims plus carinations. Of the remaining 1,552 body sherds, only three are decorated, all with simple dentate stamping. Of the body sherds, 31 have red slip, as do five of the rim sherds. The results of an attribute analysis of diagnostic sherds from Area A are presented in Table 11.15.

The sherds from Area A are highly consistent in paste and color. We did not sample them for petrographic analysis, but hand-specimen examination suggests that most sherds have a fine-grained calcareous sand temper. Relatively low temperature firing is indicated by the presence of unoxidized carbon cores in most sherds. Surface colors are typically in the range from 2.5 YR 4-5/6-8, "red," but the sherds with red slip have a deeper color of 10 R 4-5/6-8.

The rims are all of a simple everted type, with rounded lips. Although only four vessels could be reconstructed for rim diameter, the majority of rims appear to come from globular jars of form IIA, with restricted necks and simple

Table 11.12. Distribution of reconstructed vessel forms in Area B by stratigraphic zone

Vessel Type	Stratigraphic Zones						Totals
	C3	C2	C1	B2	B1	A	
IA	1		1				2
IB1	9	13	9	2	1	1	35
IB2			3				3
IIA	1	12	8	4	1		26
IIB	1	5	10	3	3		22
IIC	1	4	12	1	4	1	23
III	1	9	17	12	9	2	50
IVA		1	1				2
IVB	4	5	1			1	11
V			3		2		5
VI			2				2
Drum	1						1
Totals	19	49	67	22	20	5	182

everted rims extending between 2.5–3.5 cm from the neck constriction to the lip. Three of the reconstructed vessels are of this form IIA (ECA-V-076, -077, and -182 in the catalog of vessels). The fourth reconstructed vessel (ECA-V-079) is a simple unrestricted bowl of form IB2, with an inflected carination; this vessel is not decorated. Another large carinated sherd (A22-06-004) appears to be from a similar IB2 bowl, but is lacking the rim lip and was not reconstructed. The sherd-based analysis (Table 11.15) also indicates the presence of two sherds from pedestals (vessel form IVB).

Only three sherds from Area A have any decoration. A very small sherd (A23-02-006) from Unit W229N101 has traces of very fine dentate stamping, but the sherd (less than 1 cm^2) is too small to be able to discern the motif. A larger body sherd (A25-02-003) from W229N102, with red slip on the exterior, has a simple dentate-stamped line that makes a curved turn to then run at a 90° angle. The most elaborately decorated sherd (A22-08-011) comes from level 8 in Unit W228N100; this is a carinated rim

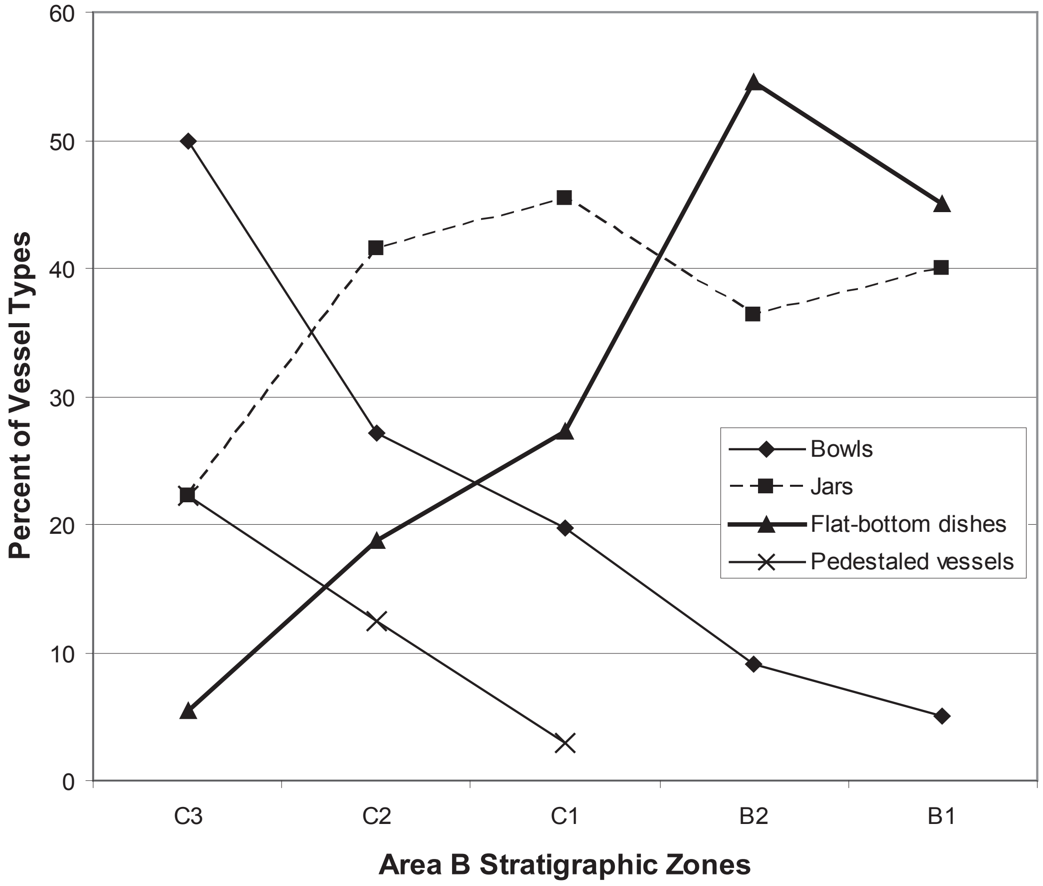


Figure 11.52. Trends in vessel form in Area B at site ECA, based on the corpus of reconstructed vessels.

Table 11.13. Frequency of main decorative techniques on reconstructed vessels, by stratigraphic zone at Area B, ECA. Each occurrence indicates the presence of that decorative technique on a single reconstructed vessel

Decorative Technique	C3	C2	C1	B2	B1	A	Totals
Fine dentate stamping	14	24	27	4	6	1	76
Coarse dentate stamping	1	8	17	10	9	4	49
Incising	1	3	16	4	4		28
Cutouts	6	12	15	3	6	2	44
Lime infill	12	26	21	6	4		69
Appliqué nubbins		1	4	4	2	1	12
Lip notching		10	5	5	1		21

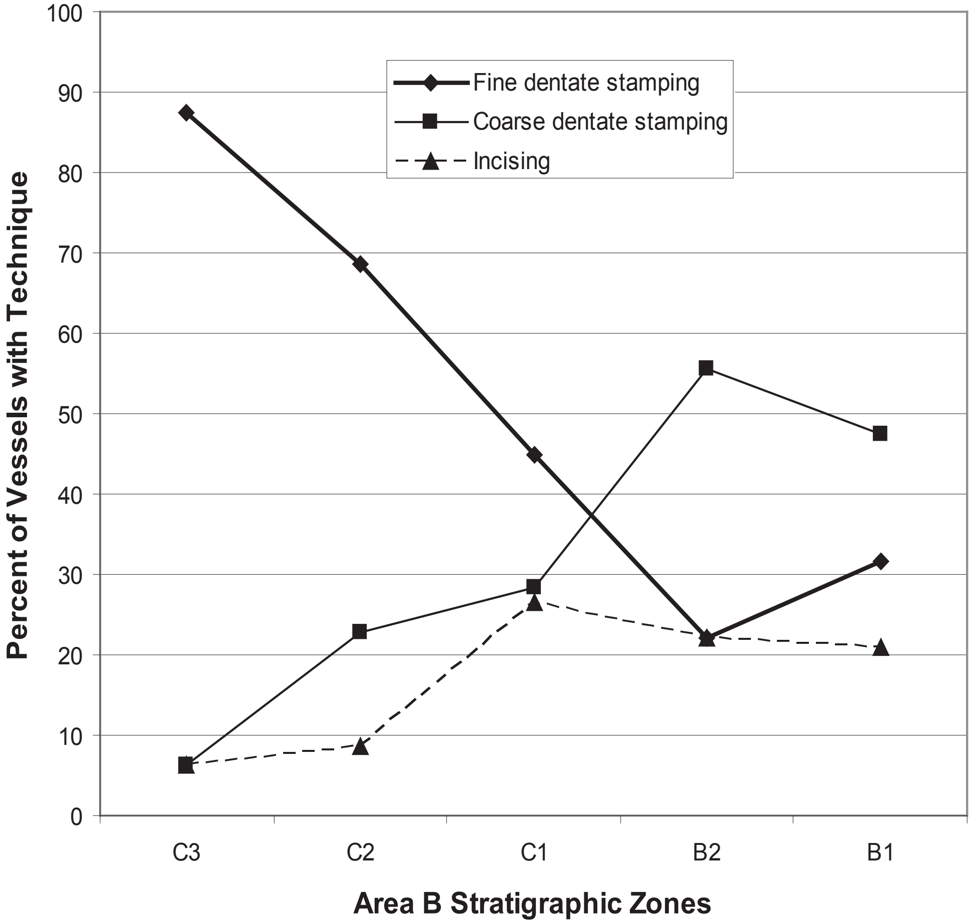


Figure 11.53. Trends in major decorative techniques in Area B at site ECA, based on the corpus of reconstructed vessels.

sherd of a form IB2 unrestricted bowl, similar in shape to reconstructed vessel ECA-V-079. The decoration, done in fine dentate stamping with lime infill, is confined to the space between the rounded lip and the carination (a distance of 1.5 cm), and consists of motif GS527, a series of regularly spaced, vertical double-stamped lines, with every other line joined at the bottom by a looping semicircle. A horizontal stamped line runs across the top of the motif. In addition to these decorated sherds, it is notable that a large number of the analyzed sherds display evidence of a red slip (Table 11.15).

Table 11.14. Frequency occurrence of selected motif categories by stratigraphic zone, Area B, site ECA. Each occurrence indicates the presence of the motif on a single reconstructed vessel

Motif category	Stratigraphic Zones					Total Occurrences
	C3	C2	C1	B2	B1	
Zigzag	6	11	10	5	2	34
Labyrinth		3	4		2	9
Bone			4	2	1	7
Tongue	5	5	1			11
Nubbins (breasts?)			4	3	2	9
Long-nosed face with headdress	1	2				3
Broad-nosed face			2	1	2	5
Long-beaked bird	1	1			1	3
Long-beaked bird rim motif	2	7	5			14

Table 11.15. Frequency of diagnostic sherd attributes for the Area A and Area C ceramic assemblages, site ECA

Category	Attribute	Area A		Area C	
		N	%	N	%
Diagnostic sherds		66		164	
Vessel form	I, Bowls	4	6.0	5	3.0
	II, Jars	8	12.1	46	28.0
	IIA, Globular jars	43	65.1	6	3.6
	IIB, Carinated jars	4	6.0	1	0.6
	IV, Pedestal vessels	2	3.0	1	0.6
Primary decorative technique	Fine dentate stamping	3	4.5		0
	Coarse dentate stamping		0	2	1.2
	Incising		0	73	44.5
	Shell impressed		0	2	1.2
Lip decoration	Notched		0	72	43.9
	Finger-pinched		0	9	5.5
Other traits	Lime infill	1	1.5		0
	Red slip	59	89.4	45	27.4

The Area C Assemblage

As described in Chapter 3, Area C at site ECA consists of two adjacent excavation blocks of 4 m^2 each, situated near the northern end of the W250 transect, excavated during the 1988 field season. As we approached the northern end of the transect, it became apparent that the ceramics were very different from those in the units at the southern end of the transect; there were virtually no dentate-stamped sherds but rather a high frequency of thin-walled sherds bearing incised decoration. Area C was opened up to obtain a larger sample of this material. Radiocarbon dating of materials from Area C, reported in Chapter 5, indicates that Area C is the youngest part of the ECA site, with Bayesian modeled start boundary of 3154–2970 BP and end boundary of 2778–2492 BP.

The excavated 8 m^2 at Area C yielded a total of 1,458 sherds, of which 1,287 are plain body sherds. There are 99 rim sherds, of which 88 are decorated. Another 67 body sherds bear some decoration, and there is one decorated rim plus carination. There are also two plain carinated sherds, and one base sherd. Because the ceramics from Area C are quite uniform in their characteristics, we treat them here as a single assemblage. An attribute analysis of 164 diagnostic sherds from Area C is presented in Table 11.15.

With few exceptions, the sherds from Area C contrast with those from Areas A and B in having thin vessel walls. A sample of sherds from Unit W250N190, typical of the Area C assemblage, has a mean vessel wall thickness of 5.5 ± 0.97. Most of the sherds also lack unoxidized carbon cores, indicating thorough firing. On the whole, these thin-walled, well-fired vessels evince a high degree of technical skill in vessel manufacture, but little interest in elaborate decoration. The paddle-and-anvil method was probably used to thin the vessel walls, although most sherds are too small to reveal anvil impressions.

Ten sherds from Area C were examined in petrographic thin-section by William Dickinson in his analysis of temper in the ECA ceramics (see Chapter 13 for details). Of the sherds sampled, three fall into Dickinson's temper group A, with exclusively calcareous sand grains, while another three are in temper group B, with primarily calcareous grains but also with rare terrigenous grains present. One sherd is from temper group G, with pyroxenic volcanic temper, one sherd from group H, with a hybrid non-placer temper, and two sherds from group J, with a quartzose-feldspathic temper. Temper group J occurs exclusively at Area C. Other temper groups C, D, E, F, and K, found in other parts of the ECA site, are all absent at Area C. The G and H temper groups may have origins in the Admiralty Islands (Manus), while temper group J may possibly derive from New Britain.

The sherds from Area C are generally of small size, making reconstruction of vessel form problematic. It appears that most of the sherds come from thin-walled, globular jars with everted rims (vessel class IIA). Most of the rim lips are flat, in some cases slightly thicker than the vessel wall itself (i.e., slightly expanded). The most frequent mode of lip decoration is that of closely spaced parallel lines or notches made by impressing a stick or other tool perpendicularly across the lip. In several cases the lip was decorated by finger-pinching, creating a crennellated effect.

Only two sherds from Area C have coarse dentate-stamped decoration, and both of these were clearly water-rolled, suggesting that they had been deposited on the reef flat prior to the main occupation at Area C (most of the Area C sherds are not water-rolled). The dominant decoration technique at Area C is simple incising (Figure. 11.54). Small sherd size prohibits the reconstruction of entire designs, but both parallel and slanting lines are evident. The lines are typically very fine and lightly done. Three sherds are of particular interest in that they replicate motifs known from classic dentate-stamped Lapita pottery, but are rather crudely executed with incising, seemingly an effort to copy the dentate-stamped motifs (see Figure 11.54, c, d). One of these sherds (ECA-90-04-007) is of temper group J. This continuation of motifs from classic dentate-stamped Lapita to later incised pottery is significant in demonstrating some continuity in artistic expression over time, and in suggesting that what we are dealing with is technological and stylistic change within a single cultural tradition.

Only a single sherd (ECA-90-02-001) was large enough to allow for reconstruction of its form and inclusion in the ceramic vessel catalog (ECA-V-185). This is a strongly out-turned rim of a globular jar with a rim diameter of 34 cm. The lip has been notched by impressing with a tool or possibly by finger-pinching. About 2.4 cm below the lip, there is a decorative band 2.6 cm wide made by rocker stamping with the naturally serrated edge of a bivalve shell (possibly *Anadara* sp.). Vessel ECA-V-185 has temper of group H, a hybrid non-placer sand.

In sum, the Area C ceramics are quite distinctive within the large ECA site assemblage, representing a late phase when vessel forms were restricted to thin-walled globular jars, dentate stamping seems no longer to have been practiced, and decoration was limited to simple rim

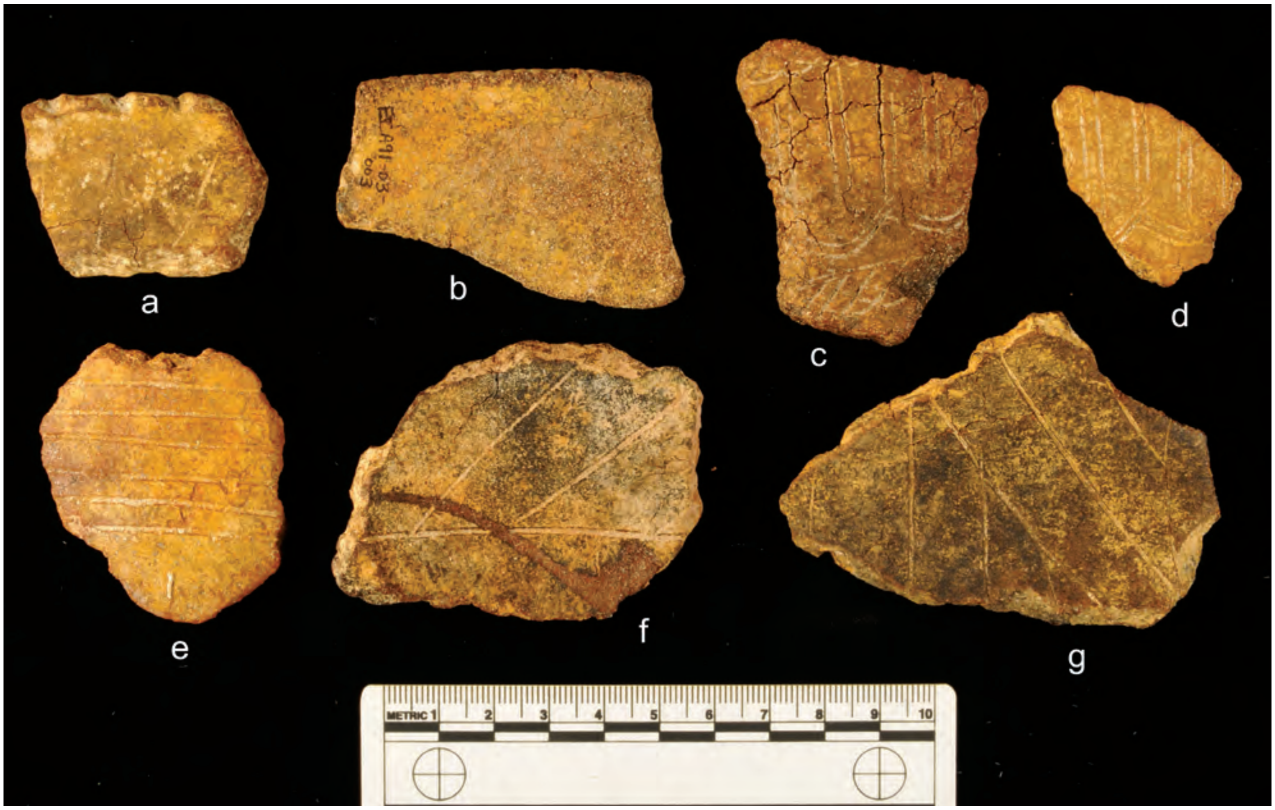


Figure 11.54. Decorated sherds from Area C at site ECA: *a*, sherd with notched rim, ECA-83-3-001; *b*, sherd with finely notched rim, ECA-91-03-003; *c*, sherd with incised decoration mimicking a dentate-stamped motif, ECA-90-4-001; *d*, sherd with incised decoration mimicking a dentate-stamped motif, ECA-90-04-210; *e*, sherd with parallel incised lines, ECA-86-6-005; *f*, sherd with slanting incised lines, ECA-85-6-008; *g*, sherd with parallel slanting incised lines, ECA-88-04-009.

lip notching and to a limited range of incised designs. The Area C ceramics are similar to those from the Epakapaka (EKQ) rockshelter site on Mussau Island, described below.

Ceramics of the W250 Transect

The W250 transect was excavated during the 1988 field season in order to sample the waterlogged cultural deposits extending northward from the mid-Holocene shoreline. The transect begins at W250N80 with 1 m^2 excavation units positioned at 10 m intervals; the final unit is W250N200. Area C was encountered while excavating the W250 transect, but the ceramics from the 8 m^2 making up Area C are treated separately (see above). While there is vertical stratification within individual units along the W250 transect, the transect as a whole exhibits a gradual horizontal temporal progression, from early to late as one proceeds from south to north. This "horizontal stratification" reflects the gradual progradation of the shoreline in a northerly direction, following the approximately 1 m drop in sea level that occurred between roughly 4000 and 2000 BP. The radiocarbon chronology along the W250 transect is discussed in detail in Chapter 5, with Bayesian modeling putting the early portion of the W250 transect between 5432–3189 (start boundary) and 3262–3087 BP (transition boundary) and the middle section of the transect (between N100 and N140) having an end boundary of 3154–2970 BP.

A sample of 314 diagnostic sherds recovered from the W250 excavation units was subjected to an attribute analysis, with the results for vessel form and decorative traits reported in Table 11.16. Trends in the frequency distribution of vessel classes along the transect are plotted in Figure 11.55, calculated as percentages of diagnostic sherds to compensate for sample size effects. Jars, vessel class II, are the most frequent vessel form in the southern units, declining in relative frequency in the middle sector, then rising again in the northern part of the transect. Bowls, class I, are most prevalent in the

Table 11.16. Frequency distribution of vessel form and decorative traits along the W250 transect, based on analysis of diagnostic sherds

Unit	N sherds	Vessel Forms							Decorative Traits					
		I, Bowls	II, Jars, unspecified	IIA, Globular jars	IIB, Carinated jars	III, Flat-bottom dishes	IV, Pedestal vessels	V, Cylinder stands	Fine dentate stamping	Coarse dentate stamping	Incising	Carving, cutouts	Lime infill	Red slip
N80	4		1											
N90	14		5						2					
N100	19	5	4	5			1		6				1	5
N110	47	3	11	2	1		1	2	22				5	10
N120	57	4	17			2	11		26	1		10	16	7
N130	45	7	10				2		15	11			10	
N140	29	2	5			1	3		9	13		2	21	
N150	20	2	6				5		5	5	1	4	6	
N160	36		4		6	3	1		5	9	15	2	8	1
N170	14	1	4			2	1				5			
N181	24		2		1				1	2	15			
N200	5		1								1			
Totals	314	24	70	7	8	8	25	2	91	41	37	18	67	23

southern part of the transect, declining to low frequency in the northern sector. Flat-bottom dishes, class III, are absent or infrequent in the southern sector, increasing in frequency in the northern sector. These trends generally mirror those occurring stratigraphically within Area B (see above).

Trends in decorative technique along the W250 transect are plotted as percentage values in Figure 11.56. These trends display especially clear differences as one proceeds from south to north along the transect, with fine dentate stamping dominating in the southern sector and virtually disappearing in the northern sector of the transect, coarse dentate stamping dominating in the middle of the transect, and incising appearing only in the northern sector and becoming essentially the only decorative technique employed on vessels at the northern end of the transect. Once again, these trends closely mirror those seen stratigraphically within Area B.

The Lapita Ceramics of Etakosarai (ECB), Etapakengaroasa (EHB), Boliu (EKE), and Epakapaka (EKQ)

Much smaller Lapita ceramic assemblages were recovered from the excavations at Etakosarai (ECB), Etapakengaroasa (EHB), and Boliu (EKE). None of these sites has the waterlogged depositional conditions found at Talepakemalai, and as a consequence the sherds are generally quite fragmented, making analysis more challenging. For the ECB site we were able to reconstruct 17 vessels (see Mussau Ceramic Catalog), but only three vessels could be reconstructed for site EHB, and just one for site EKE. The analysis of these ceramic assemblages is therefore based primarily on sherd attribute data, as presented in Table 11.17 for sites ECB and EHB.

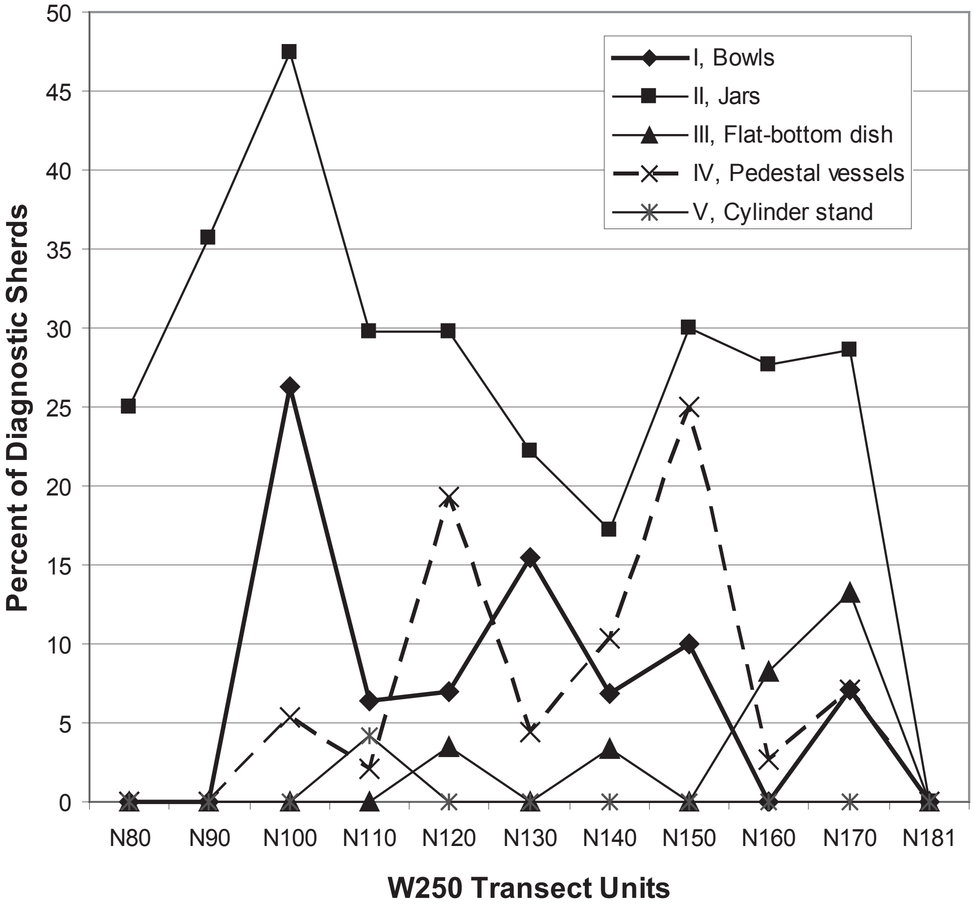


Figure 11.55. Distribution of vessel classes along the W250 transect, based on individual sherd attributes.

The Etakosarai (ECB) Assemblage

ECB is a small Lapita site originally situated on a beach facing across an open reef flat to Talepakemalai (see Chapter 4). The deposits are shallow and have been extensively turned over due to many generations of gardening, resulting in much breakage and fragmentation of sherds and questionable stratigraphic integrity. Thus the ceramic assemblage is treated as a single entity, without regard for stratigraphic context.

A large number of the ECB sherds (45.2%) are tempered exclusively with calcareous sand, and another 35.6% with mixed calcareous and terrigenous tempers. Fully 62.7% of the sherds show some red slip; another 23.6% have smoothed and/or burnished surfaces (the remainder are eroded).

Of the 377 sherds for which vessel shape can be inferred, the greatest number (236) are from some type of jar, vessel class II. These typically have everted rims with either flat or rounded lips. Bowls are the next most frequent vessel class, with 77 sherds. Unrestricted bowls of vessel class IB1 dominate, but three examples of carinated bowls (IB2) are also present. There are 45 sherds from pedestals or ring feet, which suggests that some of the form IB1 bowls were originally supported on these stands. There are six sherds from cylinder stands (vessel form V). It is noteworthy that only four sherds can be assigned to vessel class III, flat-bottom dishes.

Both fine and coarse dentate stamping are represented on the decorated sherds from ECB, although coarse stamping is far more prevalent. Incising is as frequent as fine dentate stamping. The use of carving or cutouts is also evidenced, especially on the pedestal bases. Notching of rim lips is quite common, particularly on the everted rims of vessel class II jars.

The frequency of vessel forms and decorative techniques corresponds fairly well with those of the early to middle zones at Area B in ECA (i.e., zones C3 to B2), consistent with the marine shell radiocarbon dates from ECB when compared to the dates for Area B at ECA (see Chapter 5). The low frequency of flat-bottom dishes at ECA is notable, as these are quite common in zone B1 at Area ECA. It seems likely that the ceramics at ECB accumulated over a fairly long period of time; unfortunately, however, the disturbed stratigraphy does not permit us to tease out a finer-grained ceramic chronology for the site.

The reconstructed vessels from ECB (described in the Mussau Ceramic Catalog) include eight IB1 bowls with fine dentate-stamped motifs (ECB-V-001, -004, -008, -009, -010, -011, -013, -015); some if not all of these were most likely attached to pedestals. Vessels ECB-V-011 and -013 both have elaborately decorated rim lips displaying the "long-beaked bird" motif. Also notable is vessel ECB-V-007, the carinated portion of a large class IIB jar, with intricate fine dentate-stamped decoration.

The Etapakengaroasa (EHB) Assemblage

The EHB site, situated on Emananus Island, is, like ECB, a small Lapita site (see Chapter 4), where burrowing land crabs have unfortunately also disturbed and mixed the stratigraphy. Our excavations there yielded 515 diagnostic sherds that were subject to an attribute analysis, with results presented in Table 11.17.

At EHB the percentage of sherds tempered with exclusively calcareous sand is very high (79.4%), although some mixed calcareous-terrigenous, and a few exclusively terrigenous tempers, are also evidenced (see Table 11.2). Dickinson's petrographic analysis included six sherds from EHB; four sherds had temper of either calcareous or calcareous with rare terrigenous grains, but two sherds exhibited pyroxenic volcanic and hybrid non-placer tempers (see Table 11.3, and Chapter 12). As at ECB, a high proportion of the sherds evidence some red slip (69.7%), with the remainder being either smoothed and burnished, or eroded.

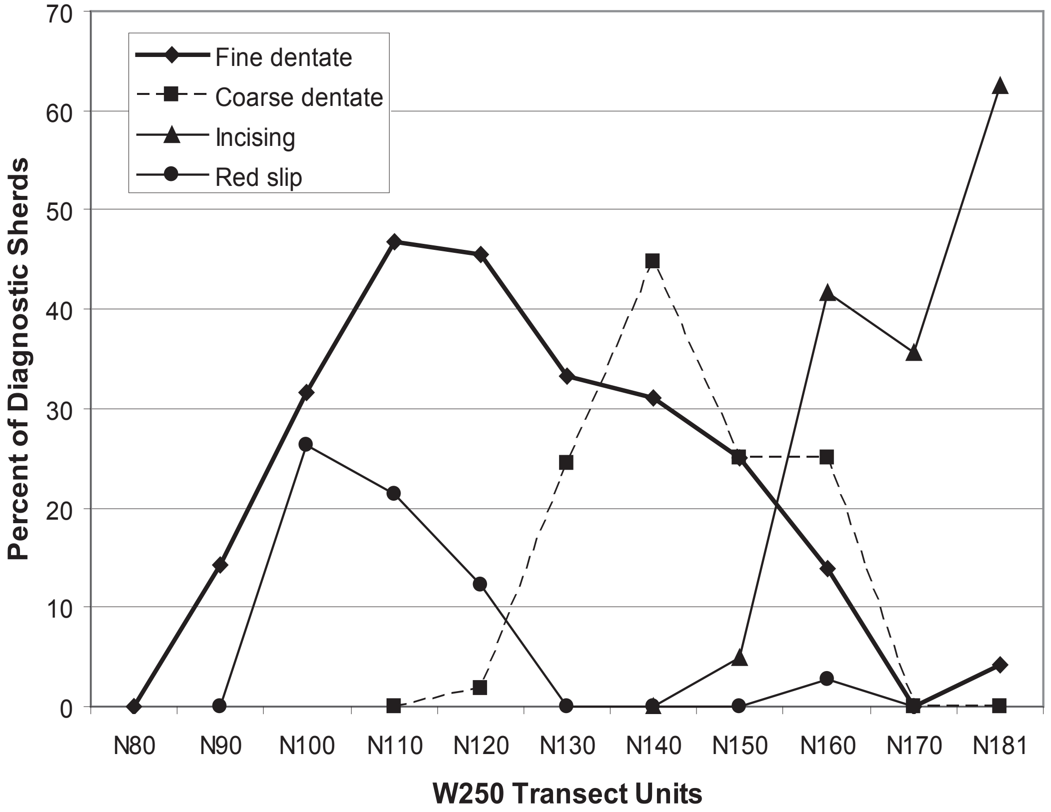


Figure 11.56. Distribution of major decoration techniques along the W250 transect, based on individual sherd attributes.

Table 11.17. Frequency distribution of diagnostic sherd attributes for the ECB and EHB site assemblages

Category	Attribute	Site ECB		Site EHB	
		N	%	N	%
Diagnostic sherds		813		515	
Vessel form	IB1, Bowls	74	9.1	21	4.1
	IB2, Carinated bowls	3	0.4	6	1.2
	II, Jar, subtype unspecified	236	29.0	26	5.0
	IIB, Carinated jars		0	2	0.4
	III, Flat-bottom dishes	4	0.5	3	0.6
	IVB, Pedestals	45	5.5	44	8.5
	V, Cylinder stands	6	0.7	2	0.4
Primary decorative technique	Fine dentate stamping	70	8.6	160	31.1
	Coarse dentate stamping	234	28.8	23	4.5
	Incising	76	9.3	79	15.3
	Carving or cutouts	36	4.4	24	4.6
Lip decoration	Fine dentate stamping	10	1.2	23	4.5
	Coarse dentate stamping	27	3.3	4	0.8
	Incising	5	0.6	12	2.3
	Carving or cutouts	12	1.5	10	1.9
	Notching	53	6.5	49	9.5
	Finger-pinched, crenate		0	1	0.2
Other traits	Lime infill	195	23.9	84	16.3
	Red slip	510	62.7	359	69.7

The most frequent vessel class at EHB is that of pedestal bases (class IVB), followed by jars (II), and then bowls, especially of class IB1 although carinated bowls (class IB2) are also present. There are two examples of carinated jars (class IIB), two of cylinder stands (class V), and two of flat-bottom dishes (class III). Reconstructed vessels in the Mussau Vessel Catalog from EHB include two pedestal bases and a lid.

Fine dentate stamping is the dominant decorative technique evidenced in the EHB assemblage with 31.1%; coarse dentate-stamped sherds constitute just 4.5%. Incising is also present (especially on the jar form vessels), as is the use of carving and cutouts.

When the EHB assemblage is compared with those from ECA Area B, and from site ECB, both the high frequency of pedestals and of fine dentate stamping at EHB stand out, as does the low frequency of flat-bottom dishes. These traits are consistent with placing the EHB assemblage early in the Mussau Lapita chronological sequence, most comparable to that of zones C3 to C1 of Area B at ECA. Radiocarbon dating, discussed in detail in Chapter 5, actually positions EHB as somewhat earlier than site ECA.

The Boliu (EKE) Assemblage

The ceramic assemblage from the EKE site on Boliu Island was obtained primarily from deeper stratigraphic layers in

Figure 11.57. Vessel EKE-V-001 from site EKE on Boliu Island, decorated with a fine dentate-stamped motif.

Figure 11.58. Unique punctate decorated sherd from TP1 of site EKE on Boliu Island.

several units (see Chapter 4), totaling 1,761 sherds, all but 19 of which are plain body sherds. Of the 19 diagnostic sherds, six are decorated body sherds, four are plain rim sherds, two are decorated rim sherds, and one is a decorated carination. No detailed attribute analysis of the EKE assemblage was carried out, but in general the assemblage exhibits many similarities to that of Area A at site ECA. Only a single vessel could be reconstructed (EKE-V-001; see Mussau Ceramic Catalog); this is a small, restricted bowl of class IA, with fine dentate-stamped decoration around the exterior (Figure 11.57).

In addition to the Lapita phase ceramics from EKE, an excavation unit at E117N327 (also designated TP1) dug into a shell midden mound containing *Terebra*-shell adzes yielded a single sherd with punctate decoration (Figure 11.58). The motif seems to mimic a dentate-stamped motif, but appears to have been made by impressing a single stick repeatedly into the clay surface, rather than with a multi-tined stamp. This was the only ceramic sherd recovered from this excavation unit, which although not radiocarbon dated clearly is of a late, post-Lapita period.

The Epakapaka (EKQ) Assemblage

The EKQ rockshelter, situated along the northwestern coast of Mussau Island (see Chapter 4), yielded an assemblage of 10,447 sherds from the two 1 m^2 excavation units. Of this total, 9,721 consist of plain body sherds, with another 726 diagnostic sherds (rims or decorated sherds). Of the diagnostic sherds, 576 are decorated, primarily with either notched rims, or with incised designs, although a small number of dentate-stamped sherds are also present. As is evident in Figure 11.59, showing the vertical distribution of sherds by decorative type in excavation Unit 1, the upper part of the EKQ sequence is aceramic. Bayesian modeling of radiocarbon dates from the lower stratigraphic levels containing pottery in Unit 1, presented in detail in Chapter 5, indicates a time span of between 3745–2997 BP (starting boundary) and 2773–2097 BP (ending boundary) for this assemblage.

The EKQ ceramic assemblage is highly fragmented, doubtless the result of repeated trampling within the confined space of the rockshelter; the small sizes of the sherds makes analysis of the assemblage challenging. Only three rim sherds were of sufficient size to reconstruct the upper portion of the vessel (see Mussau Ceramic Catalog). One of these (EKQ-V-003) is of what appears to have been a small, unrestricted bowl with a raised band or carination, decorated in coarse dentate stamping. The other two (EKQ-V-001 and -002) are plainware jars (class IIA) with everted rims, the rim lips being decorated with simple

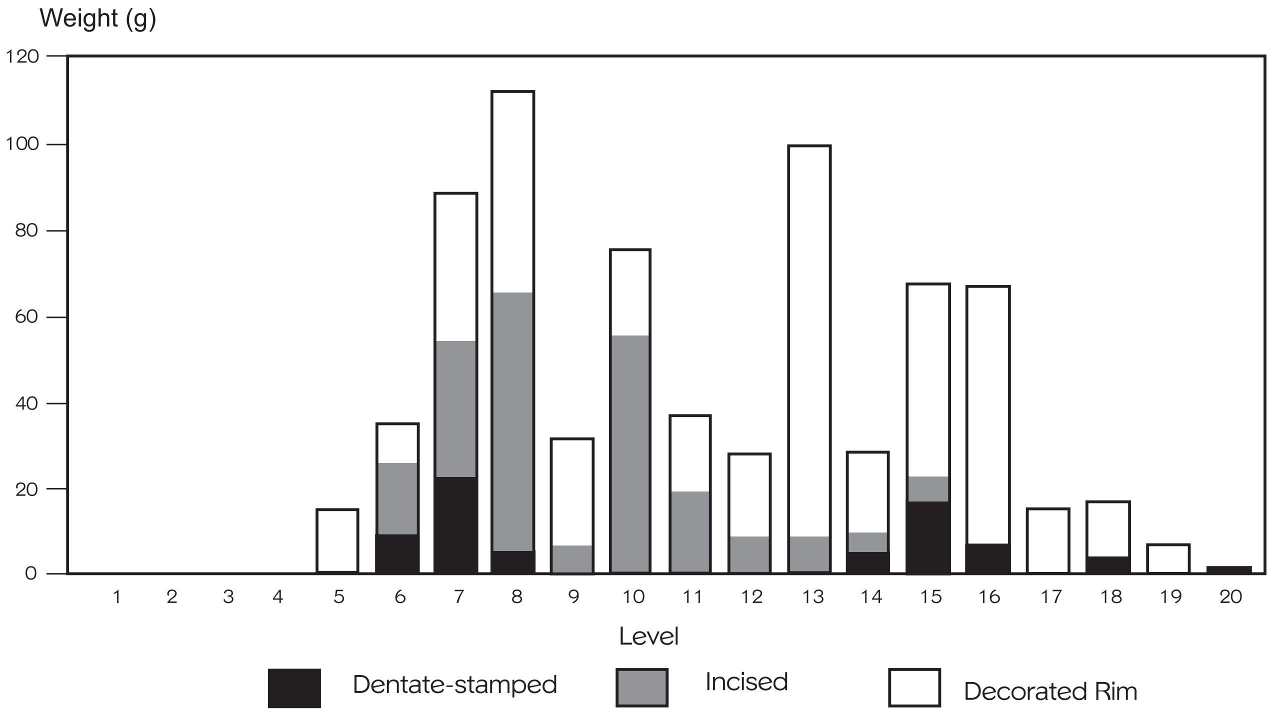


Figure 11.59. Stratigraphic distribution of ceramic sherds in excavation Unit 1 at site EKQ.

notching. Although we were not able to reconstruct additional vessels, the majority of the EKQ sherds seem to represent thin-walled jars with everted rims, much like the assemblage at Area C of site ECA. Rim sherds from EKQ are illustrated in Figure 11.60, showing the high frequency of lip notching, but also the occasional presence of punctate decoration below the rim lip.

Although dentate-stamped sherds are present in the EKQ site assemblage, the stamps are coarse and the decoration quite crude when compared with other Mussau Lapita assemblages, suggesting that the EKQ ceramics reflect the tail end of the use of dentate stamping. A selection of sherds with dentate stamping is illustrated in Figure 11.61. Sherds decorated with simple incised motifs are more common, and a selection of these is illustrated in Figure 11.62.

Ceramics at Other Mussau Sites

Limited test excavations in the small EKO rockshelter on Eloaua Island yielded an assemblage of 219 sherds (Table 11.1), mostly consisting of small, worn or eroded plain body sherds. The reddish-brown ceramics are primarily tempered with calcareous sand or shell fragments. The few rim sherds are everted, with flat lips, suggesting that they may derive from plainware jars of vessel class IIA. However, the highly fragmented nature of the sherds makes assignment of vessel form problematic. A single sherd (EKO-1-2-9) bears eroded traces of fine dentate stamping. At the nearby EHM rockshelter, two plain body sherds were also found near the base of the cultural deposit.

The Eatulawana rockshelter (EKP), a short distance from Pomanai Village on Mussau Island, yielded 63 plain body sherds, all very small and eroded. Some bear traces of red slip, and most appear to be tempered with calcareous sand. Little else can be said of this nondescript assemblage.

The Sinakasae (EKU) site on southern Mussau Island produced 55 sherds from five test excavation units. The sherds are mostly small and eroded, with a dark reddish paste tempered with dark minerals (probably pyroxene). Slightly everted rims with flat or rounded lips are present, as is a single body sherd with a carination, but little can be said about vessel form due to the fragmented nature of the sherds. Two sherd (one body sherd and one rim) have decoration consisting of parallel rows of punctate impressions (Figure 11.63). These sherds are in a late, post-Lapita

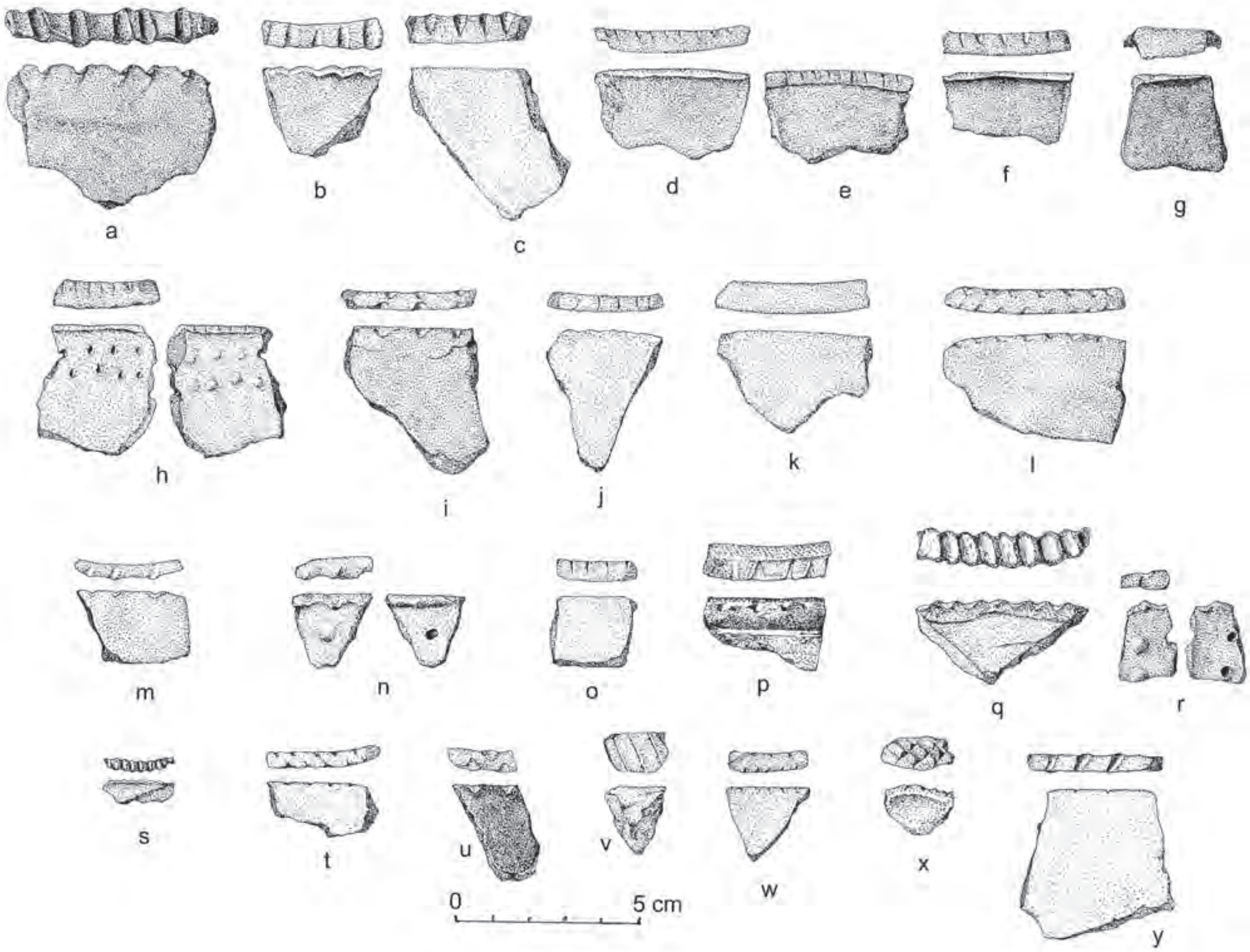


Figure 11.60. Rim sherds from site EKQ: *a*, EKQ-0-018; *b*, EKQ-2-0-1; *c*, EKQ-1-16-8; *d*, *e*, EKQ-2-8-5; *f*, EKQ-1-7-26; *g*, EKQ-2-7-5; *h*, EKQ-1-6-4; *i*, EKQ-2-16-14; *j*, EKQ-1-12-24; *k*, EKQ-1-16-19; *l*, EKQ-2-17-5; *m*, EKQ-1-15-24; *n*, EKQ-1-6-25; *o*, EKQ-1-15-27; *p*, EKQ-2-15-22; *q*, EKQ-1-8-6; *r*, EKQ-1-16-26; *s*, EKQ-1-19-25; *t*, EKQ-2-9-5; *u*, EKQ-2-15-16; *v*, EKQ-1-7-10; *w*, EKQ-2-16-21; *x*, EKQ-1-8-15; *y*, EKQ-2-14-26. (Drawing by Margaret Davidson.)

context. The Sinakasae site has a single radiocarbon date of 796–551 BP (see Chapter 5). It seems likely that the pottery at EKU was imported, possibly from Manus, which, unlike Mussau, continued to have a ceramic tradition into the ethnographic period.

Ceramic Discs

A final topic to be considered is the presence at sites ECA and ECB of circular ceramic discs, a selection of which are illustrated in Figure 11.64. These discs were not prepared and fired as such, but rather were fashioned from broken pieces of pottery that were chipped and sometimes ground around the edges to achieve the desired circular shape. This is evident from the fact that several discs retain parts of originally larger decorative motifs. There are 21 such discs from site ECA, and four from site ECB. The discs range in diameter from 2.77 to 5.77 cm, with a mean diameter of 4.62 cm.

Many of the discs show considerable battering and chipping around the edges, which may provide a clue as to their function. In various Oceanic societies, some version of a disc-pitching game is played, involving small discs of wood or even round seeds of appropriate size. Hiroa (1930:464) describes the game of *tupe* for Samoa, and also for the Cook Islands (1944:254). It seems entirely plausible that the ceramic discs found at ECA and ECB were gaming pieces for some kind of disc-pitching game, which would account for

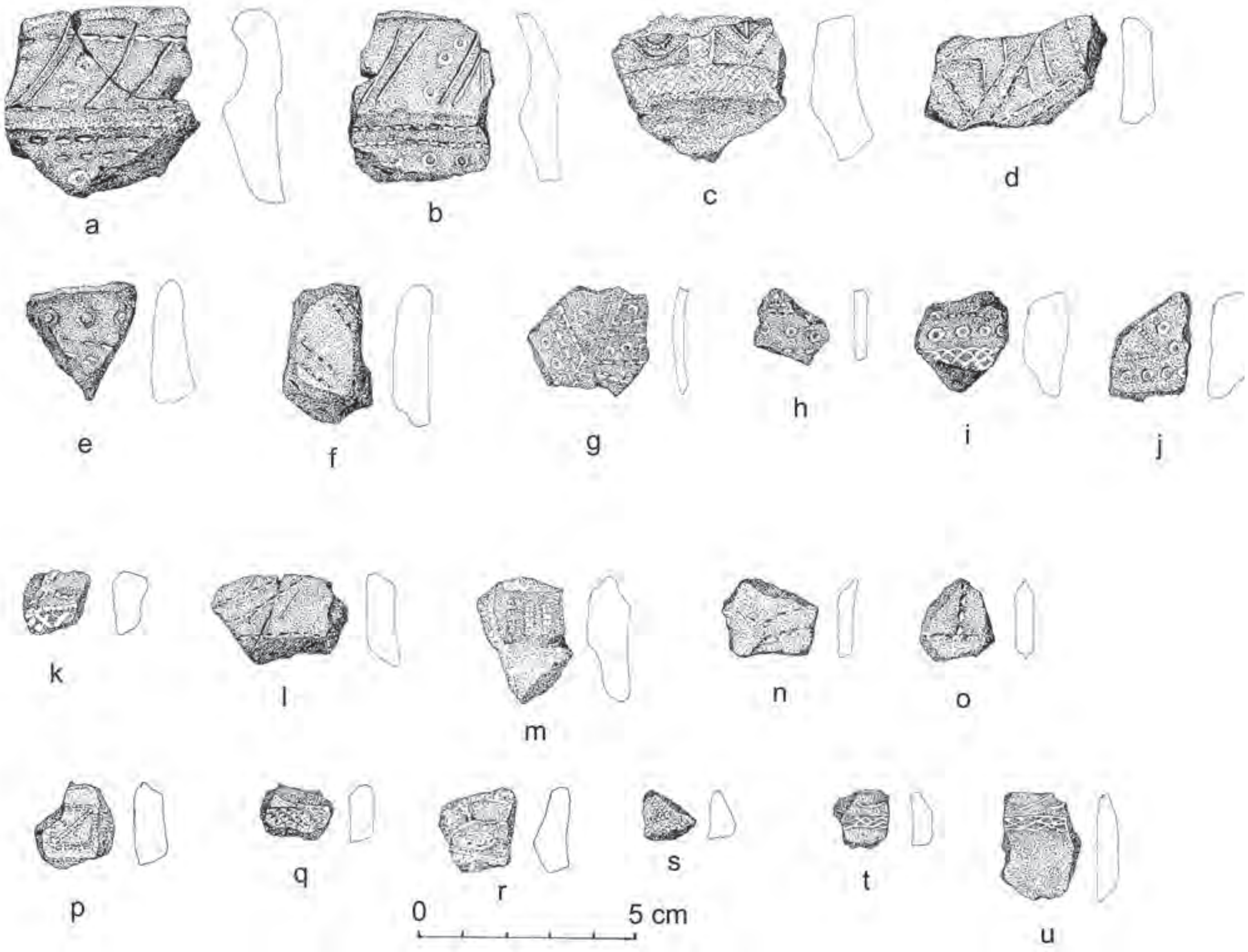


Figure 11.61. Sherds from site EKQ decorated with dentate stamping: *a*, EKQ-1-7-25; *b*, EKQ-1-5-6; *c*, EKQ-1-13-15; *d*, EKQ-2-1-3; *e*, EKQ-1-16-11; *f*, EKQ-1-7-13; *g*, EKQ-16-16; *h*, EKQ-1-5-17; *i*, EKQ-1-15-42; *j*, EKQ-1-15-8; *k*, EKQ-1-15-7; *l*, EKQ-2-0-2; *m*, EKQ-2-15-42; *n*, EKQ-2-7-9; *o*, EKQ-1-6-23; *p*, EKQ-1-16-5; *q*, EKQ-1-8-12; *r*, EKQ-1-15-43; *s*, EKQ-1-16-22; *t*, EKQ-1-15-44; *u*, EKQ-1-15-10. (Drawing by Margaret Davidson.)

their chipped and battered edges. Ceramic discs of this kind are also described and illustrated by Wu (2016:120–121) from the Apalo (FOJ) Lapita site in the Arawe Islands. Kirch (1991b:138) excavated three ceramic discs at the late Eastern Lapita site of FU-11 on Futuna Island in Western Polynesia, which suggests that such discs have a long persistence in the Lapita tradition; they may indeed have been the precursor to the later Polynesian game of *tupe*.

Summary of Ceramic Change in Mussau

The radiocarbon sequence for the Mussau Lapita sites, as modeled in Chapter 5 using a Bayesian statistical approach, provides a temporal ordering for the sites beginning with EHB as the earliest, progressing through the earlier portions of the ECA sequence (Area A > Area B > W250 transect), and ending with the late assemblages of ECA Area C and the EKQ site. To test this sequence, we applied frequency seriation (Doran and Hodson 1975:269) using the distribution of 22 motif "themes" across these ceramic assemblages. An initial seriation of motif themes in Area B, from zones C3 through B1, showed a clear pattern of decreasing frequency in the zigzag theme. We then used the zigzag theme as a time indicator to order a seriation that also included the EHB and ECB sites, along with assemblages from the larger W200 and W250 transects and from Area C. The

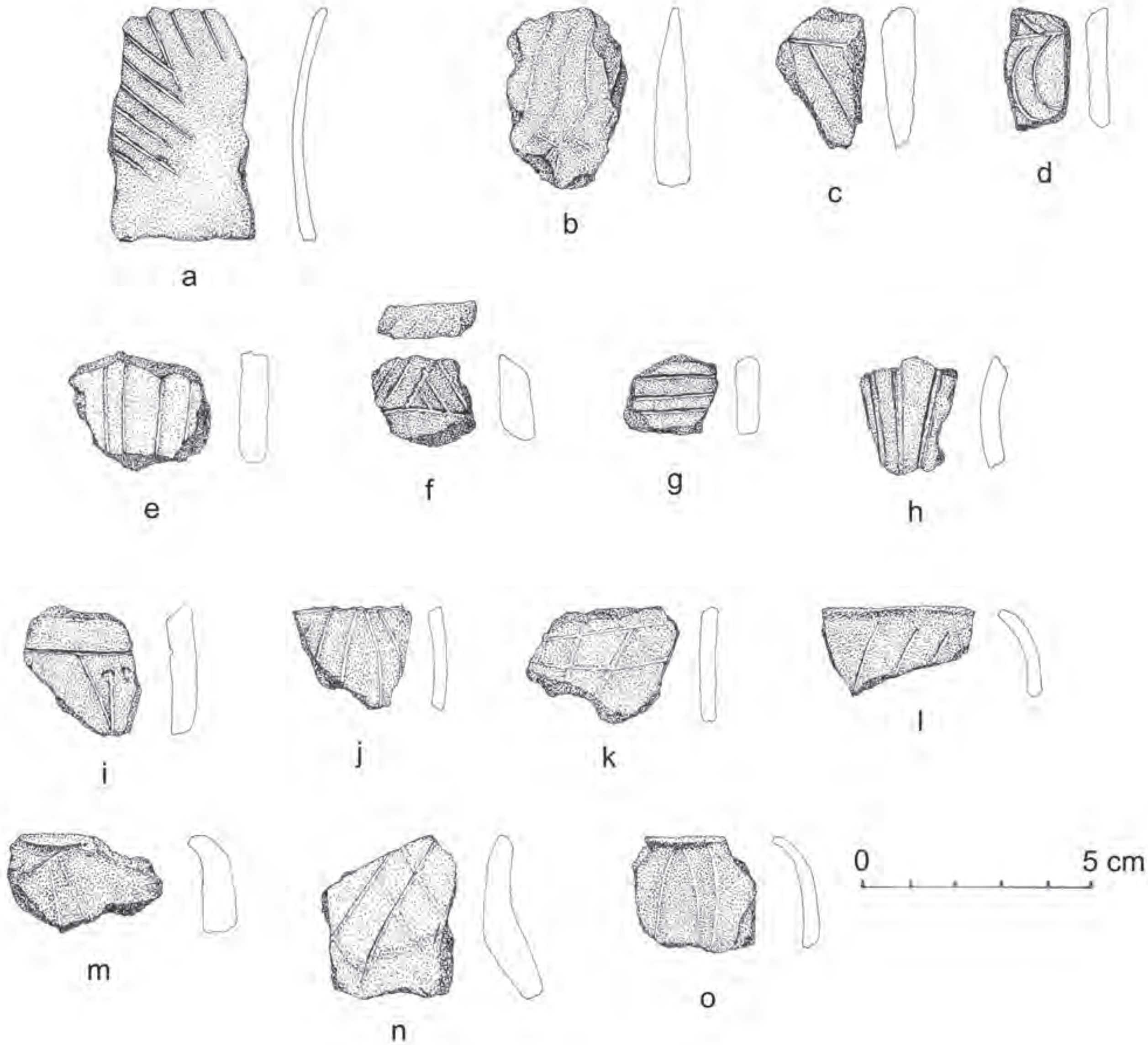


Figure 11.62. Sherds from site EKQ decorated with incised designs: *a*, EKQ-1-6-15; *b*, EKQ-1-8-37; *c*, EKQ-2-10-45; *d*, EKQ-1-10-32; *e*, EKQ-1-11-28; *f*, EKQ-2-13-27; *g*, EKQ-1-5-25; *h*, EKQ-2-10-46; *i*, EKQ-2-11-27; *j*, EKQ-1-11-29; *k*, EKQ-1-10-37; *l*, EKQ-11-11; *m*, EKQ-2-11-15; *n*, EKQ-10-7; *o*, EKQ-1-10-23. (Drawing by Margaret Davidson.)

resulting seriation, a portion of which is shown in Figure 11.65, closely replicates the sequence indicated by our analysis of the radiocarbon dates (see Chapter 5), with site EHB at the beginning of the sequence and Area C at the end. Regrettably, the very fragmentary nature of the sherds at site EKQ did not allow us to incorporate that site into the seriation, but we are quite confident that it is essentially contemporaneous with Area C at ECA.

The sequence of ceramic change in Mussau—which took place over a period of as much as six to seven centuries—can be divided into four phases. The earliest of these is that represented by site EHB, but also by the largely plainware assemblages of ECA Area A and of site EKE on Boliu Island. Indeed, it is interesting that in this early phase decorated pottery is almost entirely restricted to EHB, which may therefore have been a locus of specialized activity. At Area A and along the paleobeach ridge at ECA, and at EKE on Boliu, the ceramics are almost exclusively plainware jars with everted rims, which presumably had a utilitarian function. One exception is the

Figure 11.63. Ceramic sherds from site EKU: *a*, rim sherd, EKU-0-0-45; *b*, decorated sherd, EKU-0-0-47; *c*, decorated sherd, EKU-0-0-46.

finely decorated small bowl from EKE (Figure 11.57). This disjunct distribution of decorated and plainware pottery poses the question of whether the EHB site on Emananus Island was an aggregation locus where people from small hamlets on Eloaua and Boliu came together periodically to partake in rituals, feasting, or other specialized activities involving the decorated ceramics.

The sample of decorated pottery from site EHB is unfortunately limited, and the sherds were generally small and fragmented. Nonetheless, we can say that the most common vessel forms were bowls, many of which were supported on pedestals, and jars, some of which were carinated. Cylinder stands were present, as were flat-bottom dishes, but the latter were rare. Fine dentate stamping predominates, although some coarser stamping and incising are also present. The high frequency of red slip is notable. Among the most frequent motif themes depicted on the decorated pottery are the zigzag, house, tongue, and labyrinth; face motifs were also present.

The second phase in the Mussau ceramic sequence is that represented by analytic zones C3 and C2 at Area B and Area B extension, and by site ECB. Bowls, and

Figure 11.64. Ceramic discs from the ECA site: *a*, ECA-16-6-45; *b*, ECA-17-6-16; *c*, ECA-61-6-40; *d*, ECA-42-9-22; *e*, ECA-35-12-12; *f*, ECA-37-9-19; *g*, ECA-46-6-27; *h*, ECA-33-8-29.

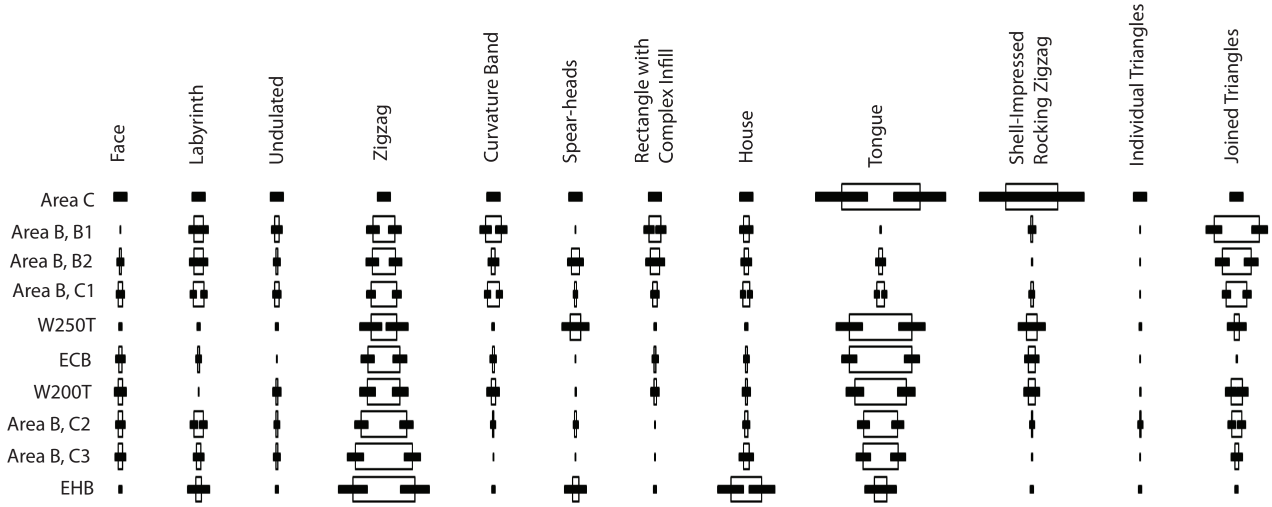


Figure 11.65. Frequency seriation of ceramic assemblages at sites ECA, ECB, and EHB, using the zigzag motif as the time indicator; only the most prominent 12 of the 22 motif themes are graphed here. (Diagram by S. Chiu.)

particularly bowls supported on pedestals, continue to be a major vessel form in this phase. Jars, including carinated jars, are also well represented. Fine dentate stamping continues to dominate in terms of decorative technique, often combined with cutouts and lime infill, but coarse dentate stamping is present (and increases from analytic zone C3 to C2), as well as incising. In terms of motif themes, the zigzag theme remains the most common, with the house motif decreasing, the tongue motif increasing in frequency. Anthropomorphic faces are well represented, as is the long-beaked bird motif.

The third phase of the Mussau ceramic sequence is that evidenced by the upper zones C1 through B1 at Area B and Area B extension, and by the middle section of the W250 transect. In vessel form, the major change is that flat-bottom dishes now become the most prominent type, although jars (especially large plainware jars with everted rims) are also common. In decorative technique, there is a sharp decline in the frequency of fine dentate stamping, with coarse dentate stamping now dominating the assemblage; incising continues to be used as well. The zigzag motif theme continues to be present but the joined triangles motif theme becomes more frequent. Anthropomorphic faces continue, now executed in coarse dentate stamping.

The greatest changes in the Mussau ceramic sequence are evident with the final phase, represented by Area C at ECA and by the assemblage in site EKQ. Vessel forms are now almost exclusively of globular jars with everted rims, often quite thin-walled. Dentate stamping is very rare, limited to a few examples of coarse stamping as in the lower levels at EKQ. Instead, most of the decoration consists of simple incised designs, or of notched rims.

The Mussau Ceramic Catalog

The Mussau Ceramic Catalog includes 269 partially reconstructed vessels, defined as those for which at least a rim or carination diameter could be determined, and a standard archaeological pottery drawing prepared. The text of the Catalog is available online in the Supplementary Materials for this volume. Please see www.dig.ucla.edu/talepakemalai. Illustrations of these vessels are provided here in Figures 11.66 through 11.118, with the reconstructed vessels grouped by vessel type and by site. Each reconstructed vessel has been assigned a number (e.g., ECA-V-001); the Catalog is arranged in numeric order by site and vessel number. The Catalog provides details of site and stratigraphic provenience, vessel form, rim and lip form, measurements, temper, firing, surface treatment, motifs present, and a description of the decoration.

Ceramic Vessel Reconstructions

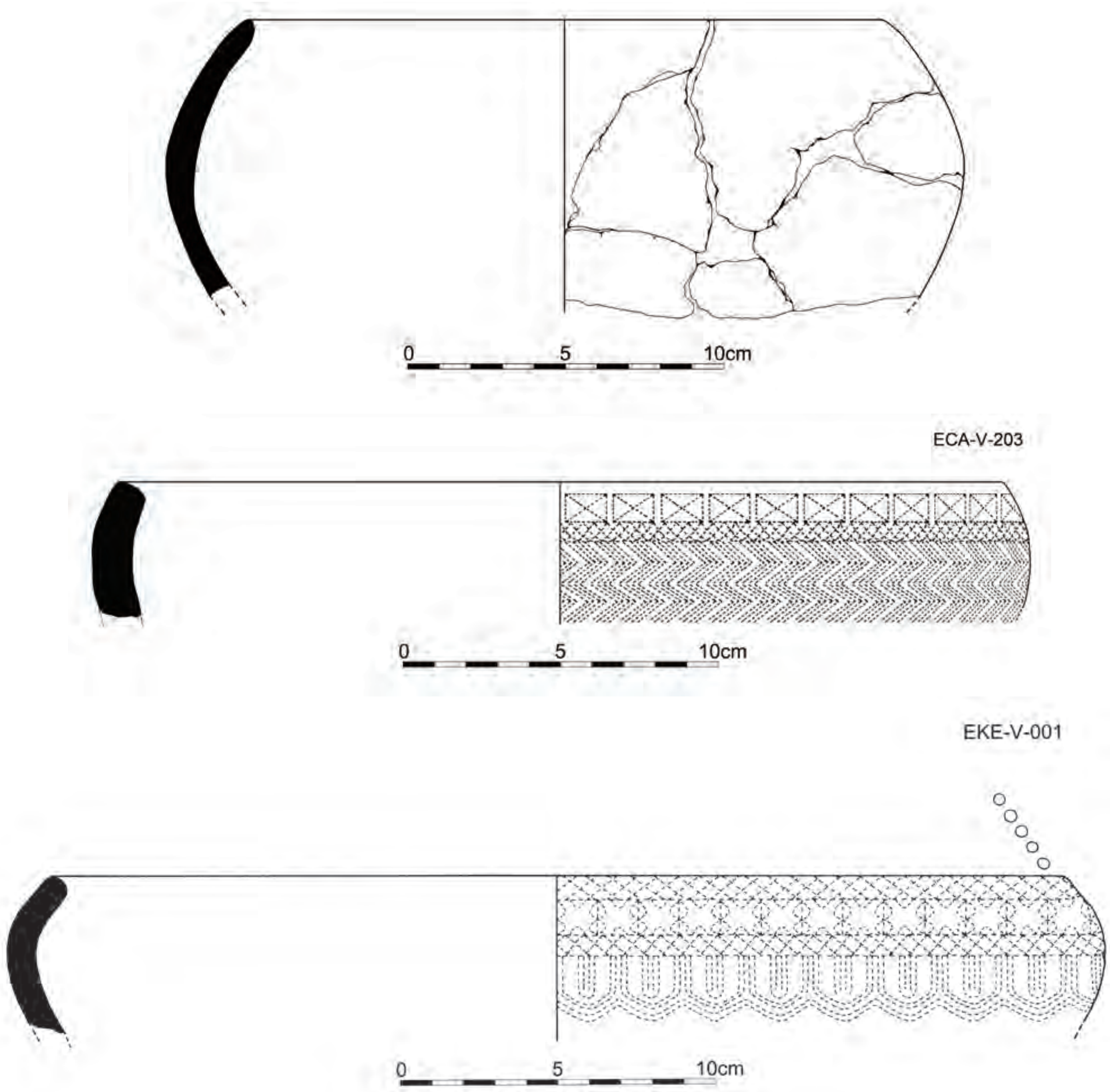


Figure 11.66. Reconstructed vessels of class IA: ECA-V-026, -039, -203; EKE-V-001. (Drawings by Lapita Pottery Online Database team.)

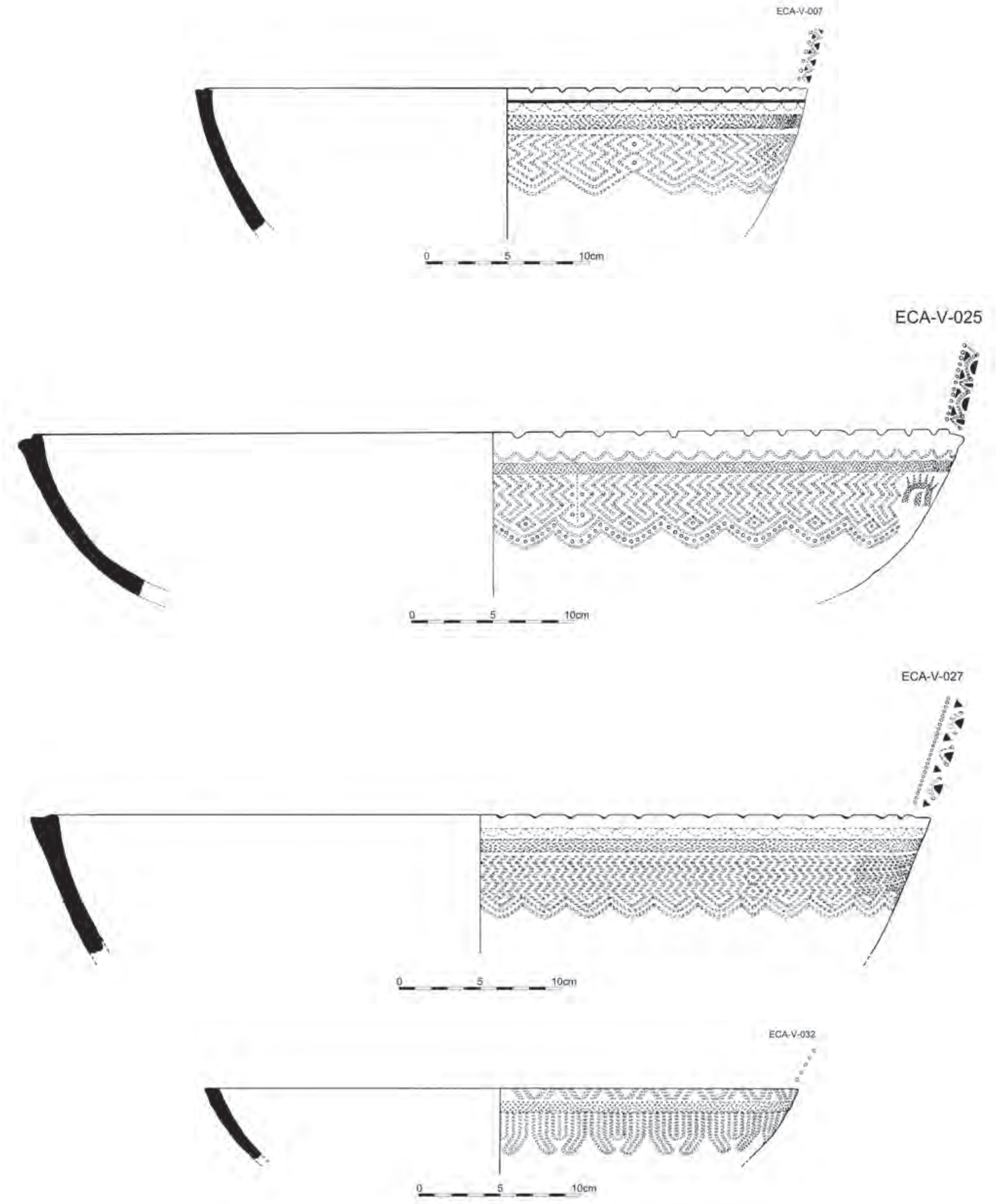


Figure 11.67. Reconstructed vessels of class IB1: ECA-V-007, -025, -027, and -032.

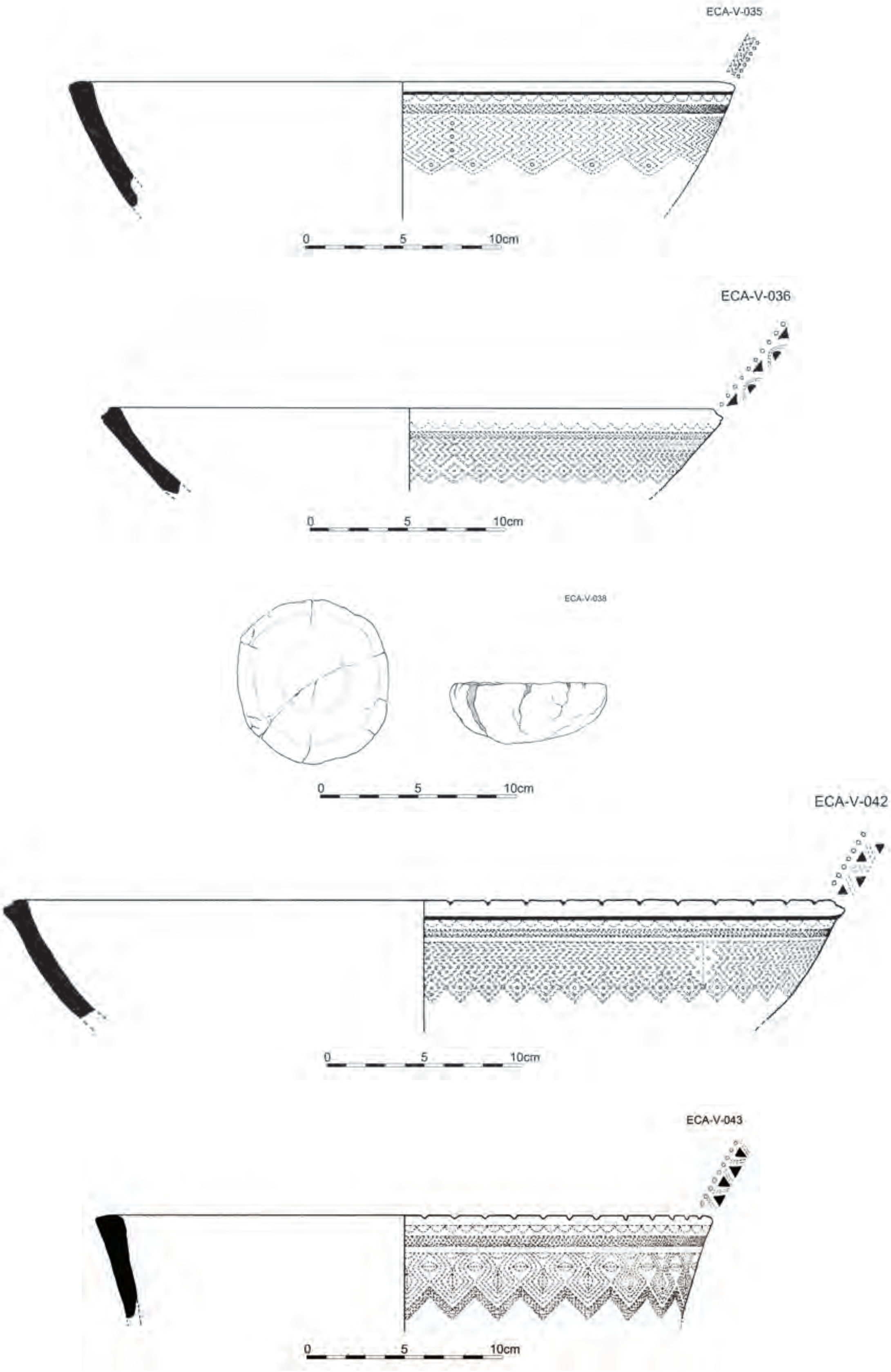


Figure 11.68. Reconstructed vessels of class IB1: ECA-V-035, -036, -038, -042, and -043. (Drawings by Lapita Pottery Online Database team.)

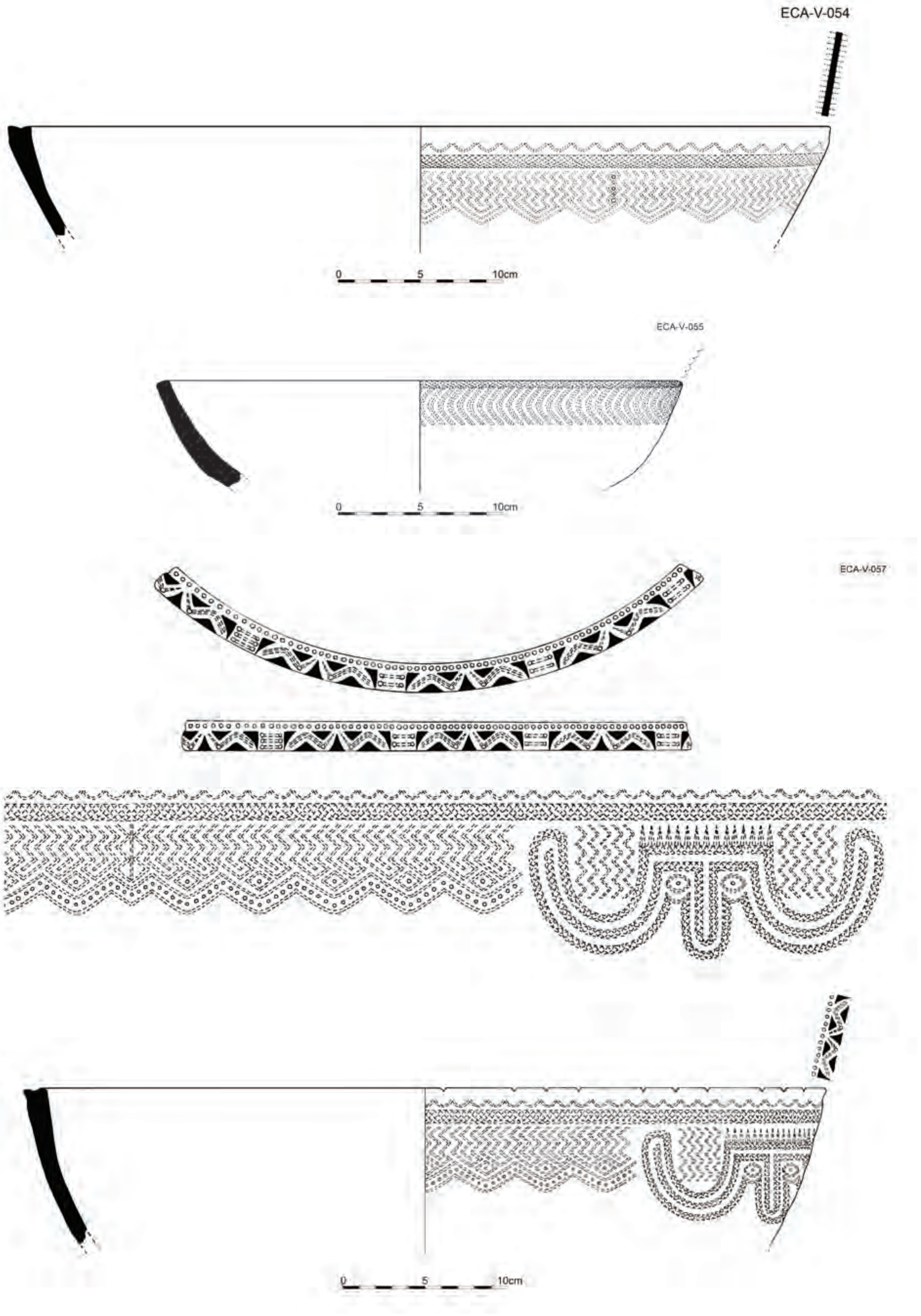


Figure 11.69. Reconstructed vessels of class IB1: ECA-V-054, -055, and -057. (Drawings by Lapita Pottery Online Database team.)

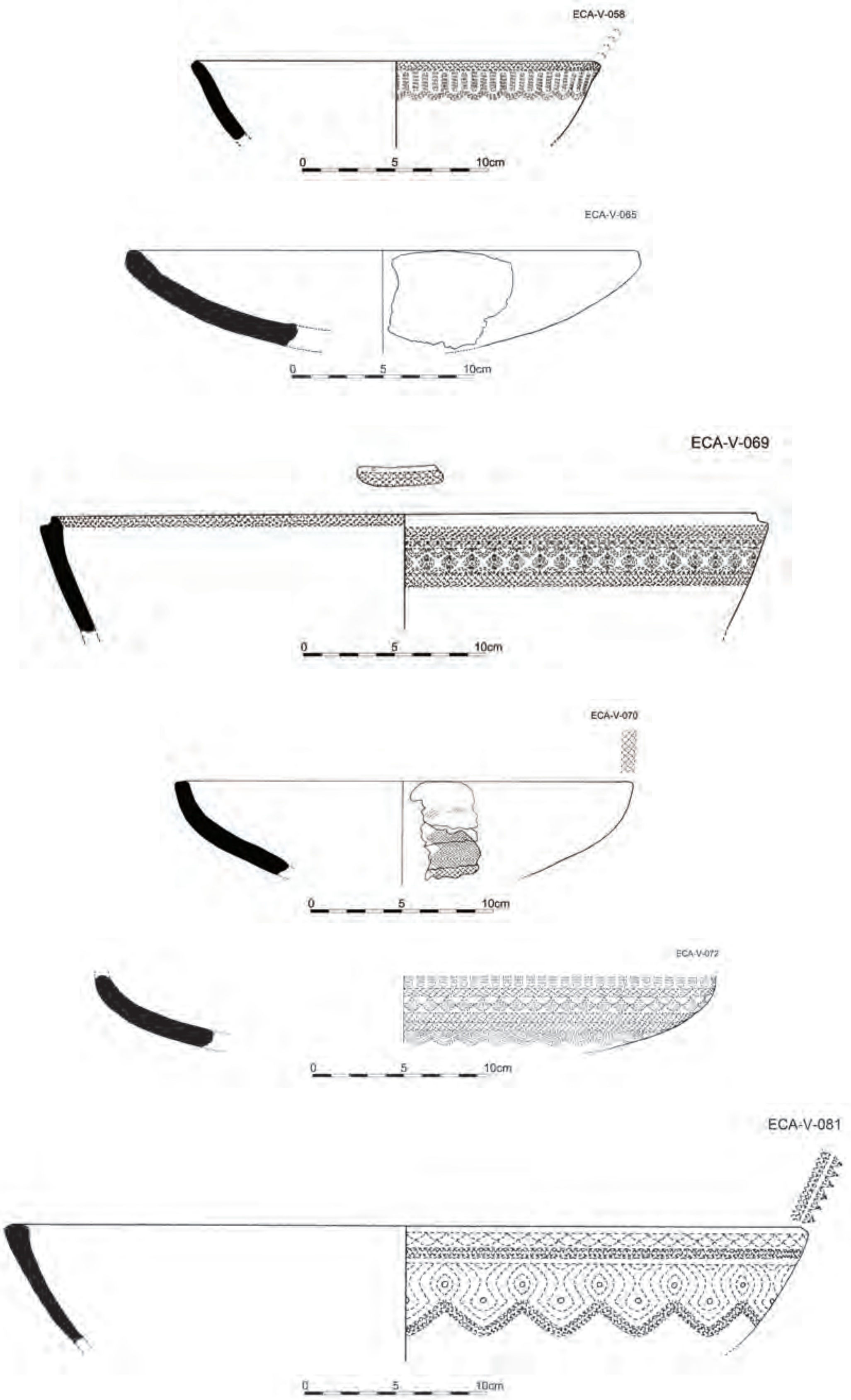


Figure 11.70. Reconstructed vessels of class IB1: ECA-V-058, -065, -069, -070, -072, and -081. (Drawings by Lapita Pottery Online Database team.)

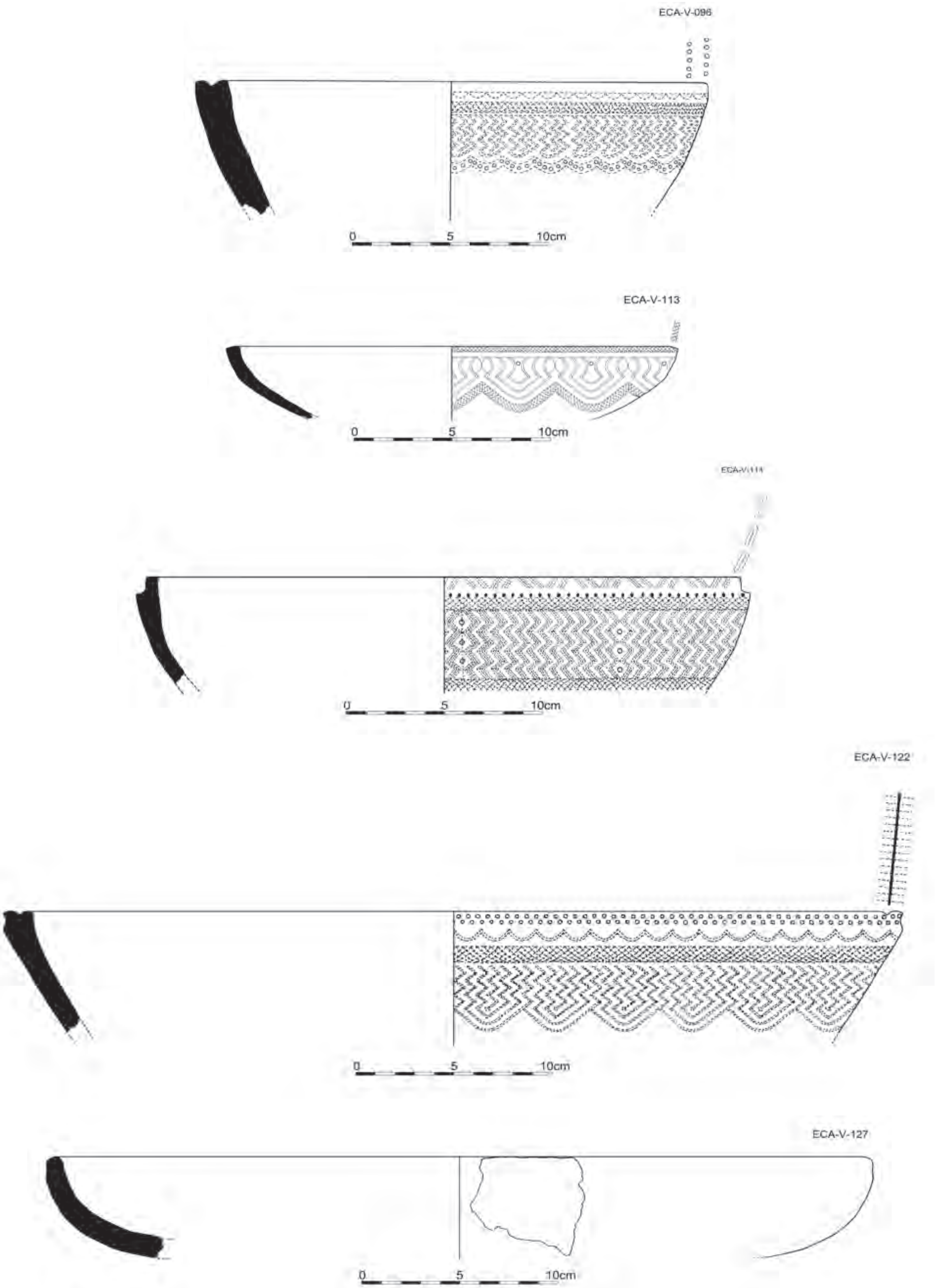


Figure 11.71. Reconstructed vessels of class IB1: ECA-V-096, -113, -114, -122, and -127. (Drawings by Lapita Pottery Online Database team.)

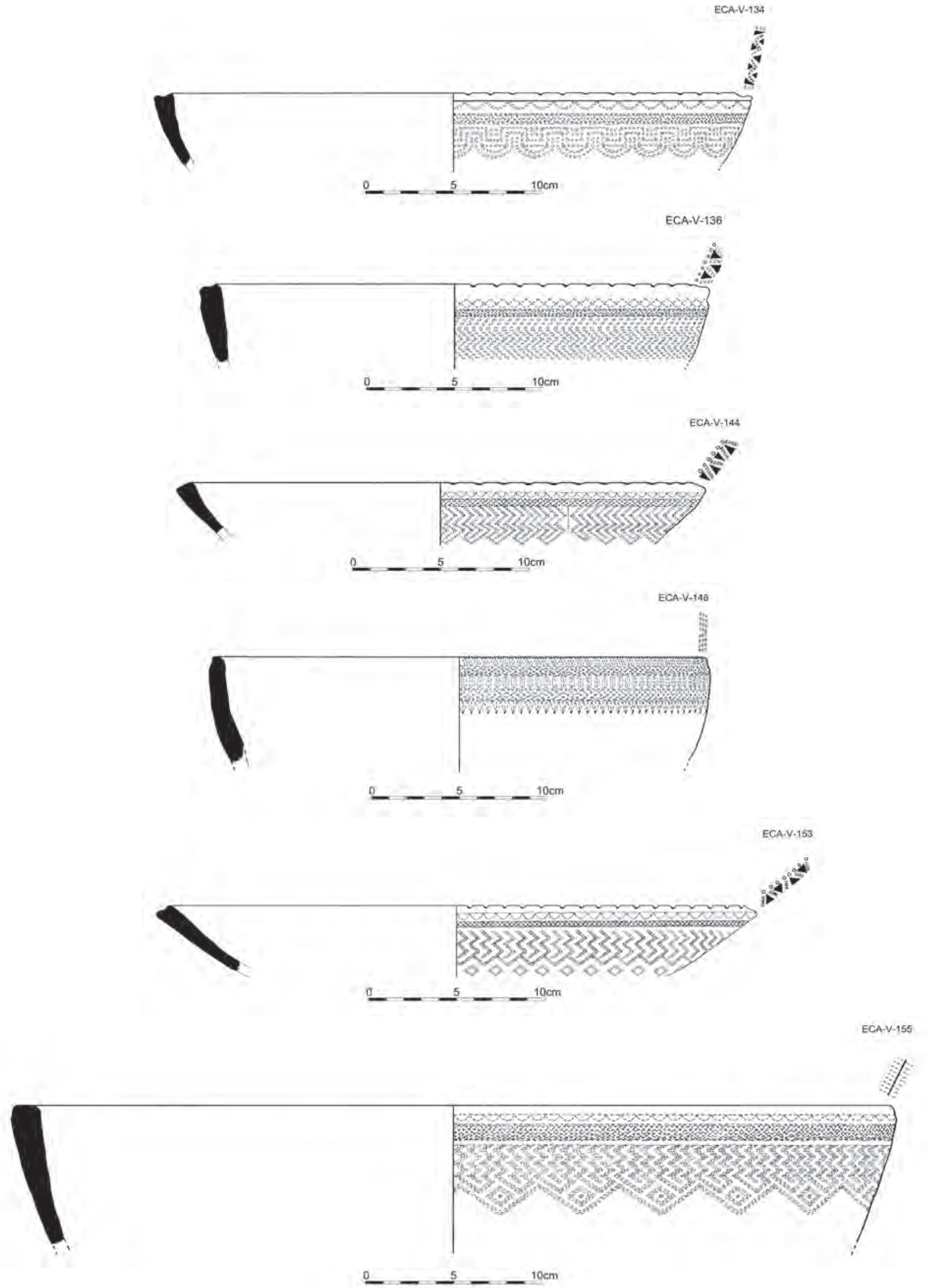


Figure 11.72. Reconstructed vessels of class IB1: ECA-V-134, -136, -144, -148, -153, and -155. (Drawings by Lapita Pottery Online Database team.)

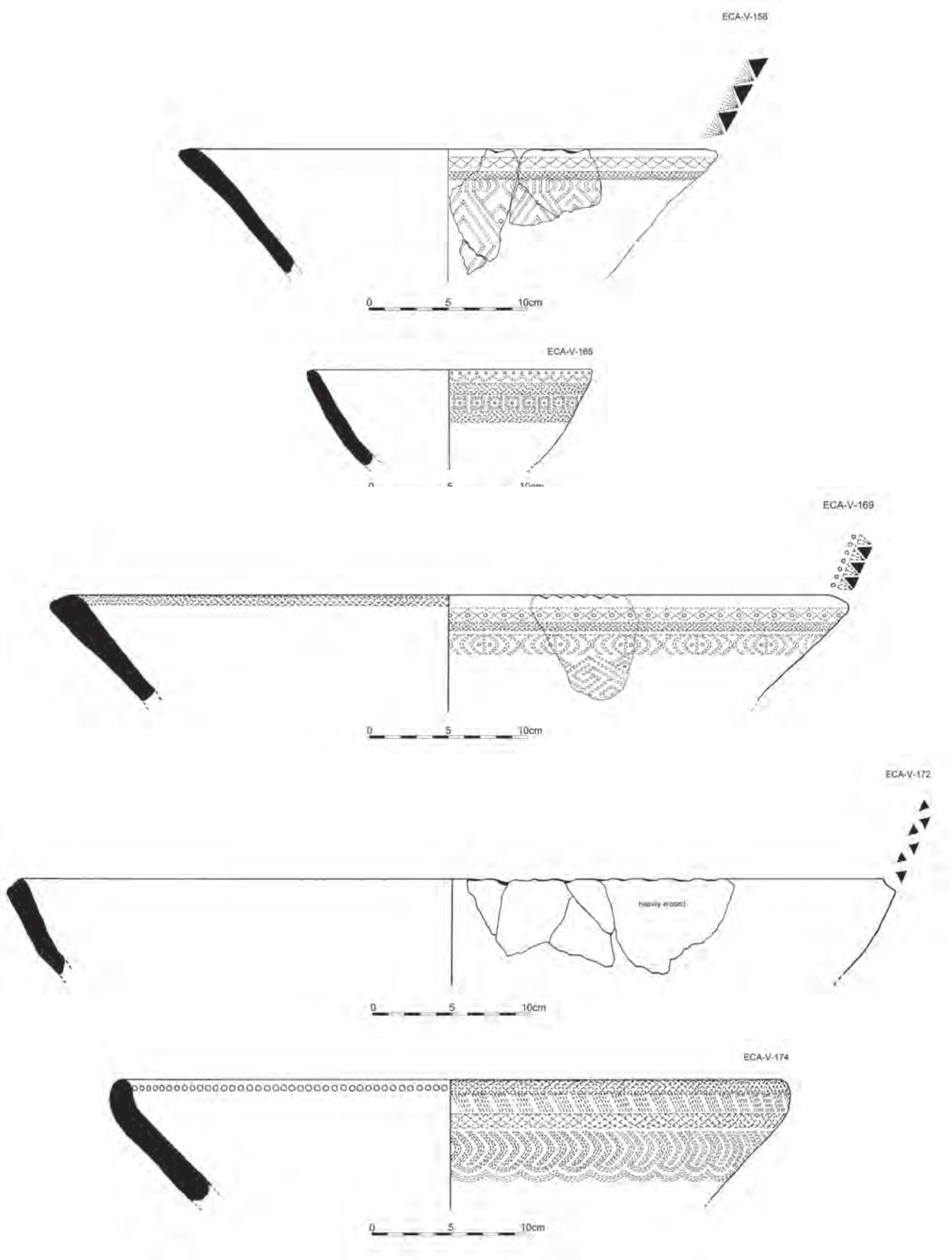


Figure 11.73. Reconstructed vessels of class IB1: ECA-V-158, -165, -169, -172, and -174. (Drawings by Lapita Pottery Online Database team.)

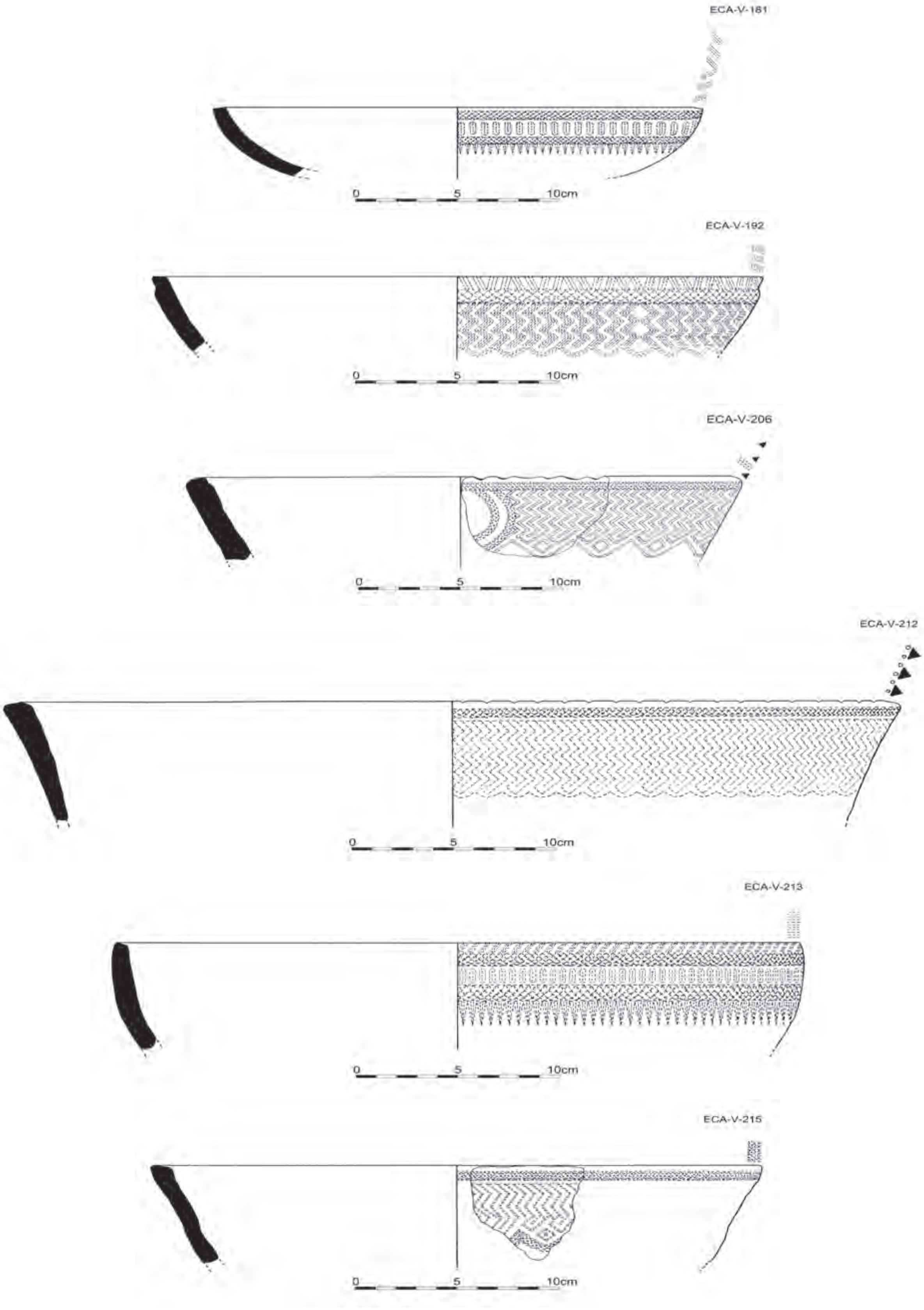


Figure 11.74. Reconstructed vessels of class IB1: ECA-V-181, -192, -206, -212, -213, and -215. (Drawings by Lapita Pottery Online Database team.)

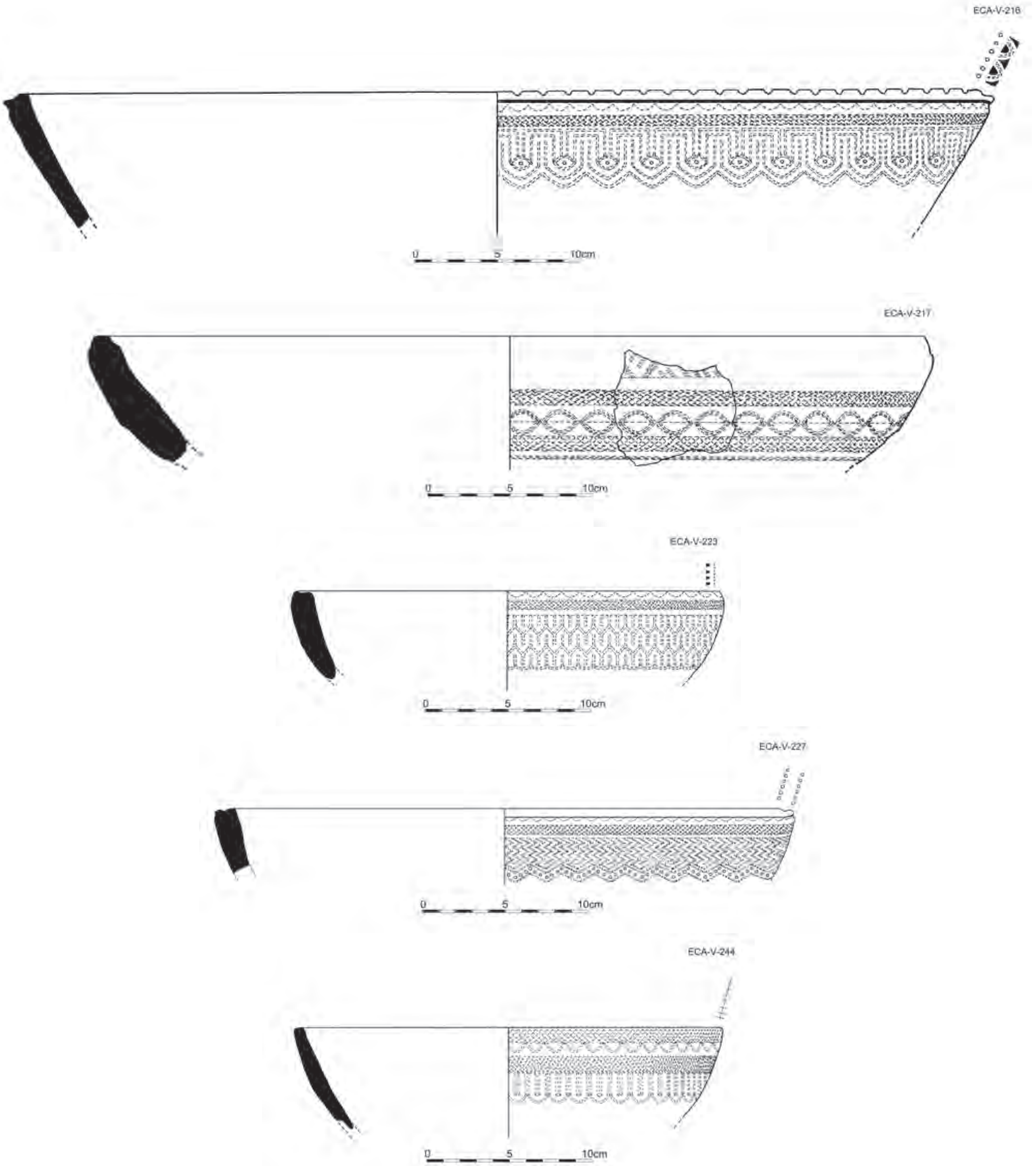


Figure 11.75. Reconstructed vessels of class IB1: ECA-V-216, -217, -223, -227, and -244. (Drawings by Lapita Pottery Online Database team.)

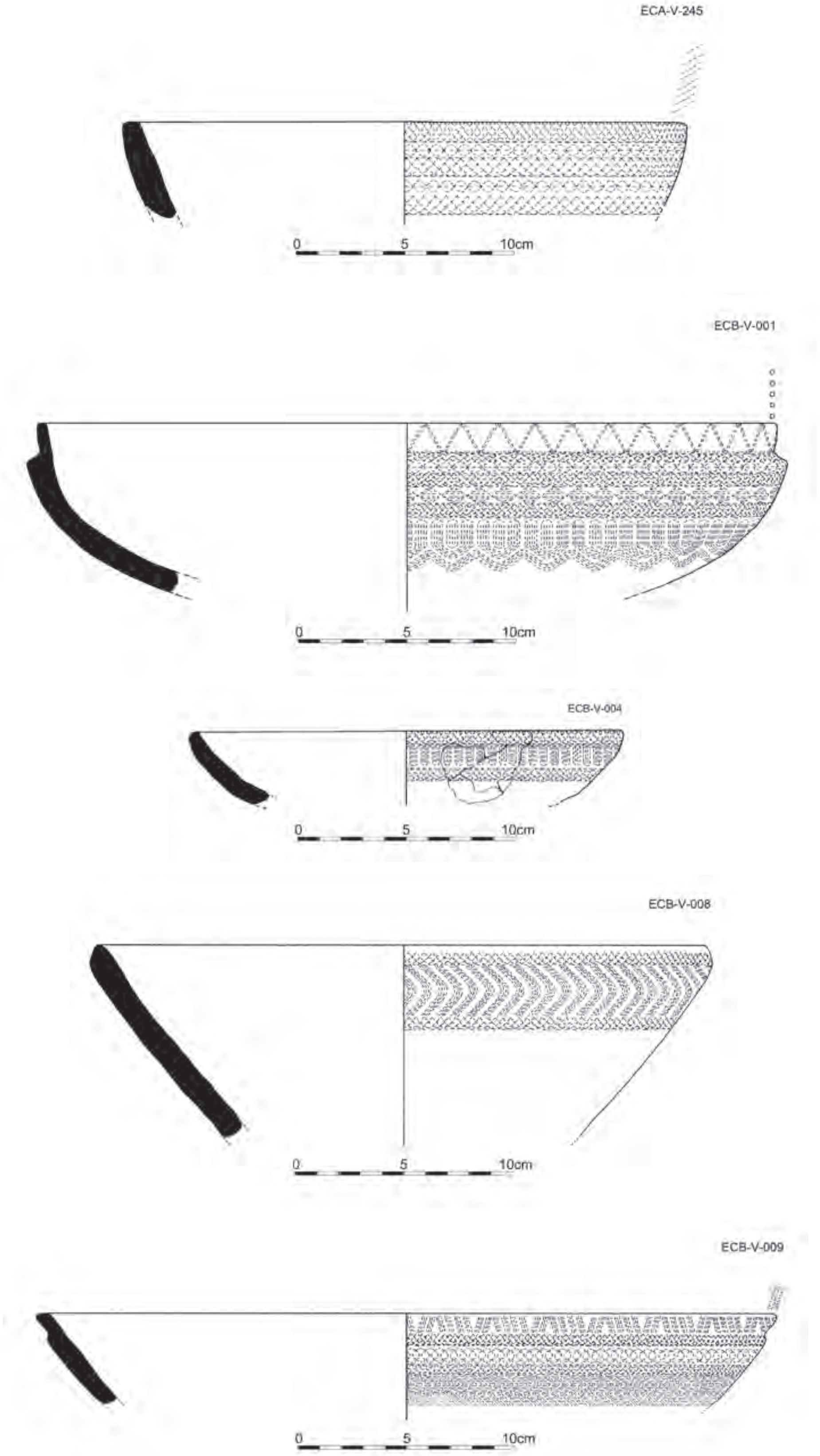


Figure 11.76. Reconstructed vessels of class IB1: ECA-V-245; ECB-V-001, -004, -008, and -009. (Drawings by Lapita Pottery Online Database team.)

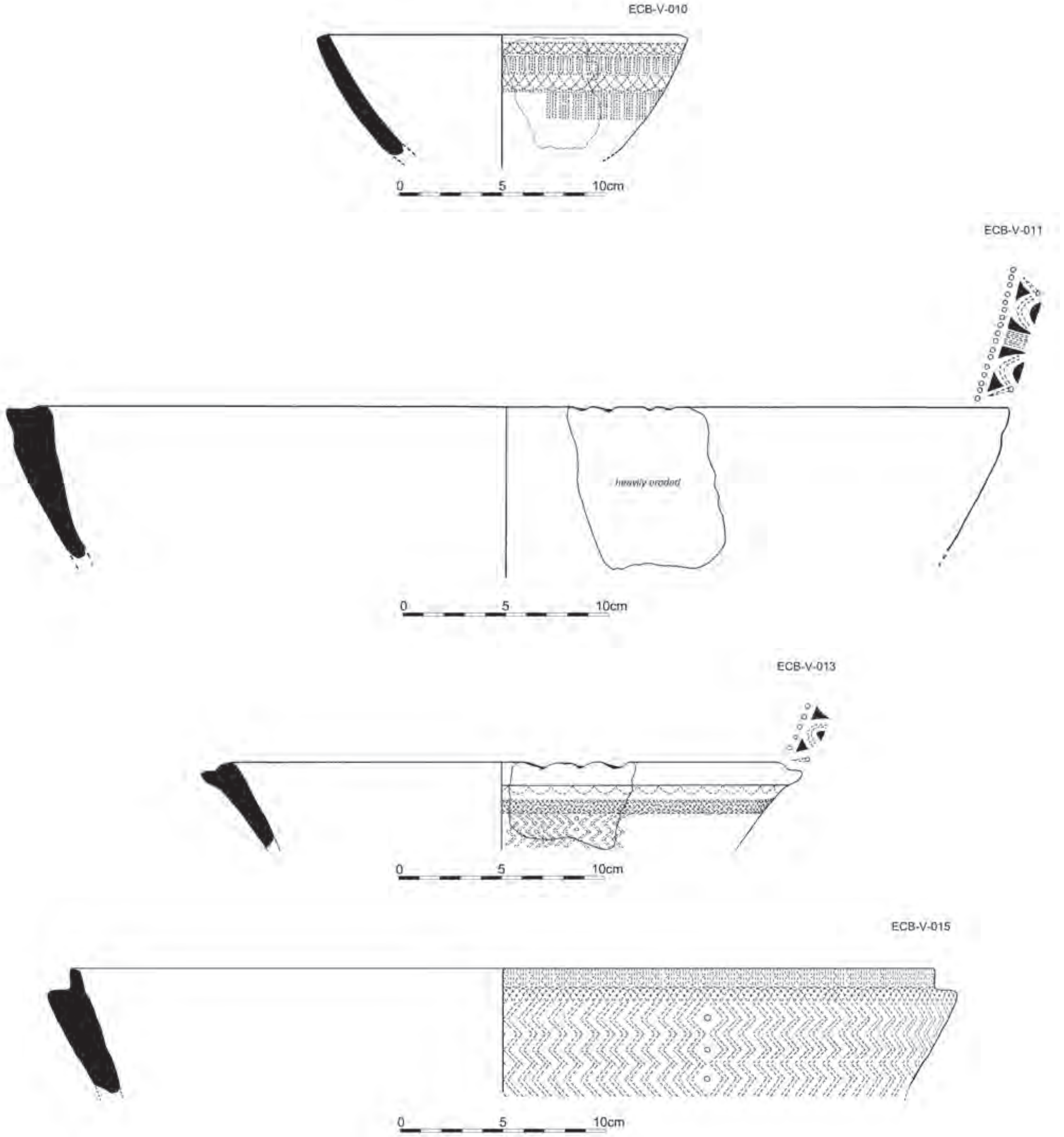


Figure 11.77. Reconstructed vessels of class IB1: ECB-V-010, -011, -013, and -015. (Drawings by Lapita Pottery Online Database team.)

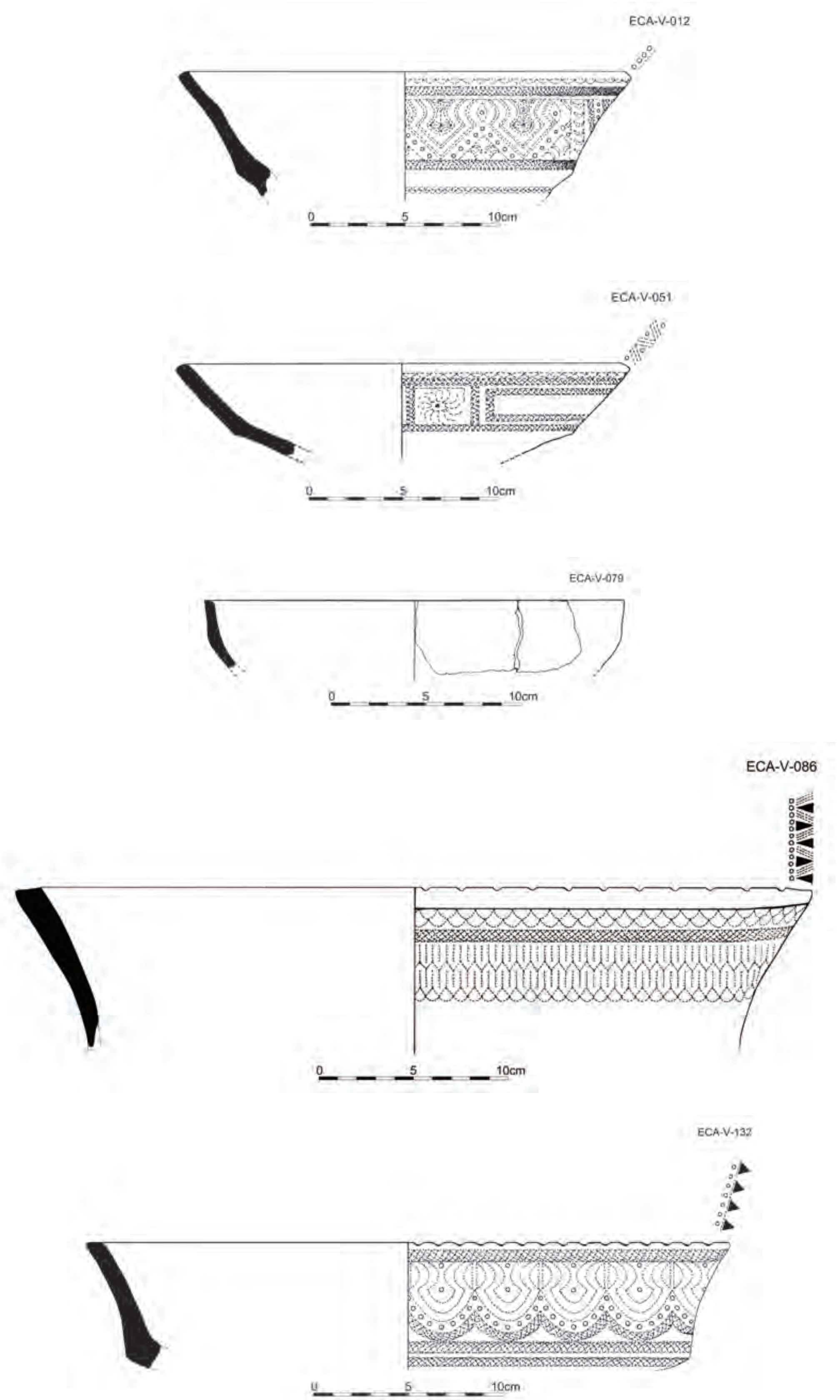


Figure 11.78. Reconstructed vessels of class IB2: ECA-V-012, -051, -079, -086, and -132. (Drawings by Lapita Pottery Online Database team.)

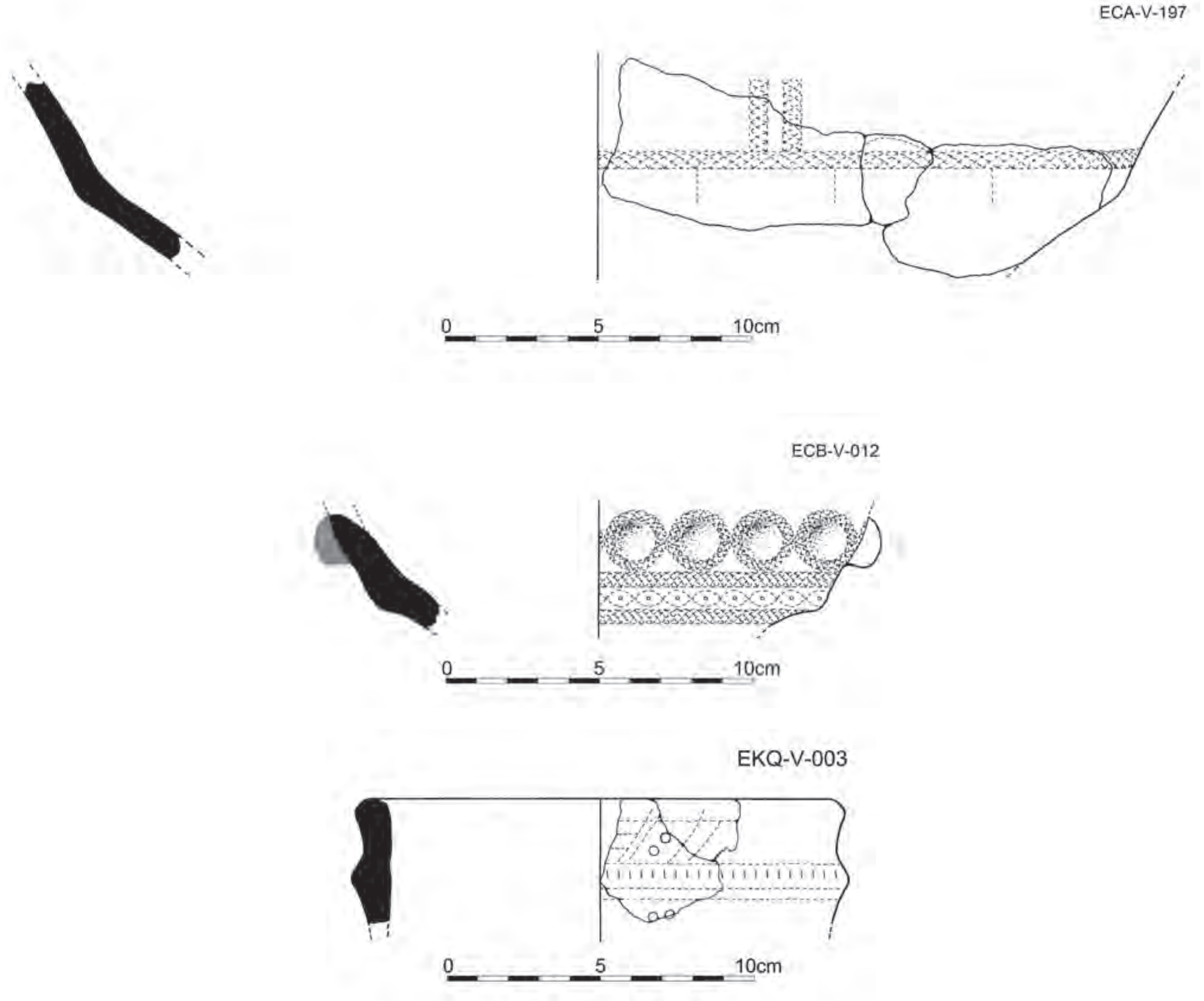


Figure 11.79. Reconstructed vessels of class IB2: ECA-V-197, ECB-V-012, and EKQ-V-003. (Drawings by Lapita Pottery Online Database team.)

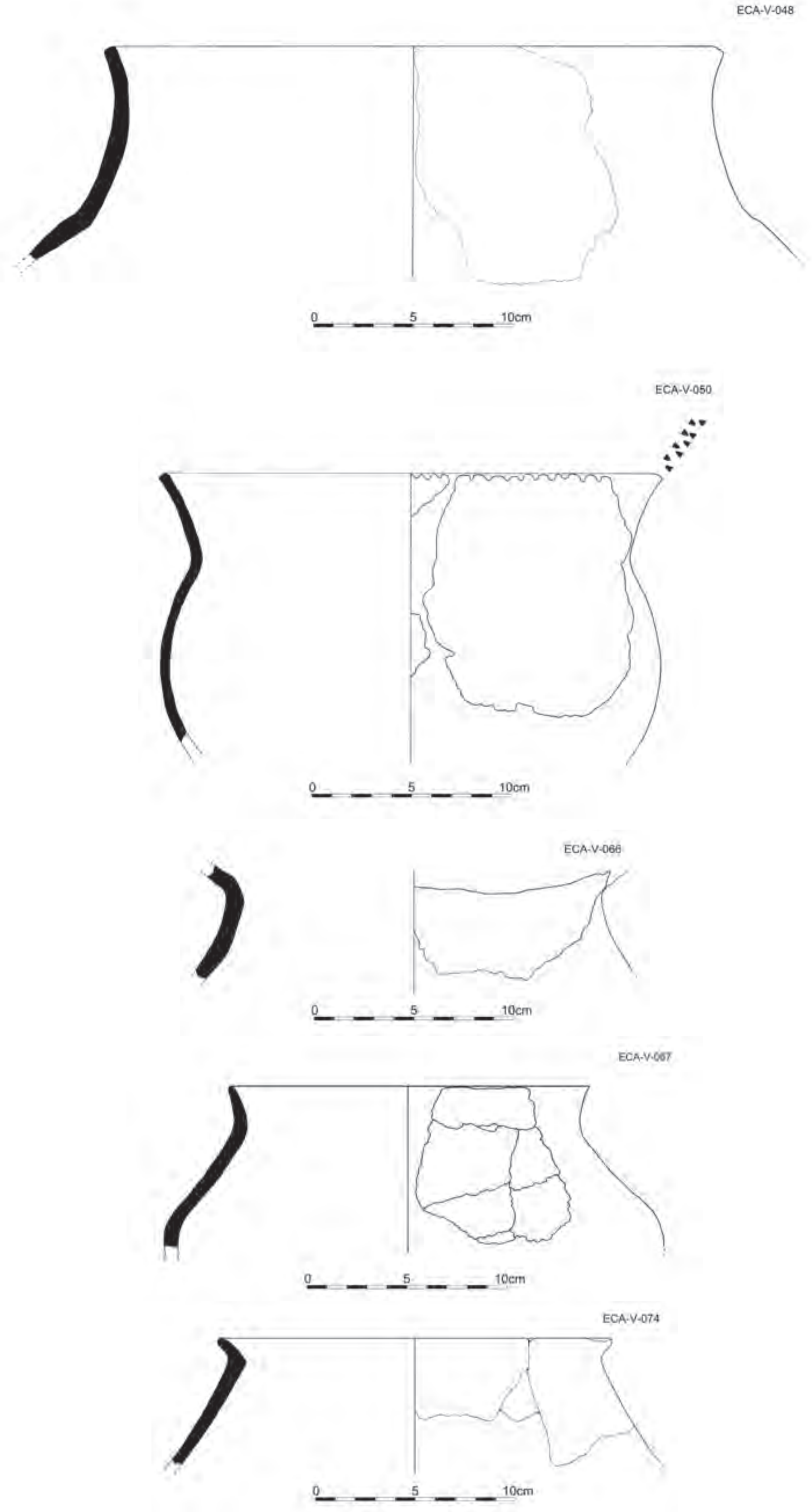


Figure 11.80. Reconstructed vessels of class IIA: ECA-V-048, -050, -066, -067, and -074. (Drawings by Lapita Pottery Online Database team.)

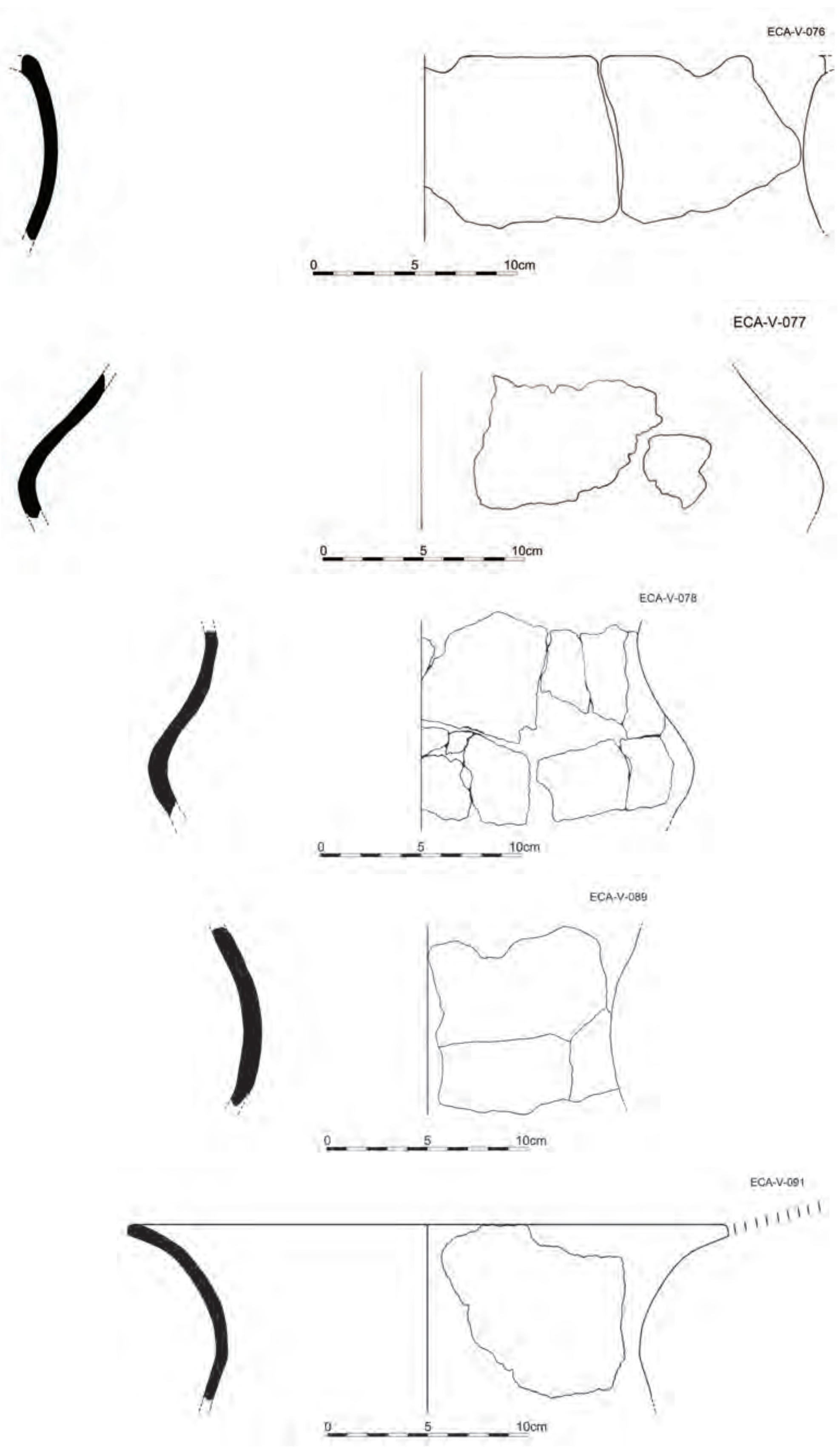


Figure 11.81. Reconstructed vessels of class IIA: ECA-V-076, -077, -078, -089, and -091. (Drawings by Lapita Pottery Online Database team.)

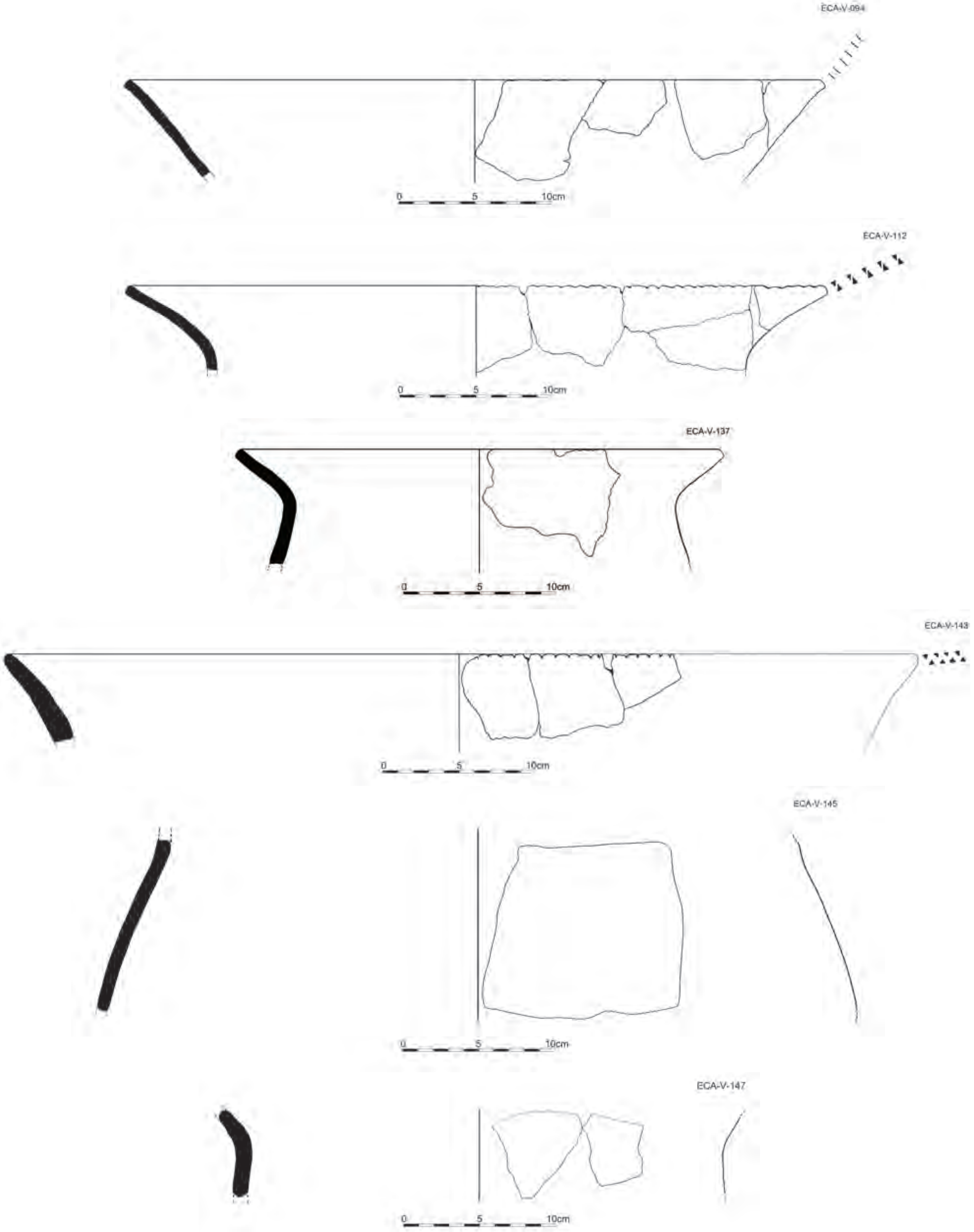


Figure 11.82. Reconstructed vessels of class IIA: ECA-V-094, -112, -137, -143, -145, and -147. (Drawings by Lapita Pottery Online Database team.)

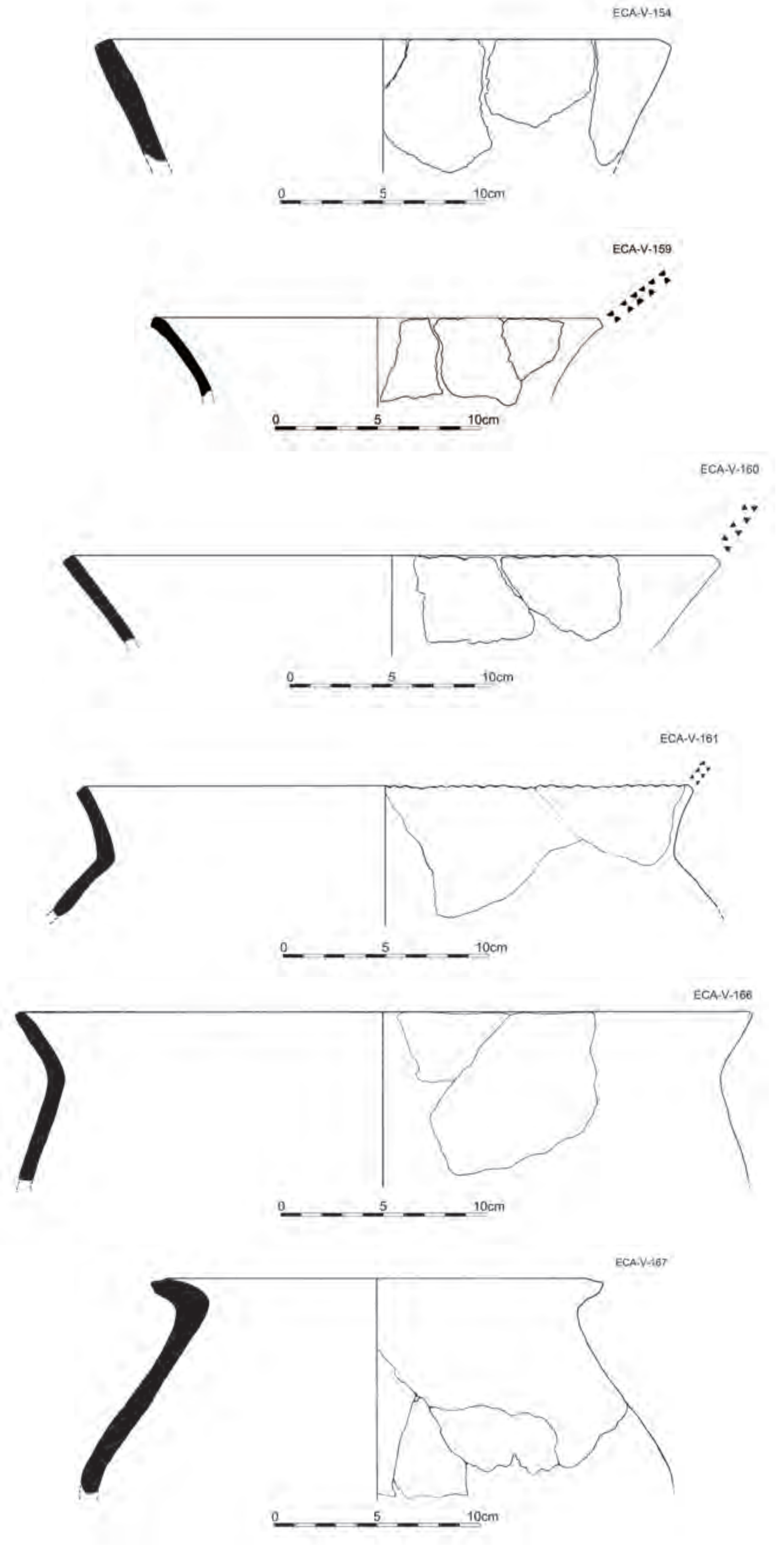


Figure 11.83. Reconstructed vessels of class IIA: ECA-V-154, -159, -160, -161, -166, and -167. (Drawings by Lapita Pottery Online Database team.)

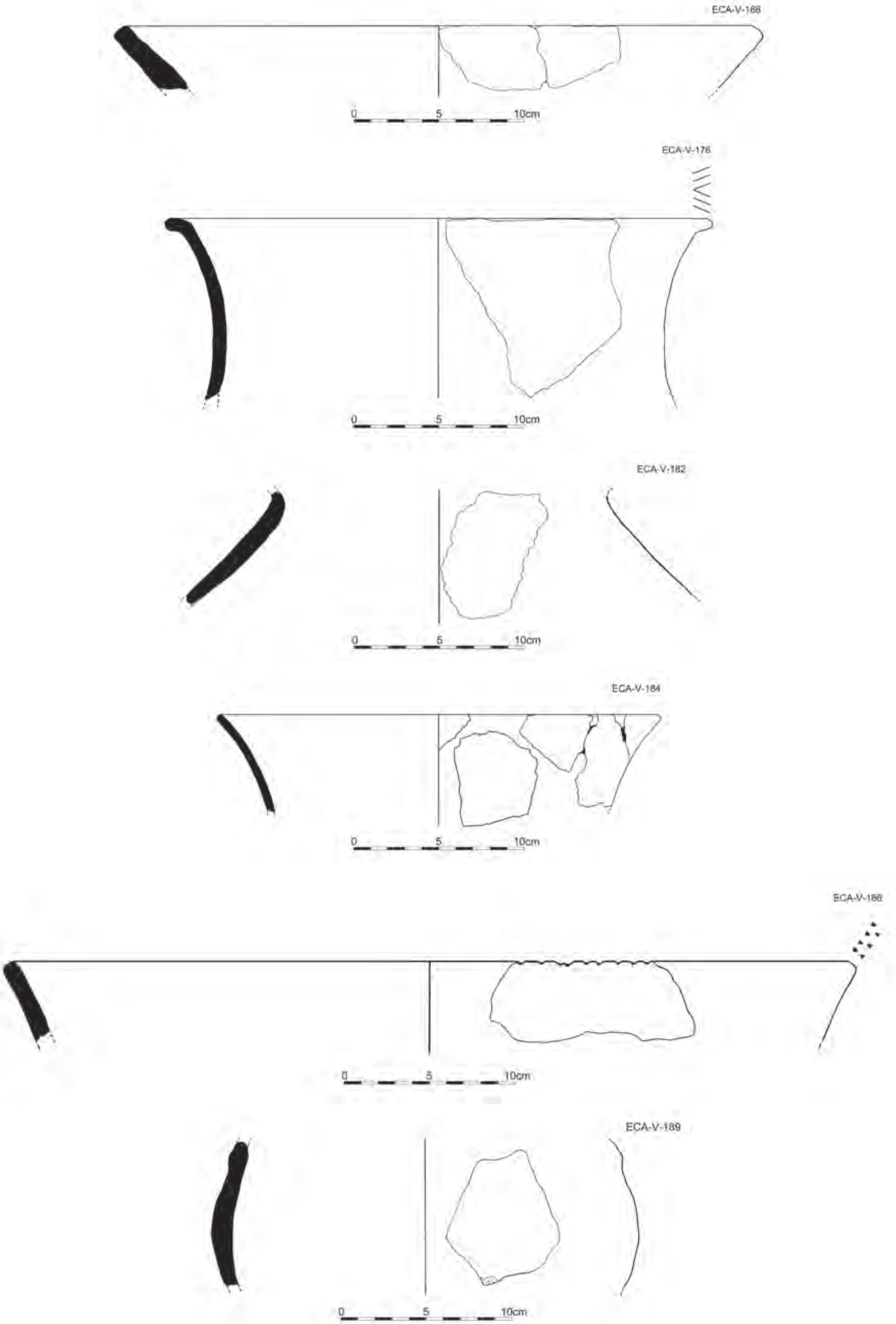


Figure 11.84. Reconstructed vessels of class IIA: ECA-V-168, -176, -182, -184, -186, and -189. (Drawings by Lapita Pottery Online Database team.)

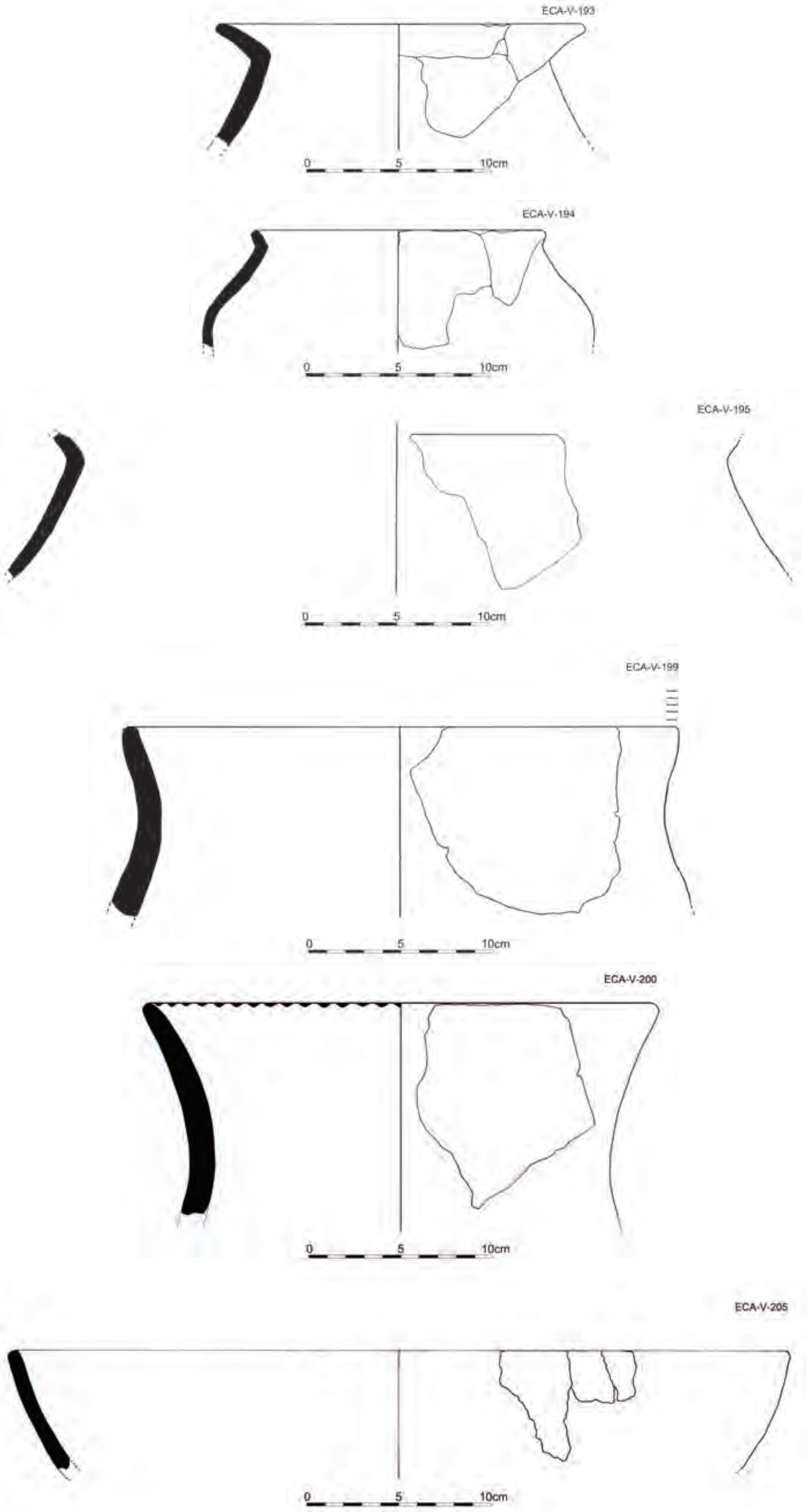


Figure 11.85. Reconstructed vessels of class IIA: ECA-V-193, -194, -195, -199, -200, and -205. (Drawings by Lapita Pottery Online Database team.)

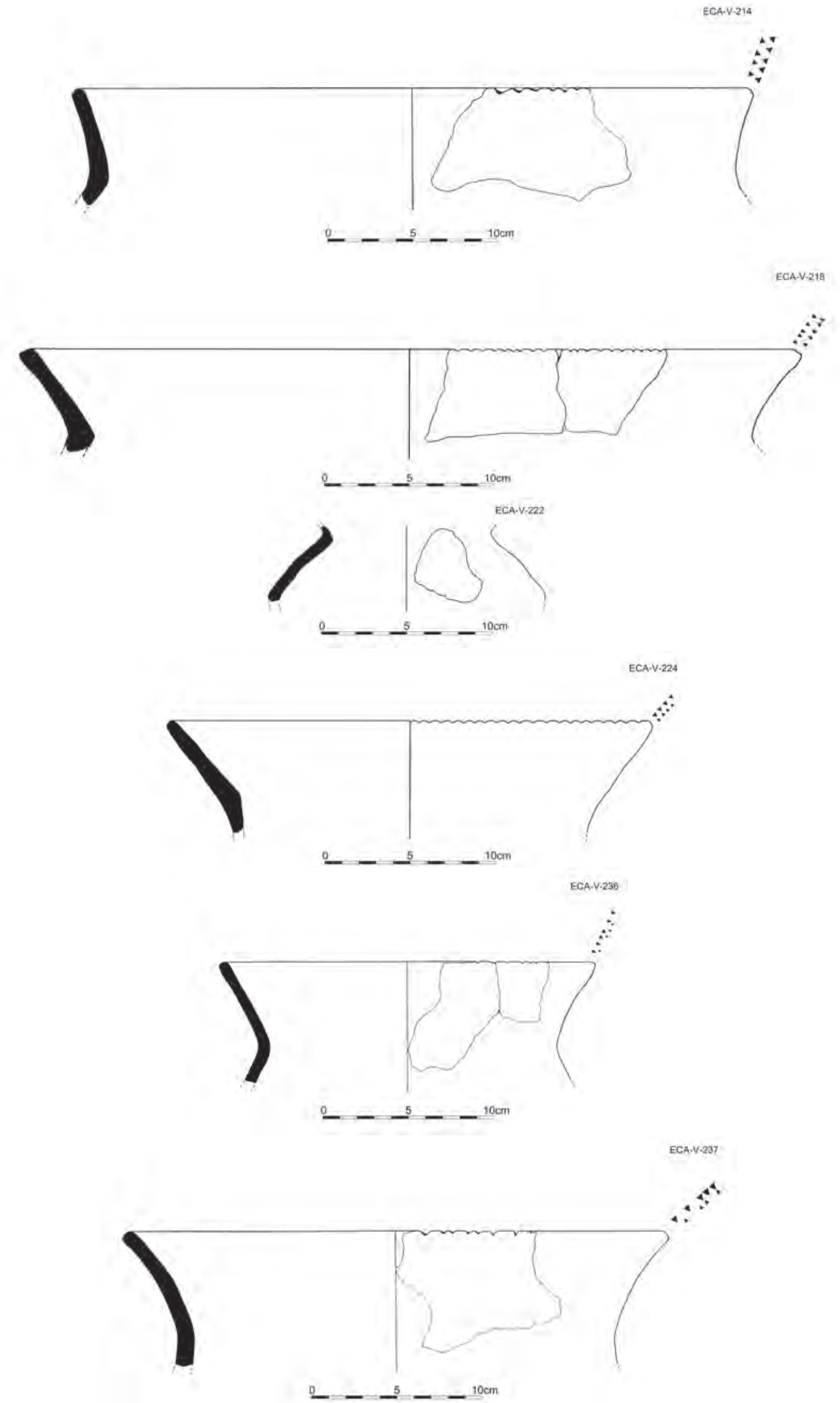


Figure 11.86. Reconstructed vessels of class IIA: ECA-V-214, -218, -224, -236, and -237. (Drawings by Lapita Pottery Online Database team.)

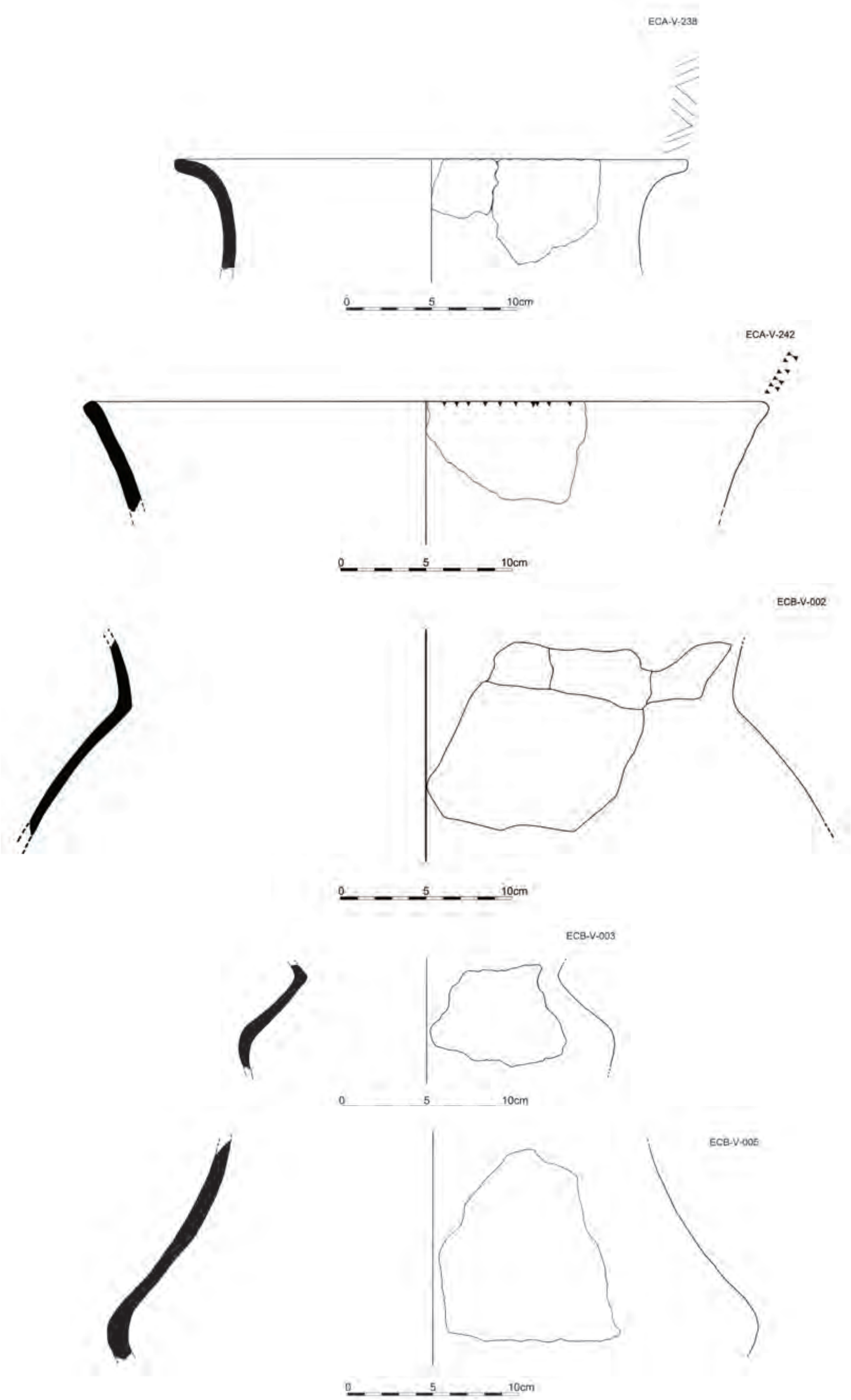


Figure 11.87. Reconstructed vessels of class IIA: ECA-V-238, -242, ECB-V-002, -003, and -005. (Drawings by Lapita Pottery Online Database team.)

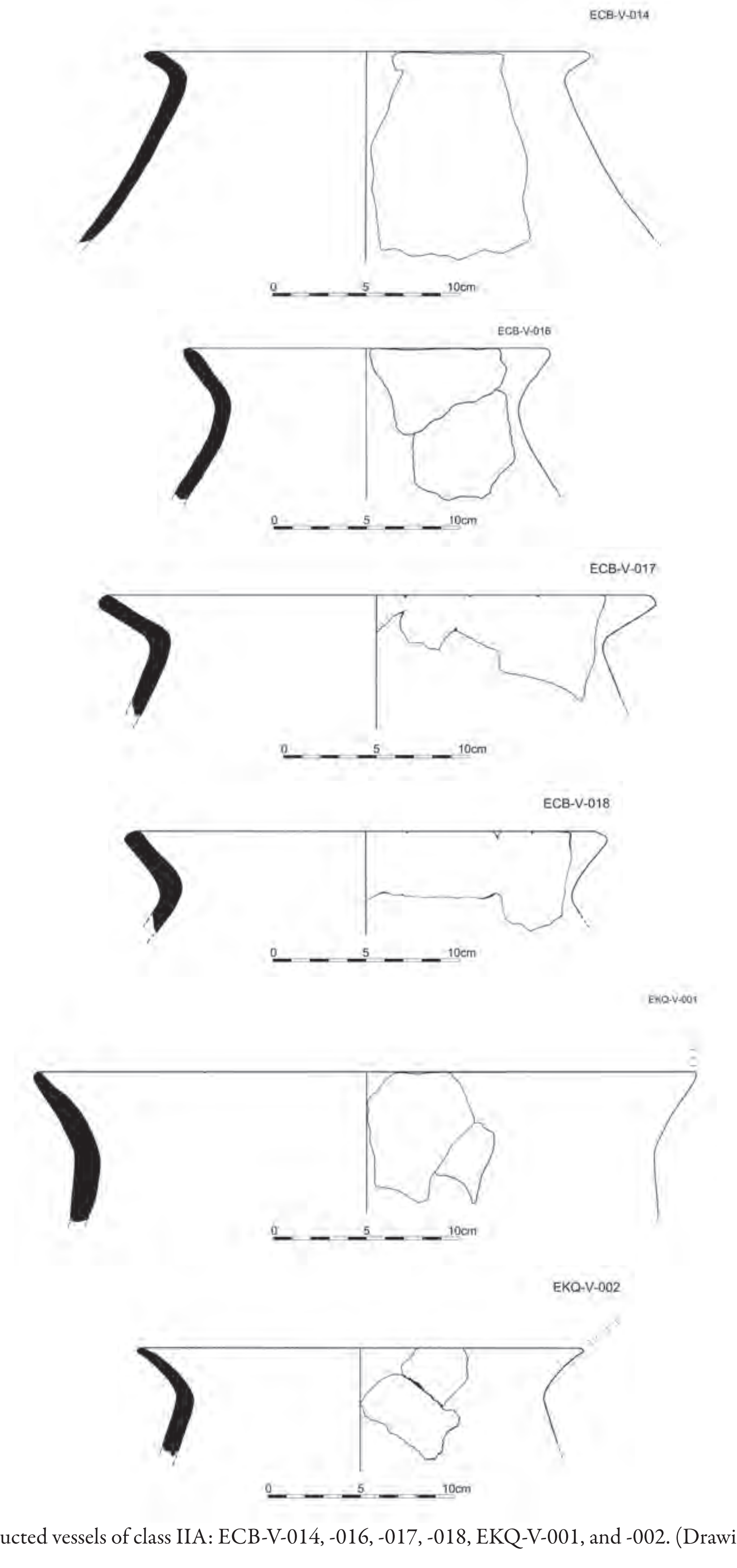


Figure 11.88. Reconstructed vessels of class IIA: ECB-V-014, -016, -017, -018, EKQ-V-001, and -002. (Drawings by Lapita Pottery Online Database team.)

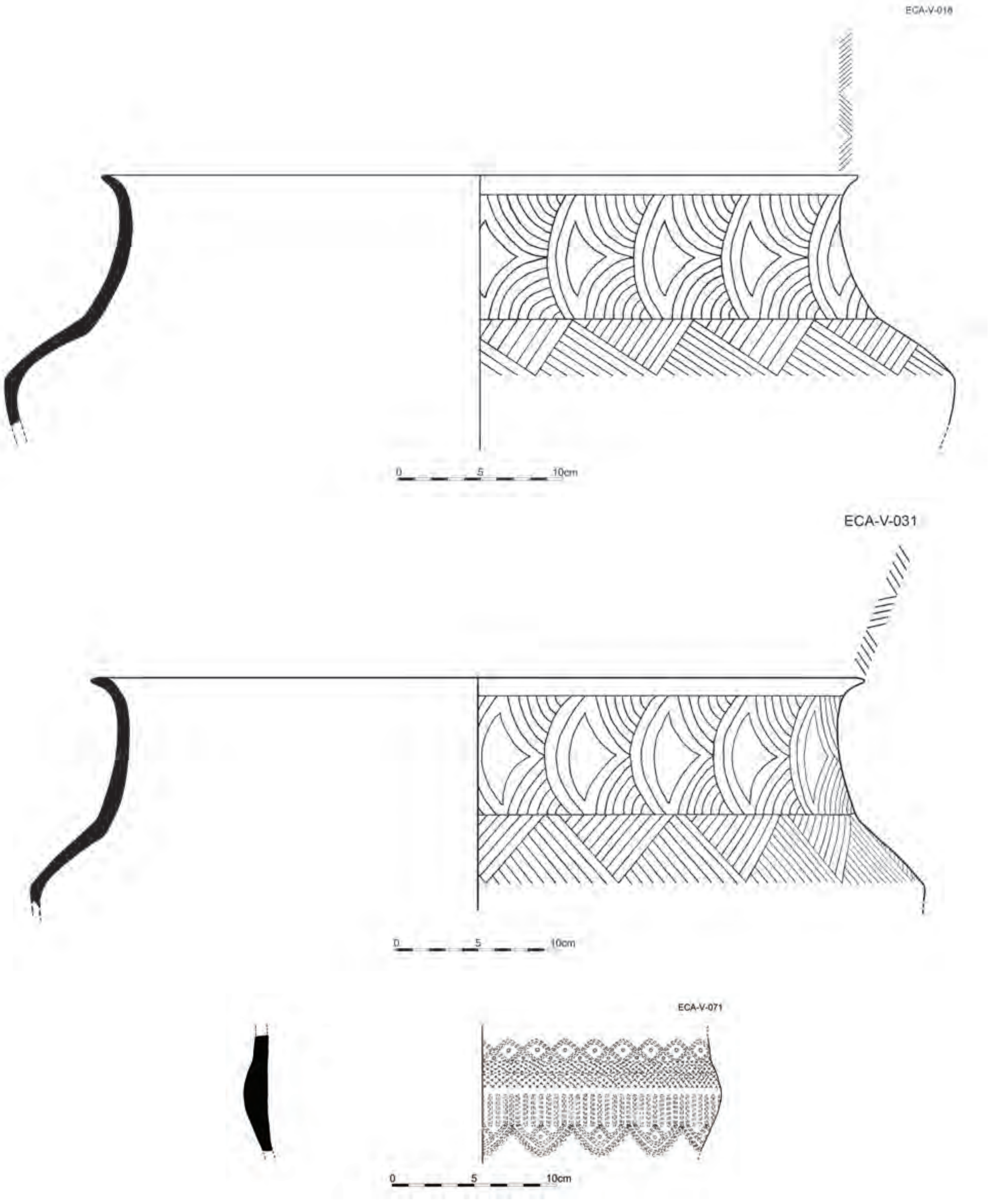


Figure 11.89. Reconstructed vessels of class IIB: ECA-V-018, -031, and -071. (Drawings by Lapita Pottery Online Database team.)

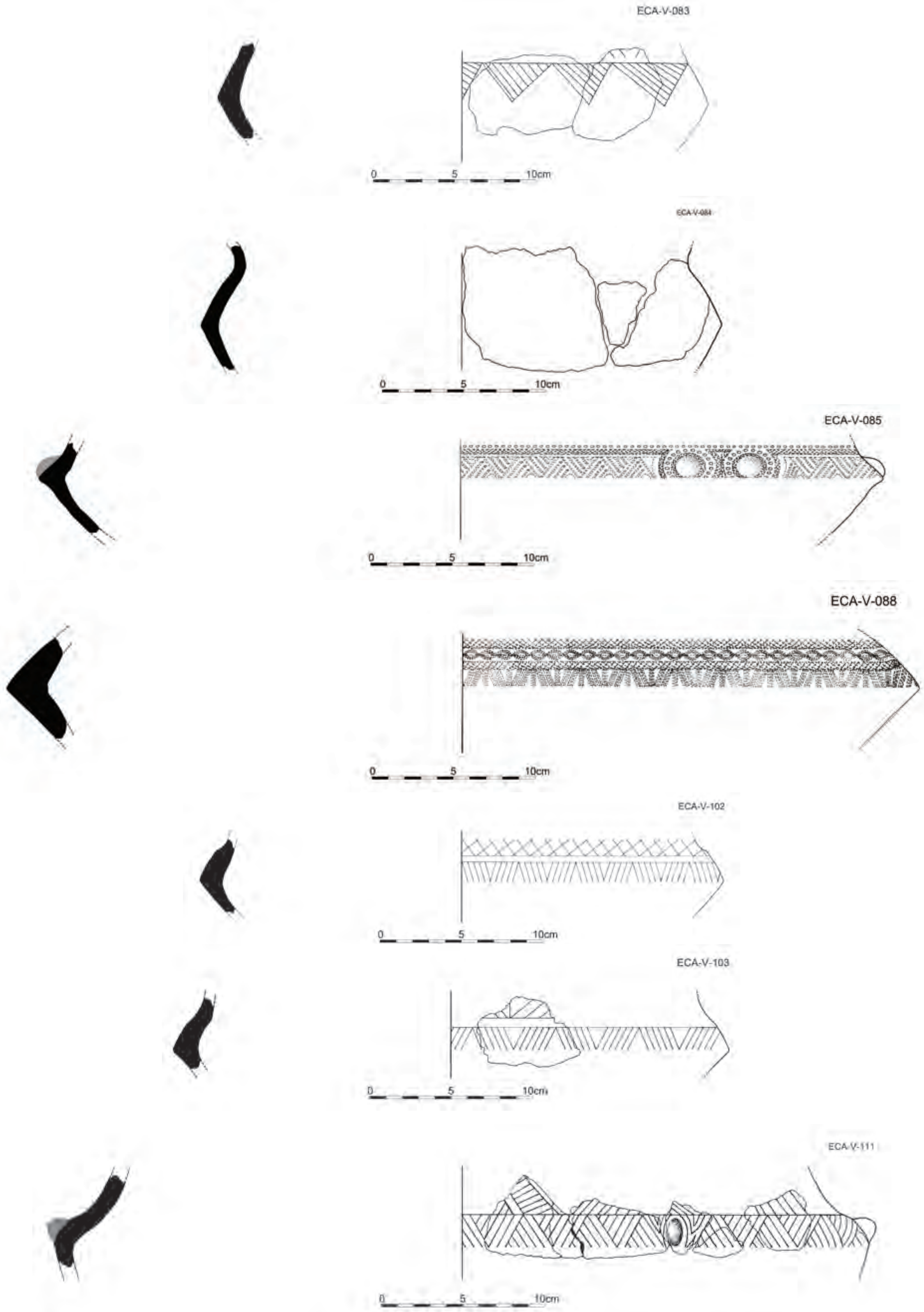


Figure 11.90. Reconstructed vessels of class IIB: ECA-V-083, -084, -085, -088, -102, -103, and -111. (Drawings by Lapita Pottery Online Database team.)

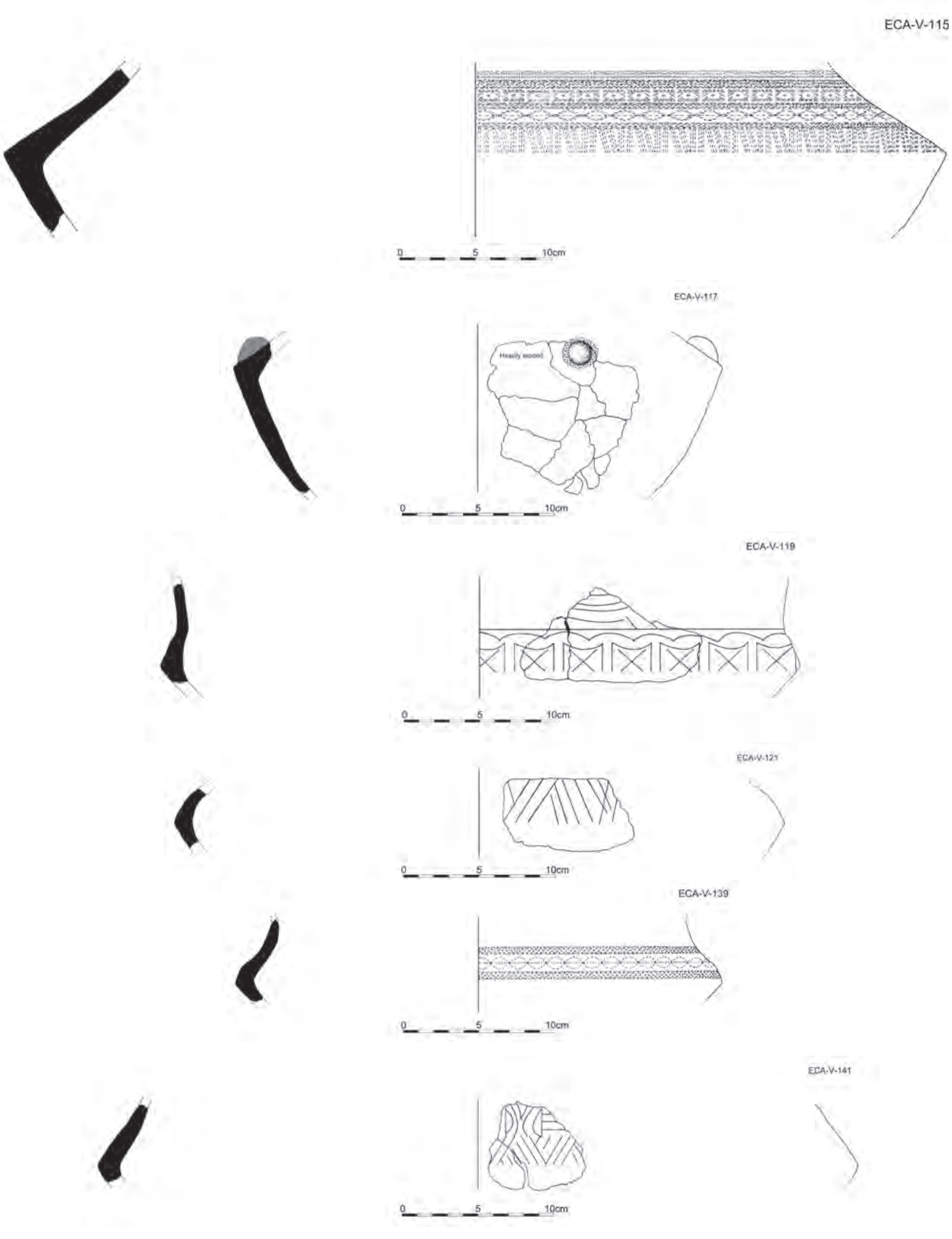


Figure 11.91. Reconstructed vessels of class IIB: ECA-V-115, -117, -119, -121, -139, and -141. (Drawings by Lapita Pottery Online Database team.)

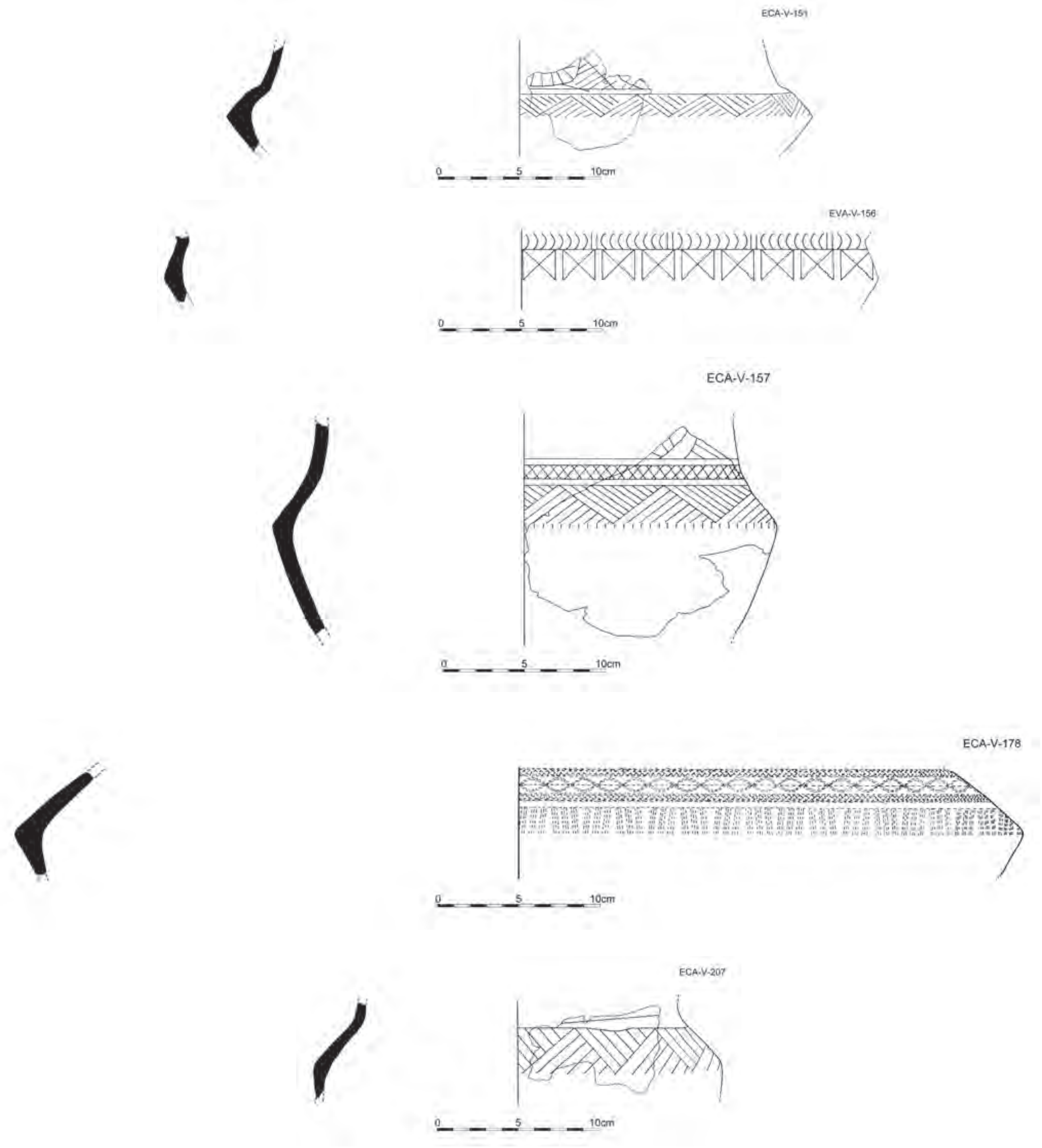


Figure 11.92. Reconstructed vessels of class IIB: ECA-V-151, -156, -157, -178, and -207. (Drawings by Lapita Pottery Online Database team.)

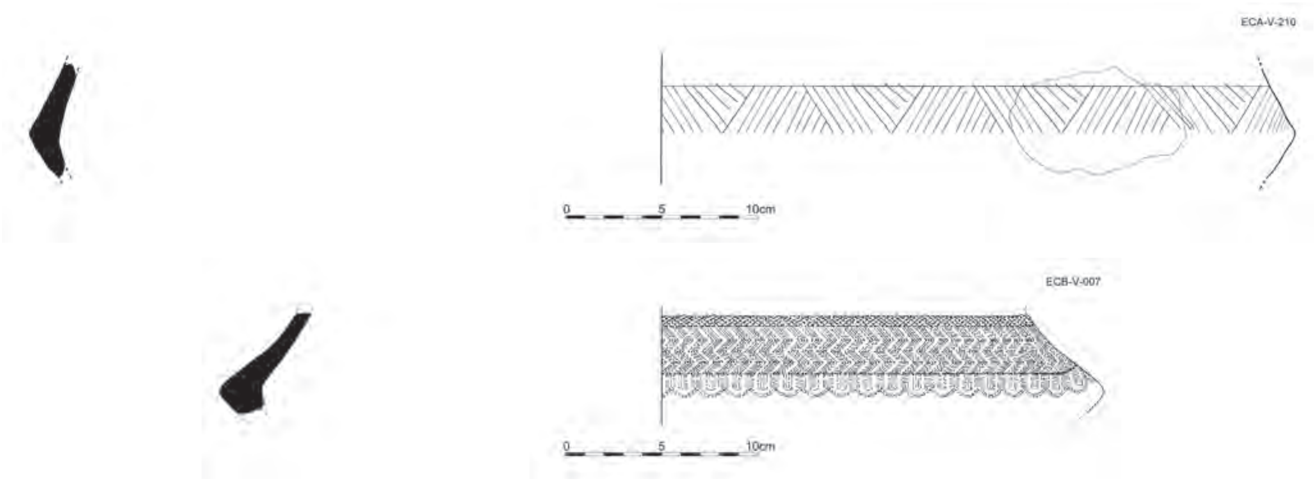


Figure 11.93. Reconstructed vessels of class IIB: ECA-V-210, ECB-V-007. (Drawings by Lapita Pottery Online Database team.)

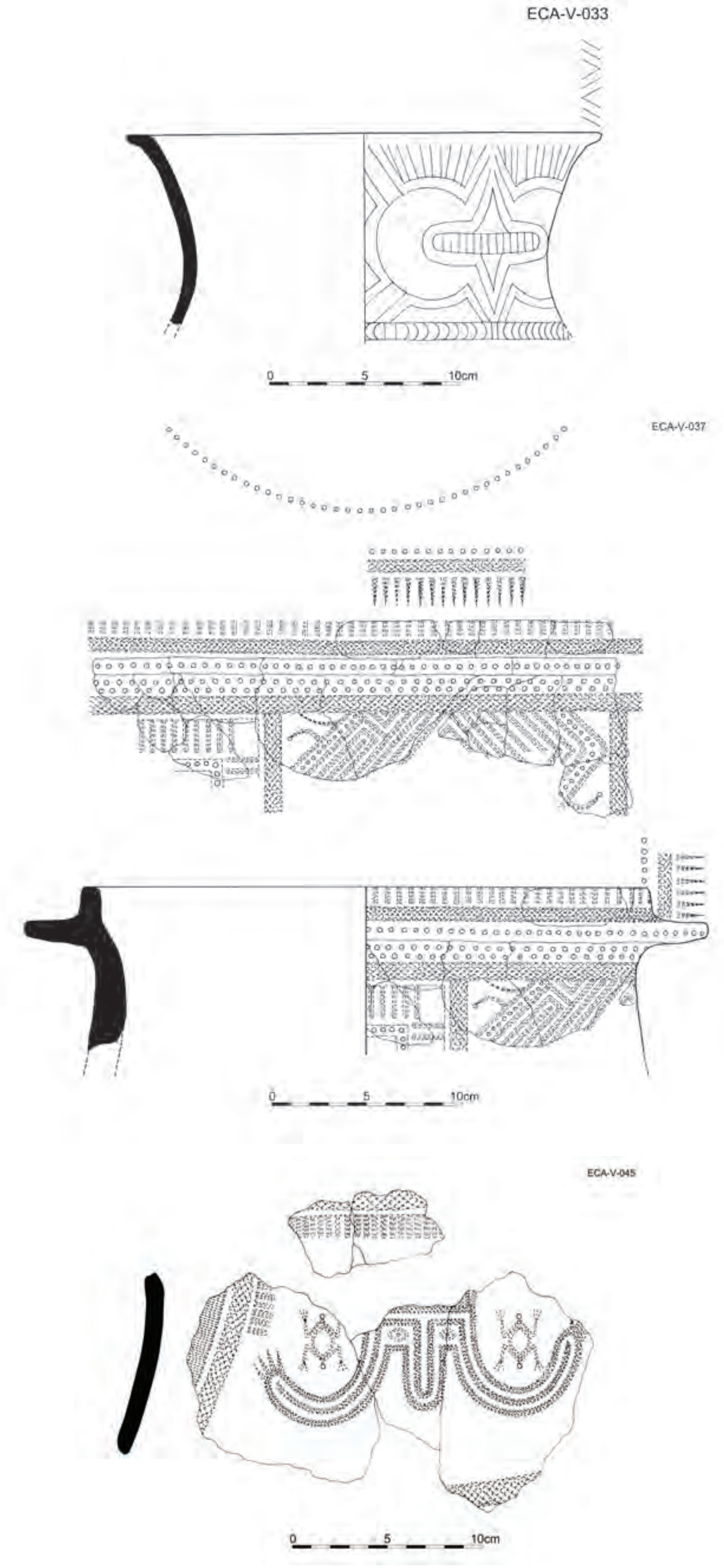


Figure 11.94. Reconstructed vessels of class IIC: ECA-V-033, -037, and -045. (Drawings by Lapita Pottery Online Database team.)

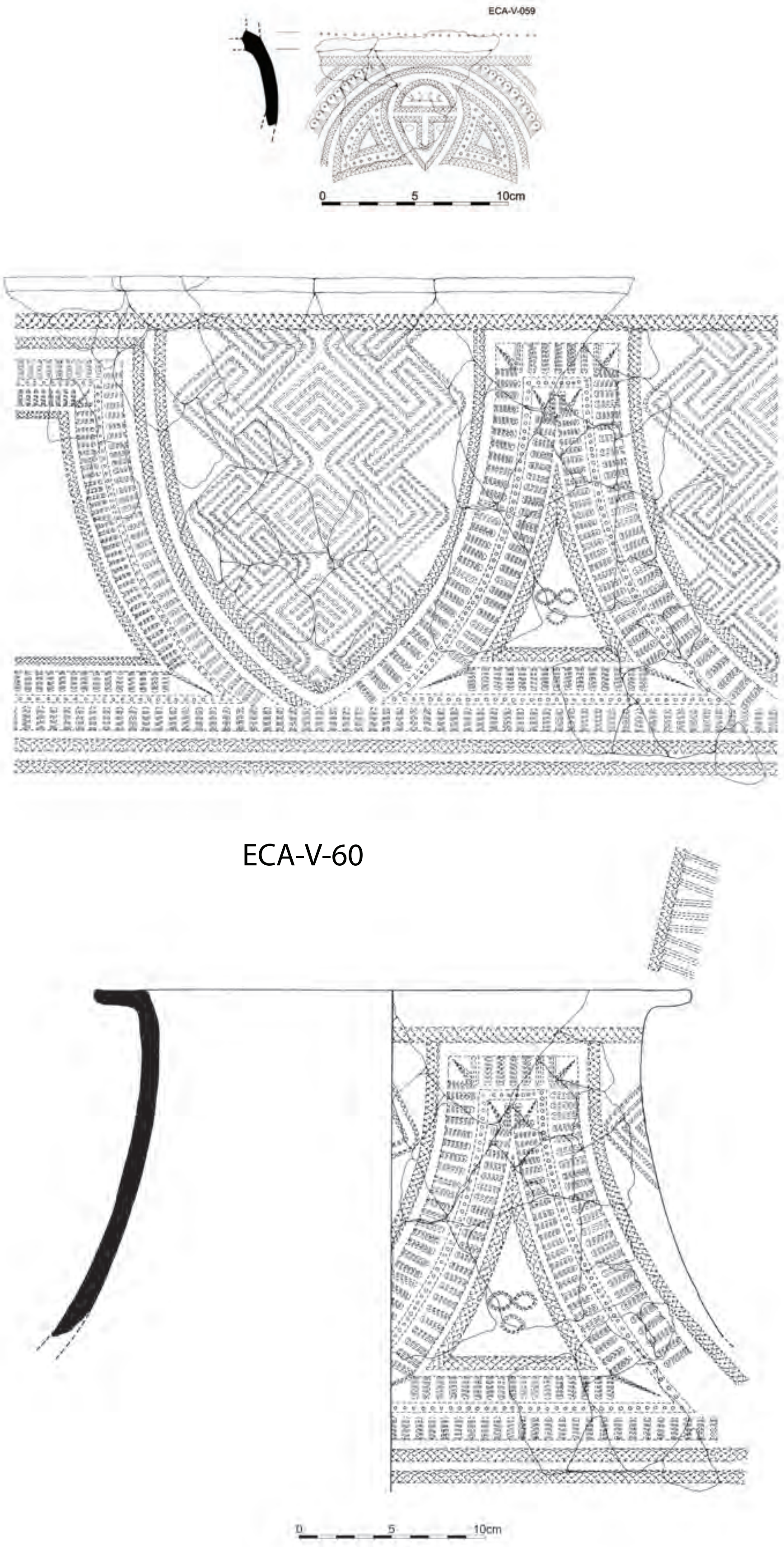


Figure 11.95. Reconstructed vessels of class IIC: ECA-V-059 and -060. (Drawings by Lapita Pottery Online Database team.)

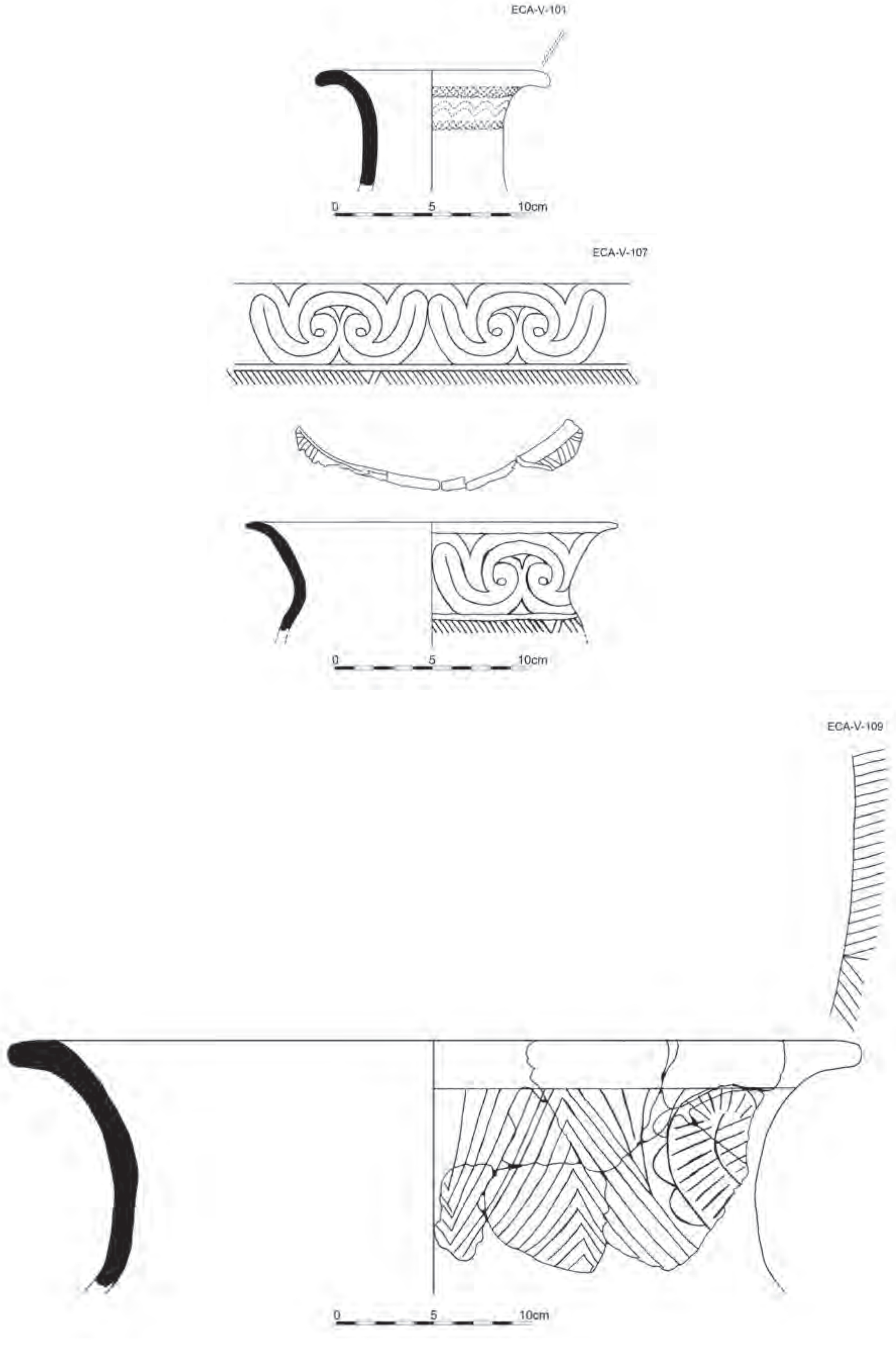


Figure 11.96. Reconstructed vessels of class IIC: ECA-V-101, -107, and -109. (Drawings by Lapita Pottery Online Database team.)

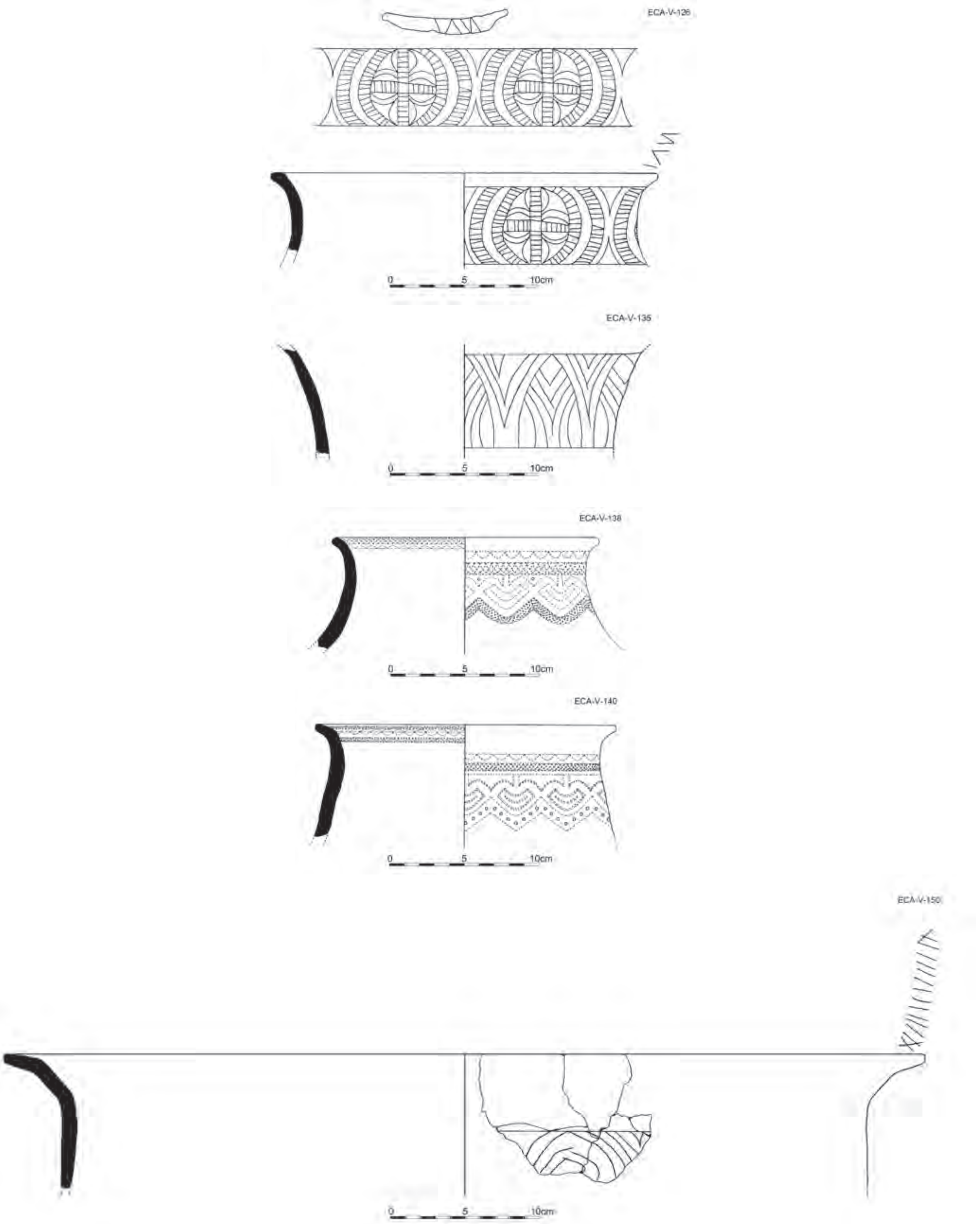


Figure 11.97. Reconstructed vessels of class IIC: ECA-V-126, -135, -138, -140, and -150. (Drawings by Lapita Pottery Online Database team.)

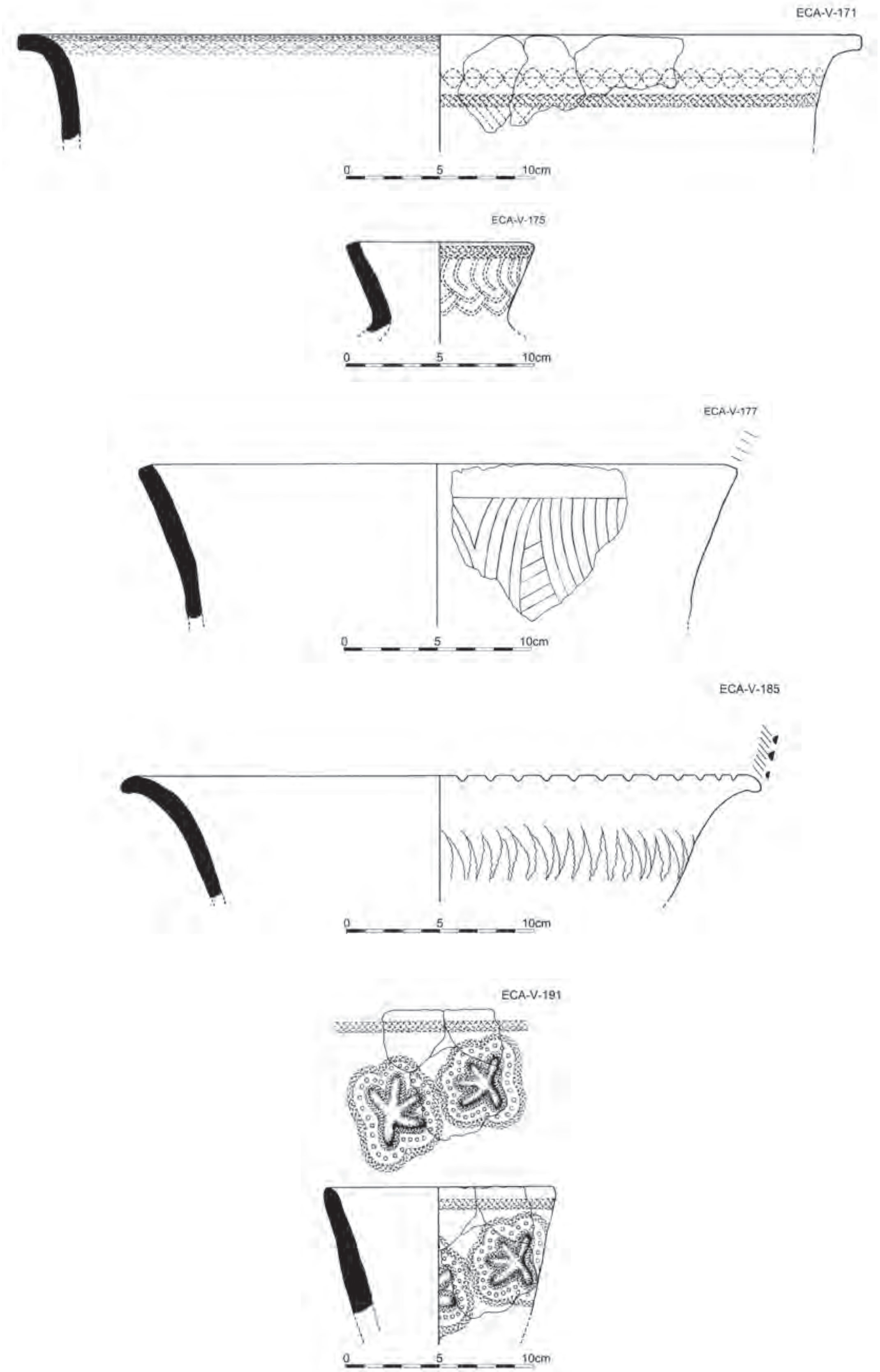


Figure 11.98. Reconstructed vessels of class IIC: ECA-V-171, -175, -177, -185, and -191. (Drawings by Lapita Pottery Online Database team.)

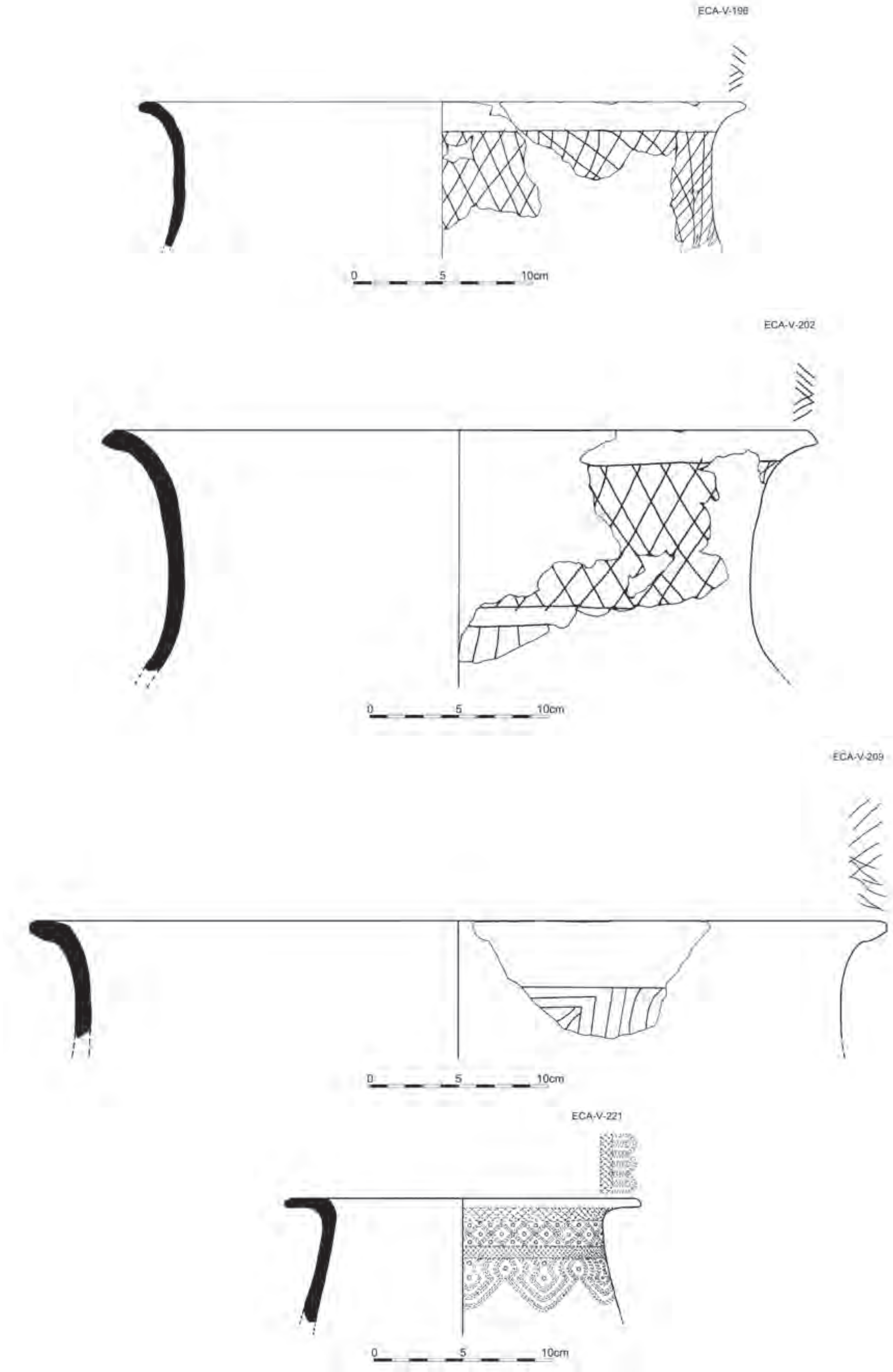


Figure 11.99. Reconstructed vessels of class IIC: ECA-V-196, -202, -209, and -221. (Drawings by Lapita Pottery Online Database team.)

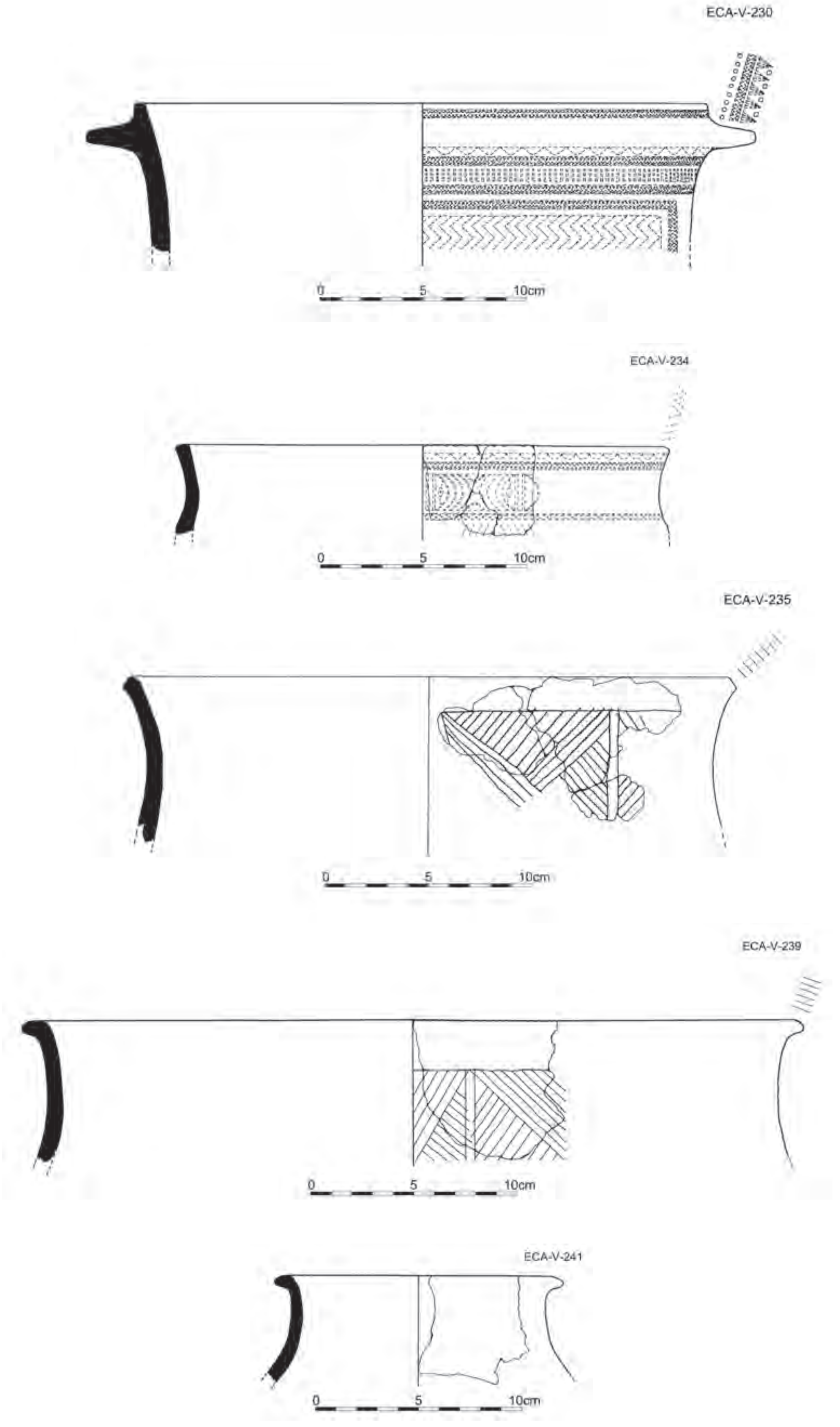


Figure 11.100. Reconstructed vessels of class IIC: ECA-V-230, -234, -235, -239, and -241. (Drawings by Lapita Pottery Online Database team.)

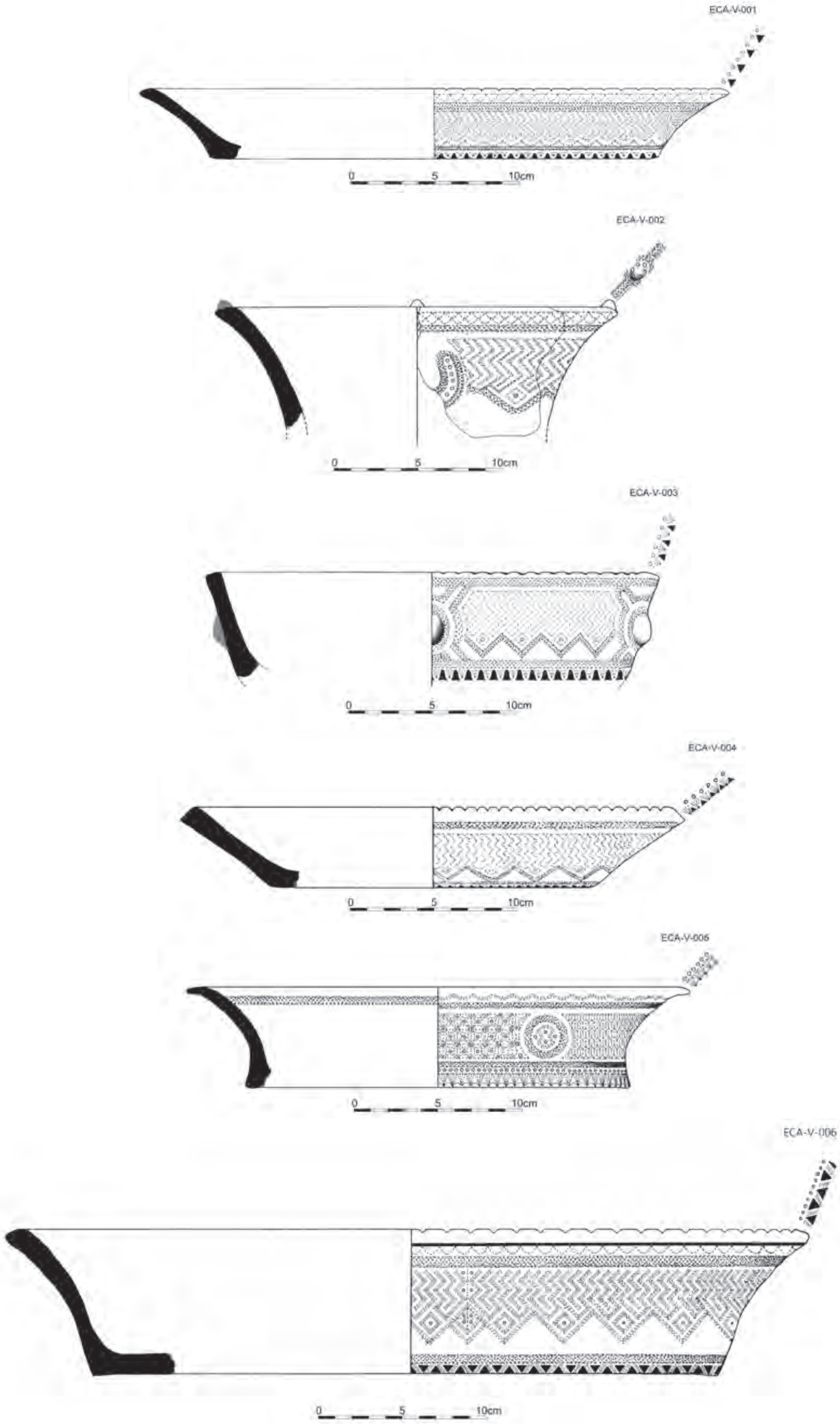


Figure 11.101. Reconstructed vessels of class III: ECA-V-001, -002, -003, -004, -005, and -006. (Drawings by Lapita Pottery Online Database team.)

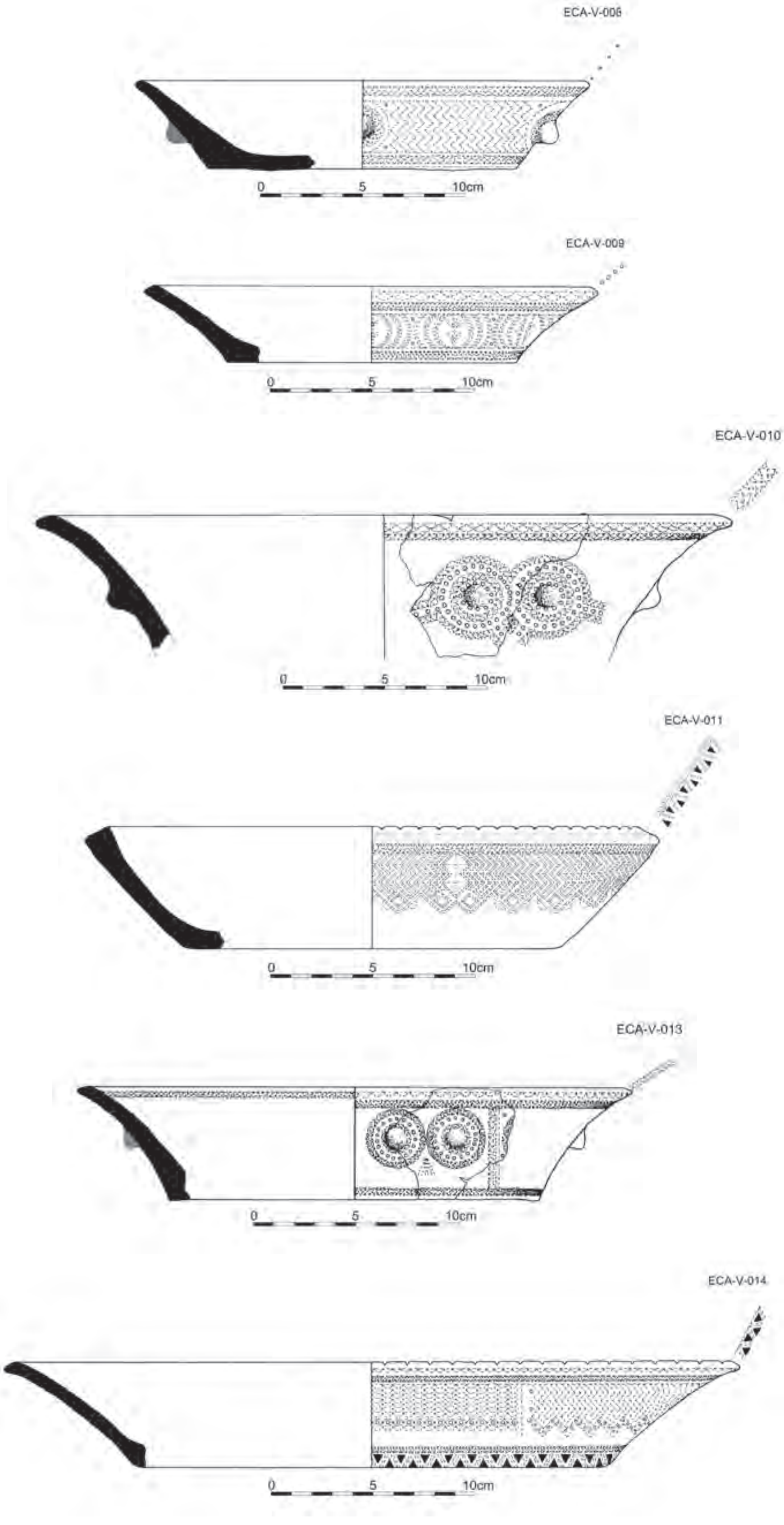


Figure 11.102. Reconstructed vessels of class III: ECA-V-008, -009, -010, -011, -013, and -014. (Drawings by Lapita Pottery Online Database team.)

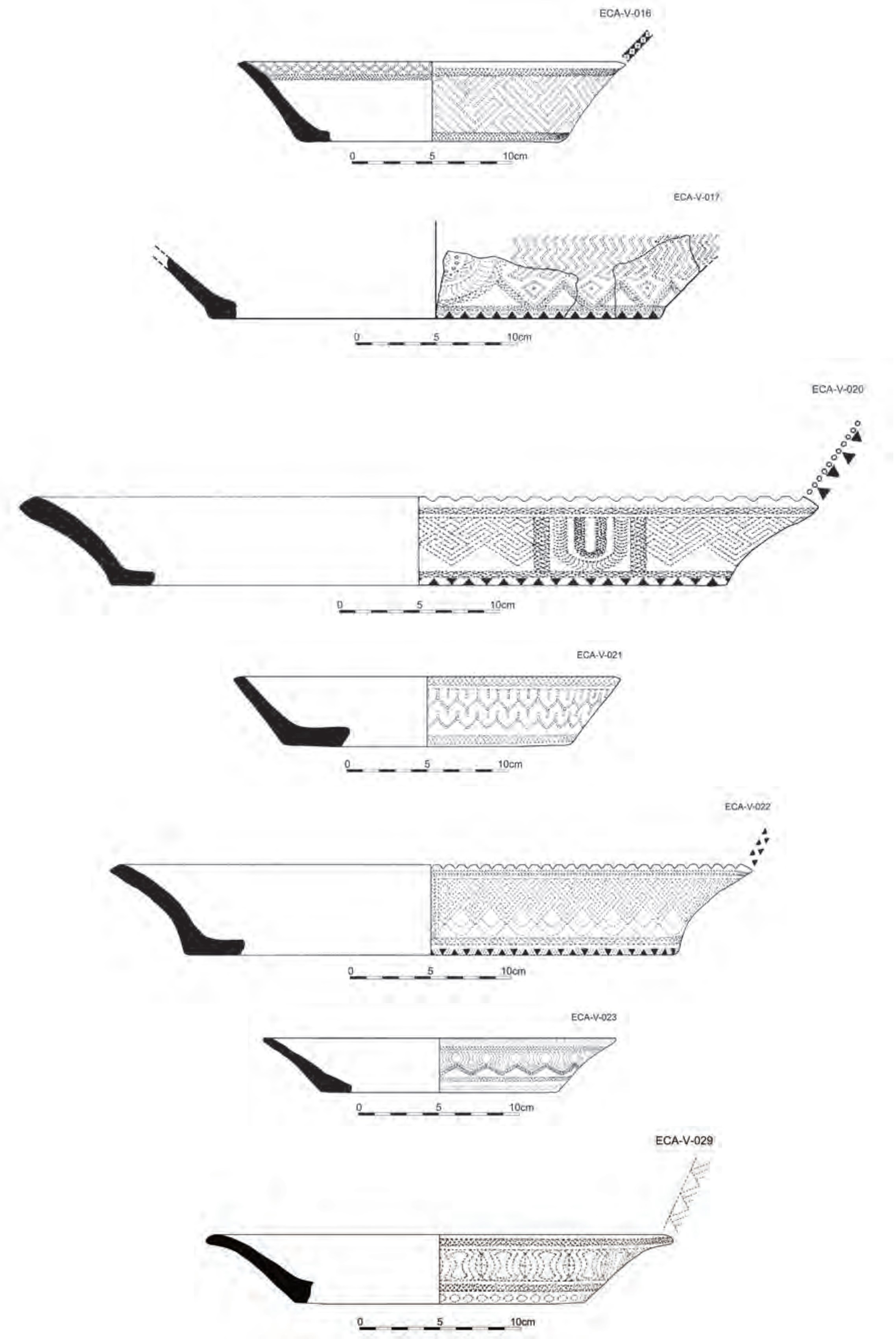


Figure 11.103. Reconstructed vessels of class III: ECA-V-016, -017, -020, -021, -022, -023, and -029. (Drawings by Lapita Pottery Online Database team.)

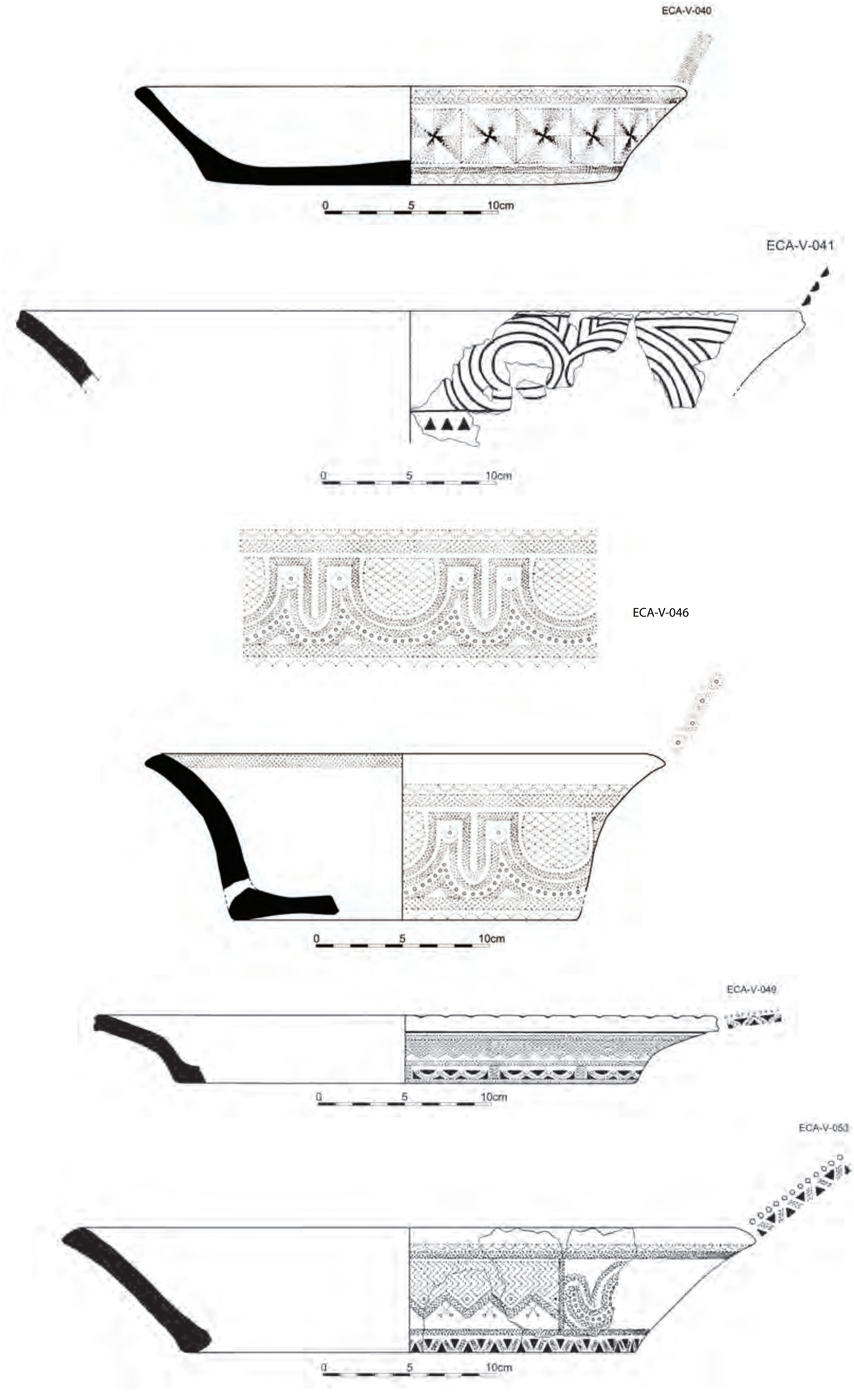


Figure 11.104. Reconstructed vessels of class III: ECA-V-040, -041, -046, -049, and -053. (Drawings by Lapita Pottery Online Database team.)

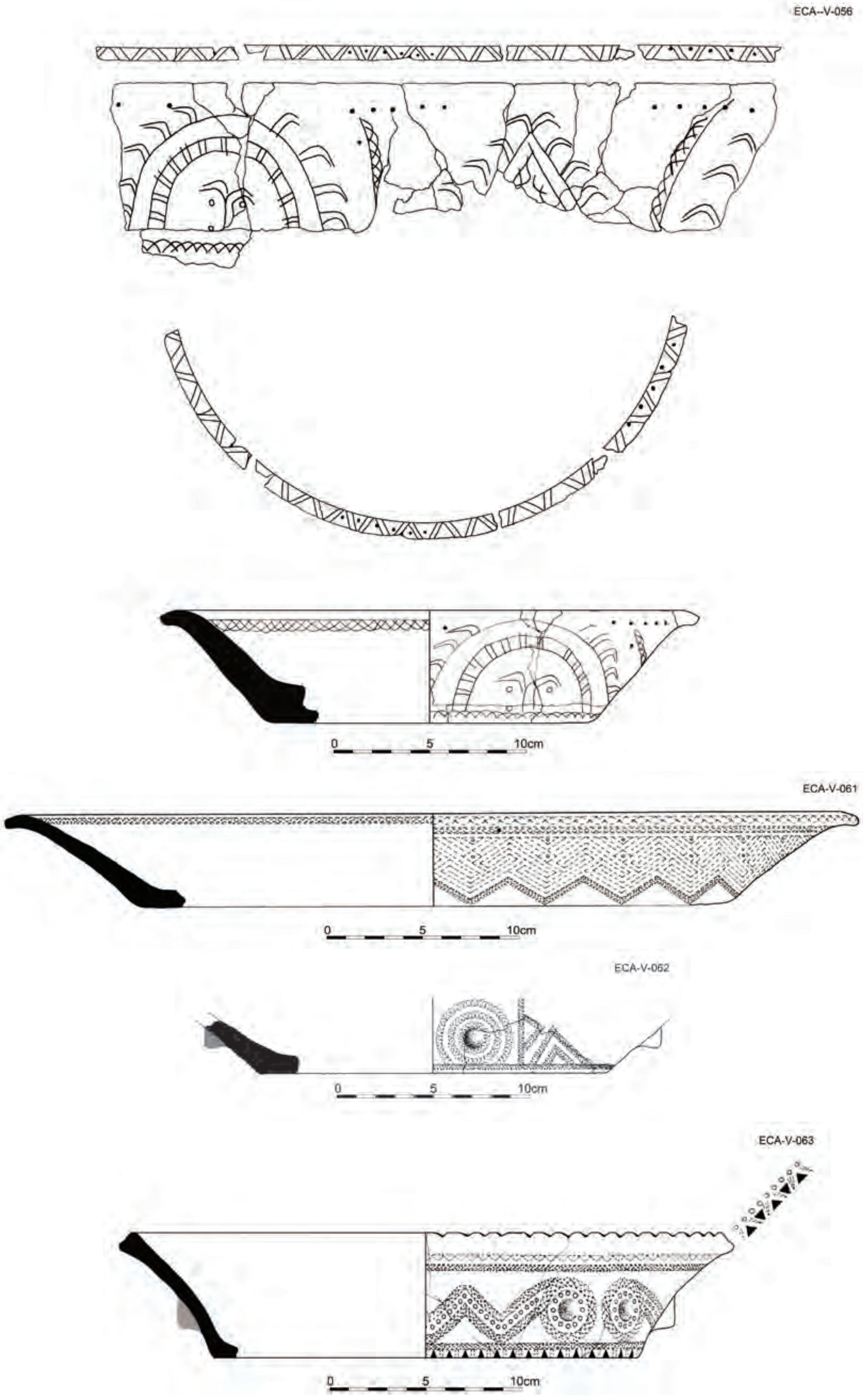


Figure 11.105. Reconstructed vessels of class III: ECA-V-056, -061, -062, and -063. (Drawings by Lapita Pottery Online Database team.)

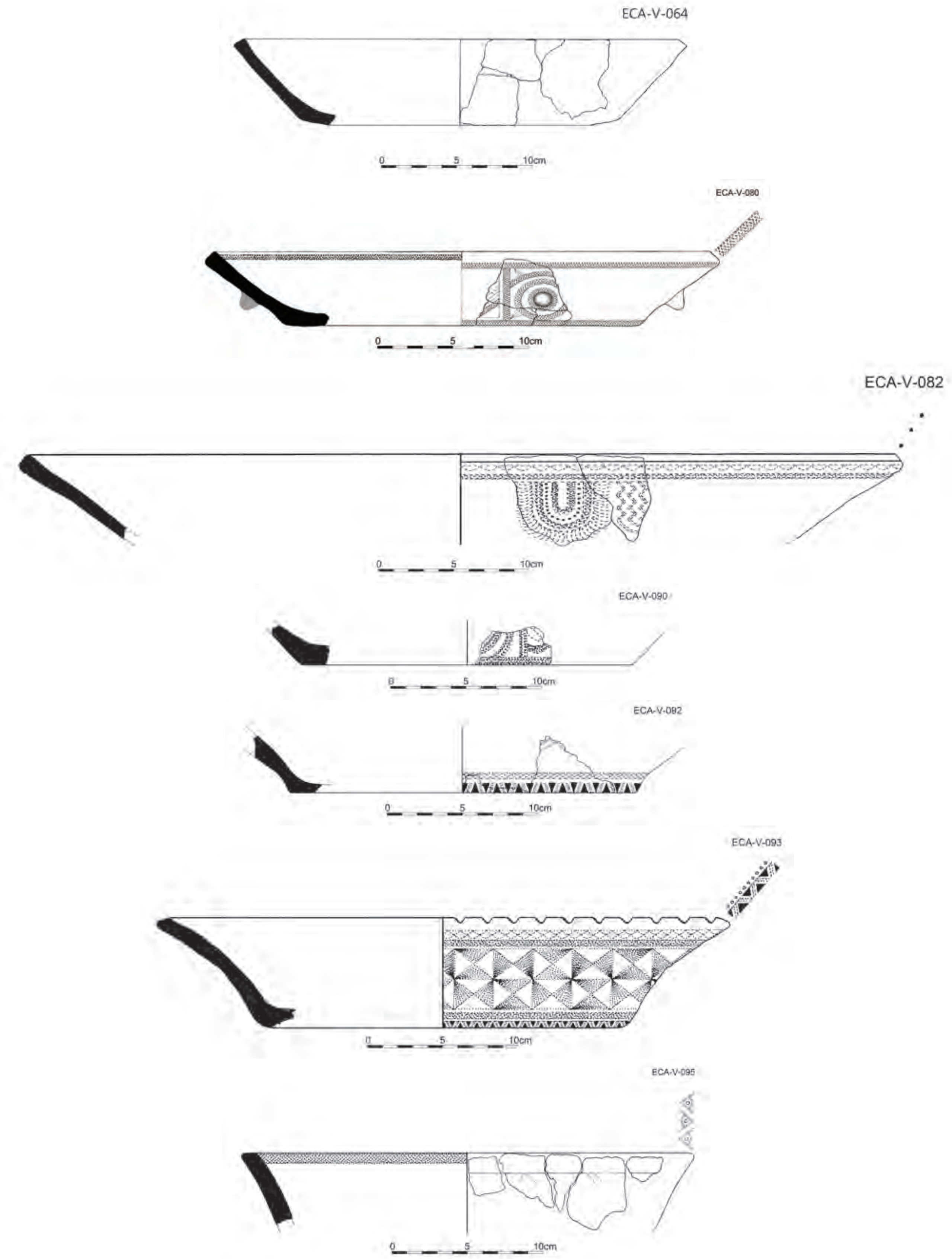


Figure 11.106. Reconstructed vessels of class III: ECA-V-064, -080, -082, -090, -092, -093, and -095. (Drawings by Lapita Pottery Online Database team.)

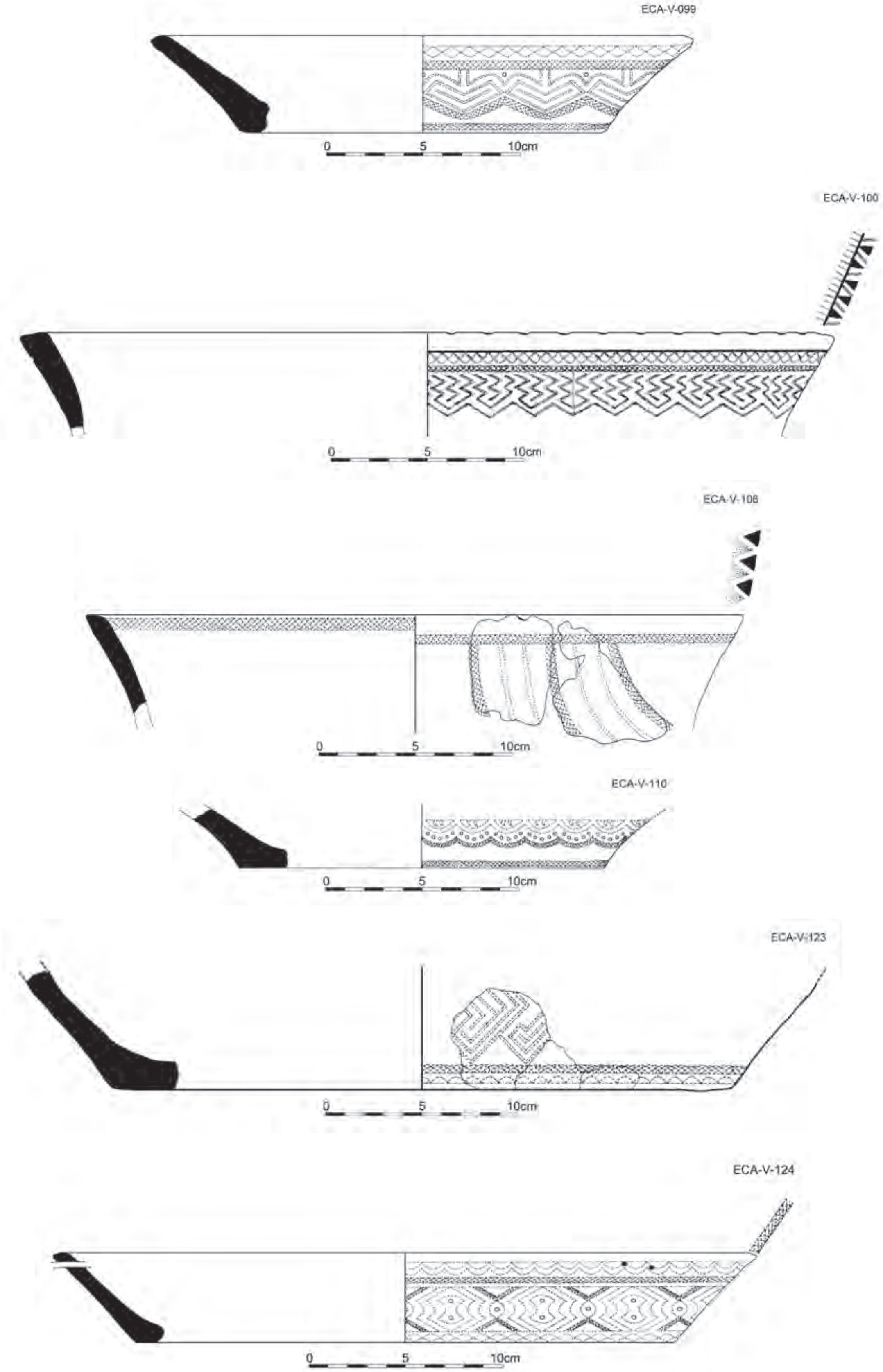


Figure 11.107. Reconstructed vessels of class III: ECA-V-099, -100, -106, -110, -123, and -124. (Drawings by Lapita Pottery Online Database team.)

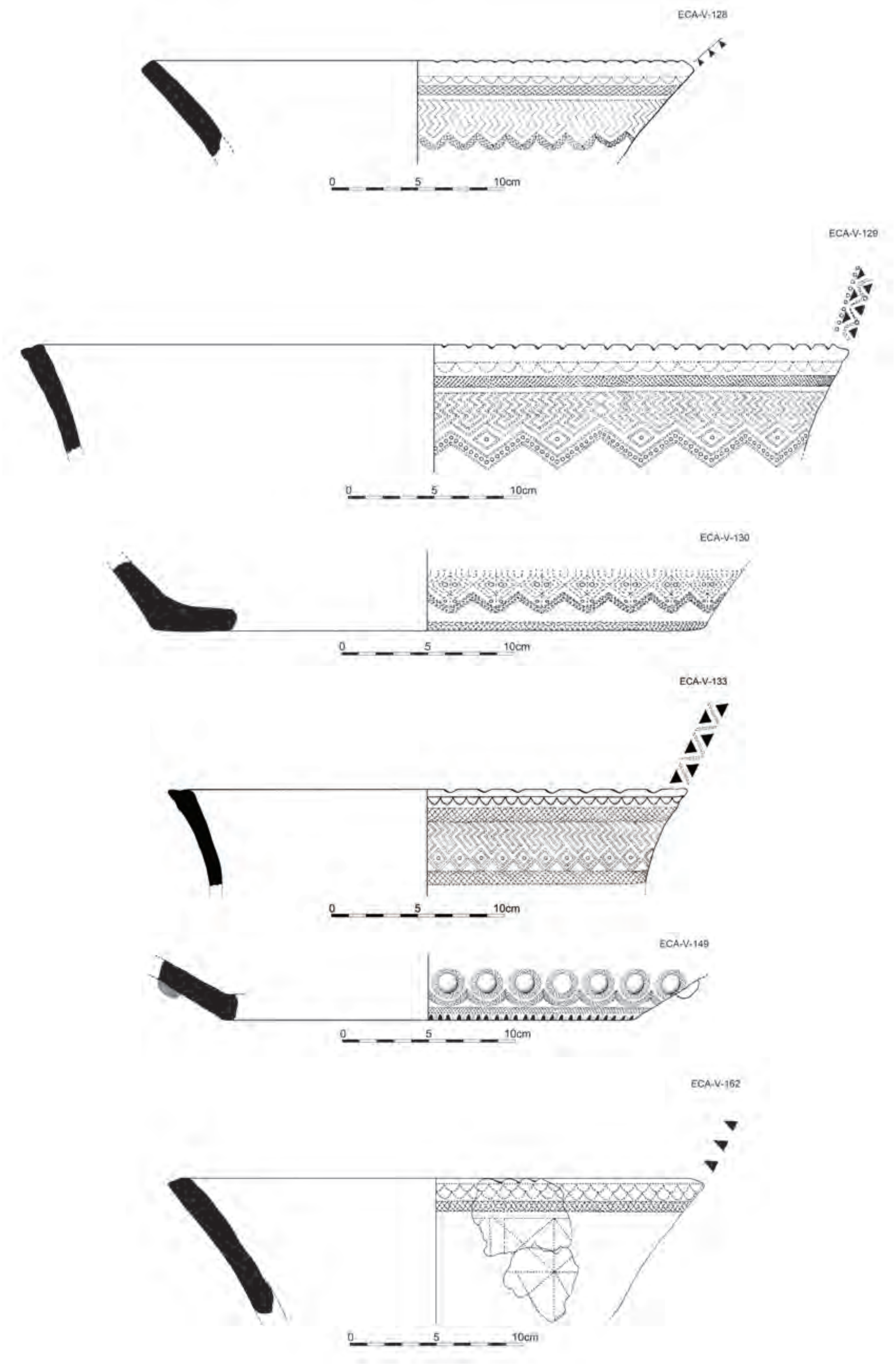


Figure 11.108. Reconstructed vessels of class III: ECA-V-128, -129, -130, -133, -149, and -162. (Drawings by Lapita Pottery Online Database team.)

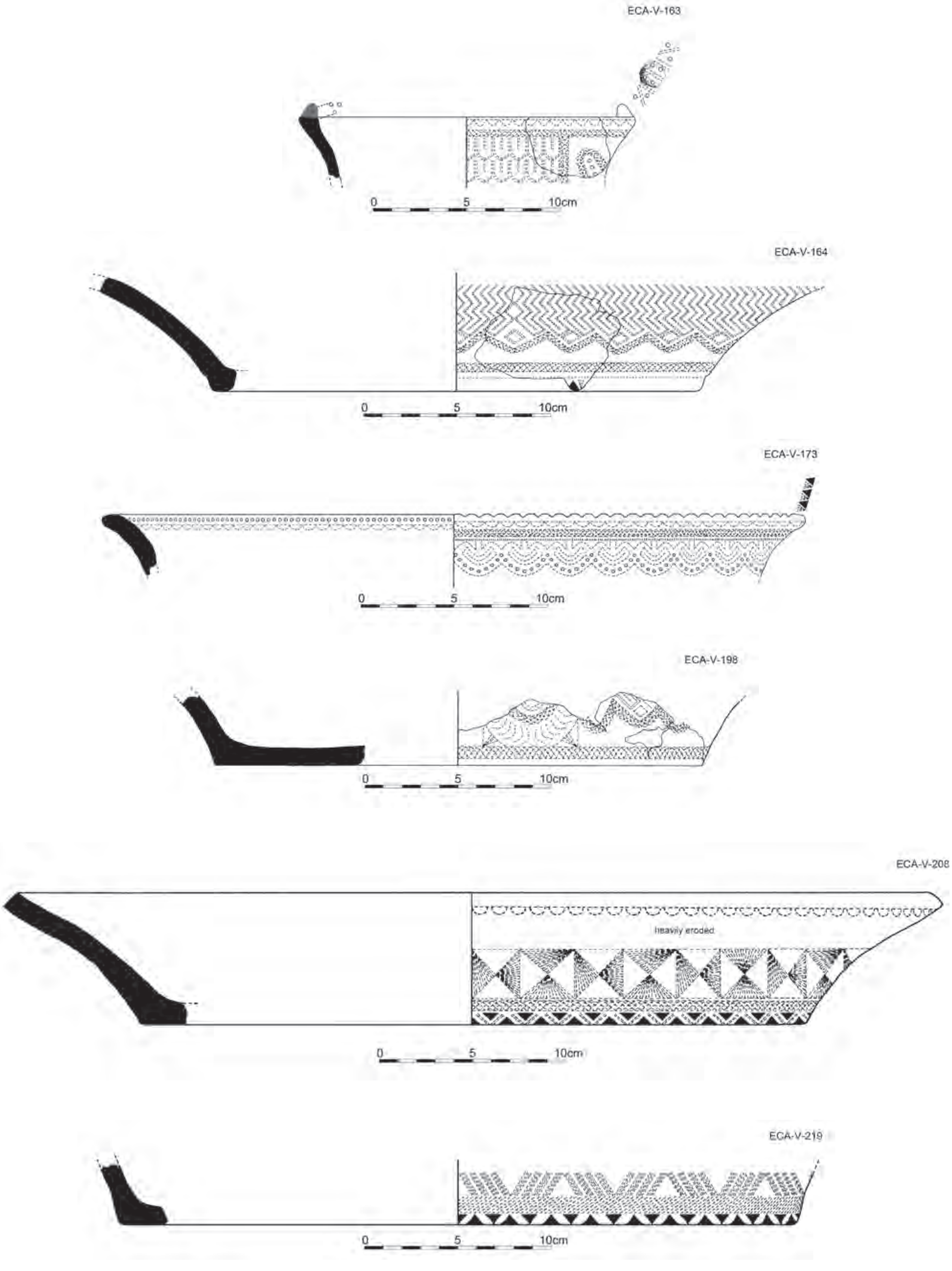


Figure 11.109. Reconstructed vessels of class III: ECA-V-163, -164, -173, -198, -208, and -219. (Drawings by Lapita Pottery Online Database team.)

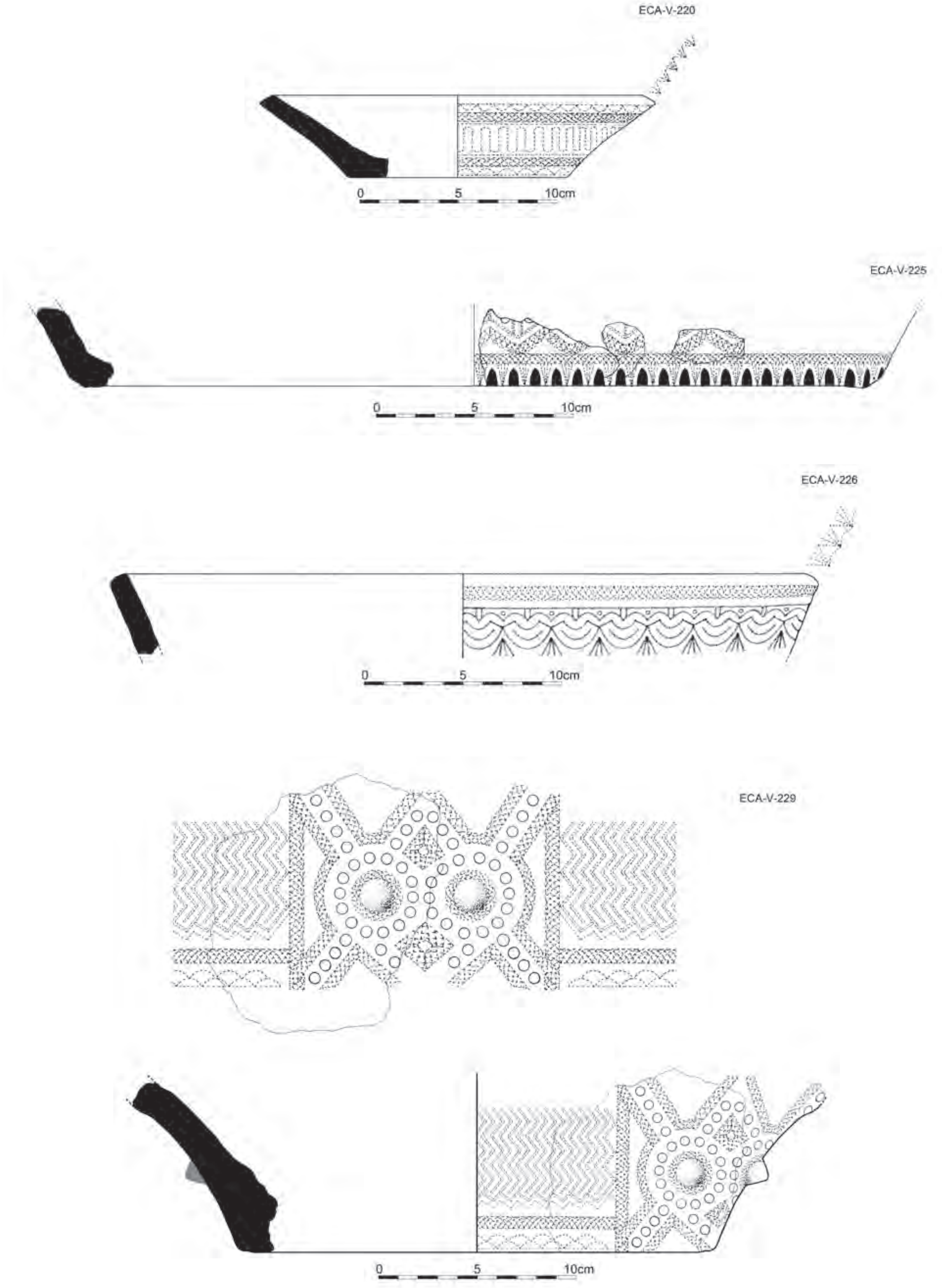
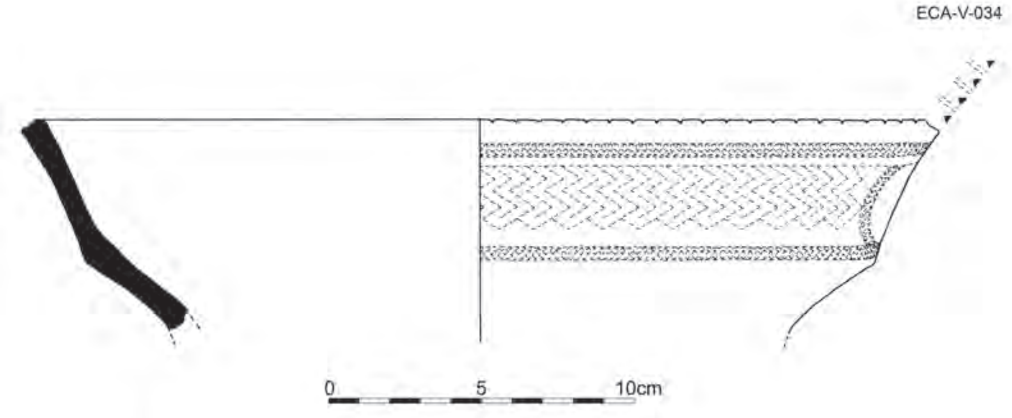
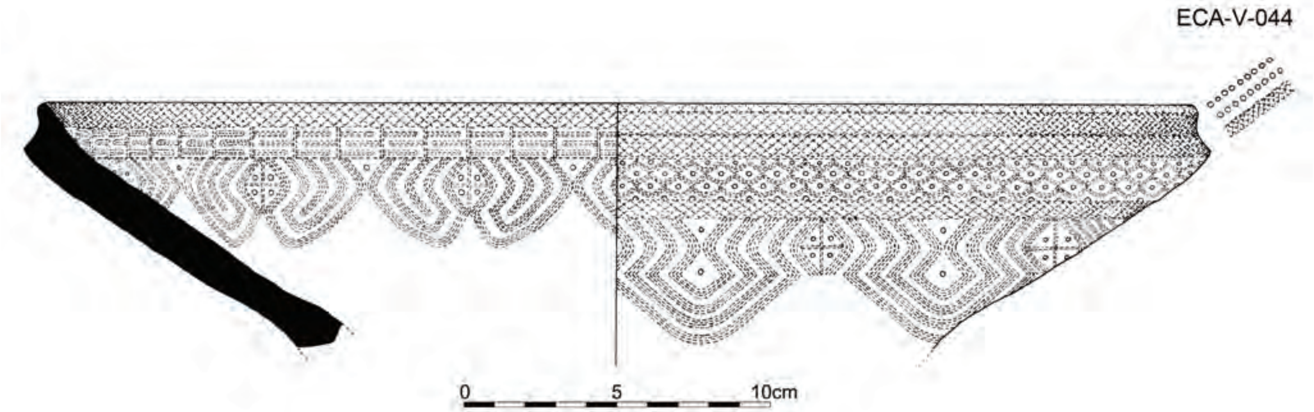


Figure 11.110. Reconstructed vessels of class III: ECA-V-220, -225, -226, and -229. (Drawings by Lapita Pottery Online Database team.)





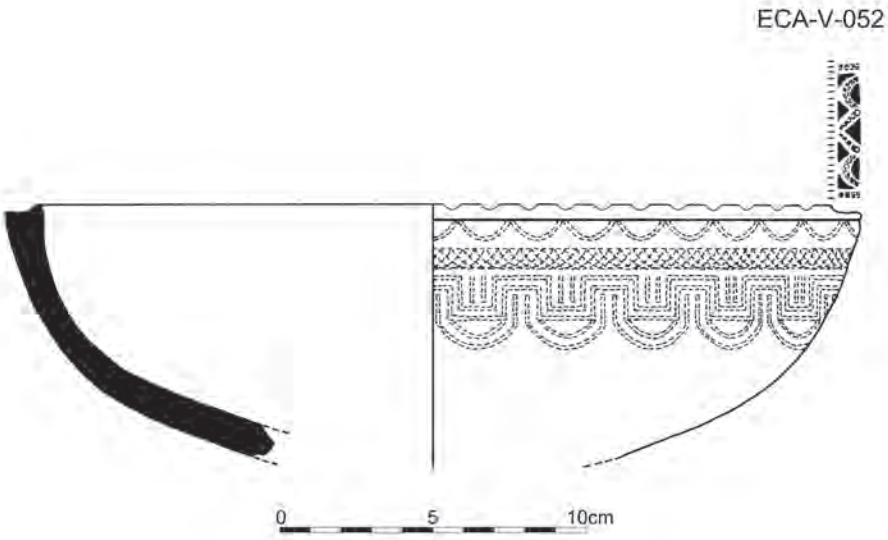


Figure 11.111. Reconstructed vessels of class IVA: ECA-V-034, -044, and -052. (Drawings by Lapita Pottery Online Database team.)

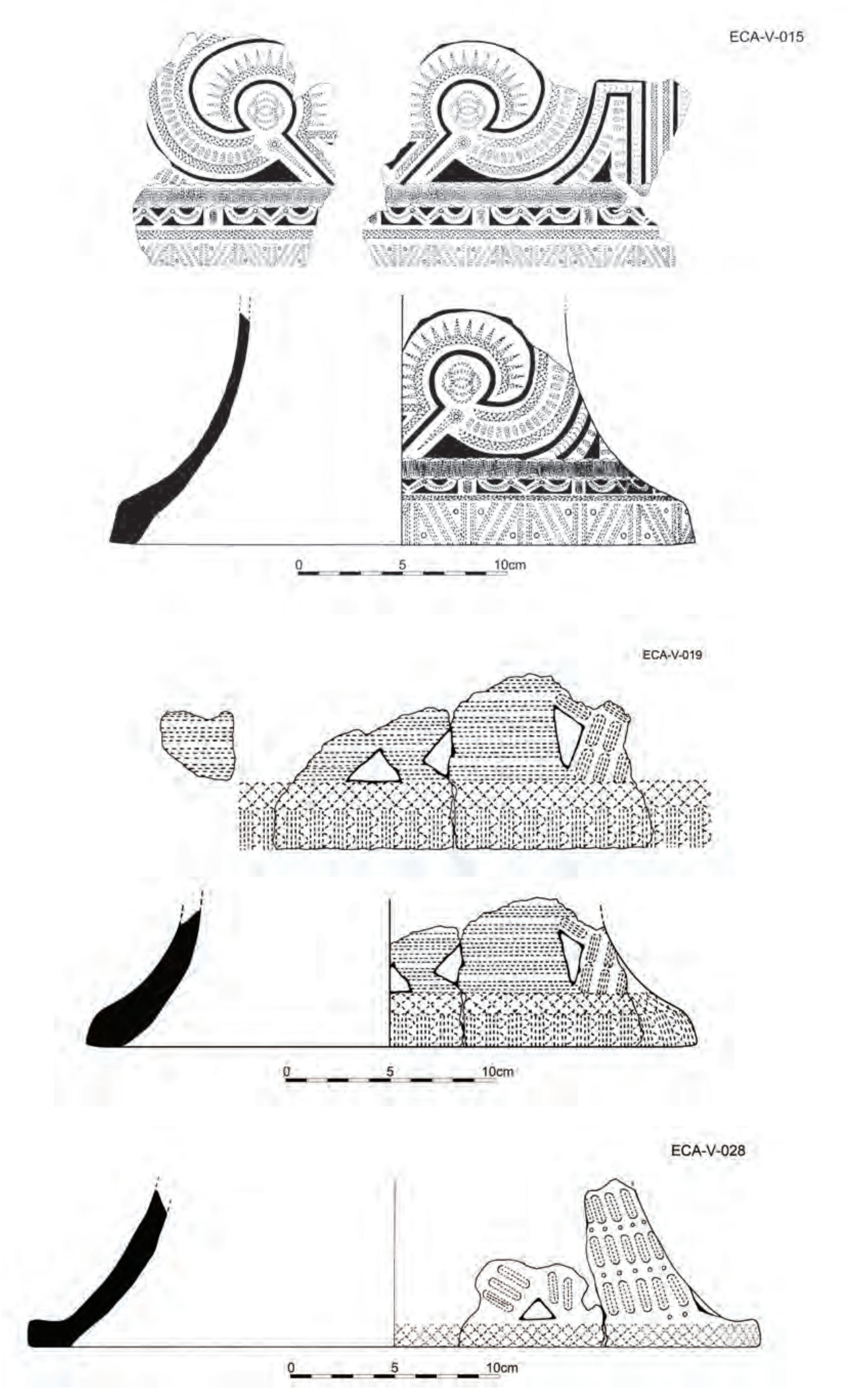


Figure 11.112. Reconstructed vessels of class IVB: ECA-V-015, -019, and -028. (Drawings by Lapita Pottery Online Database team.)

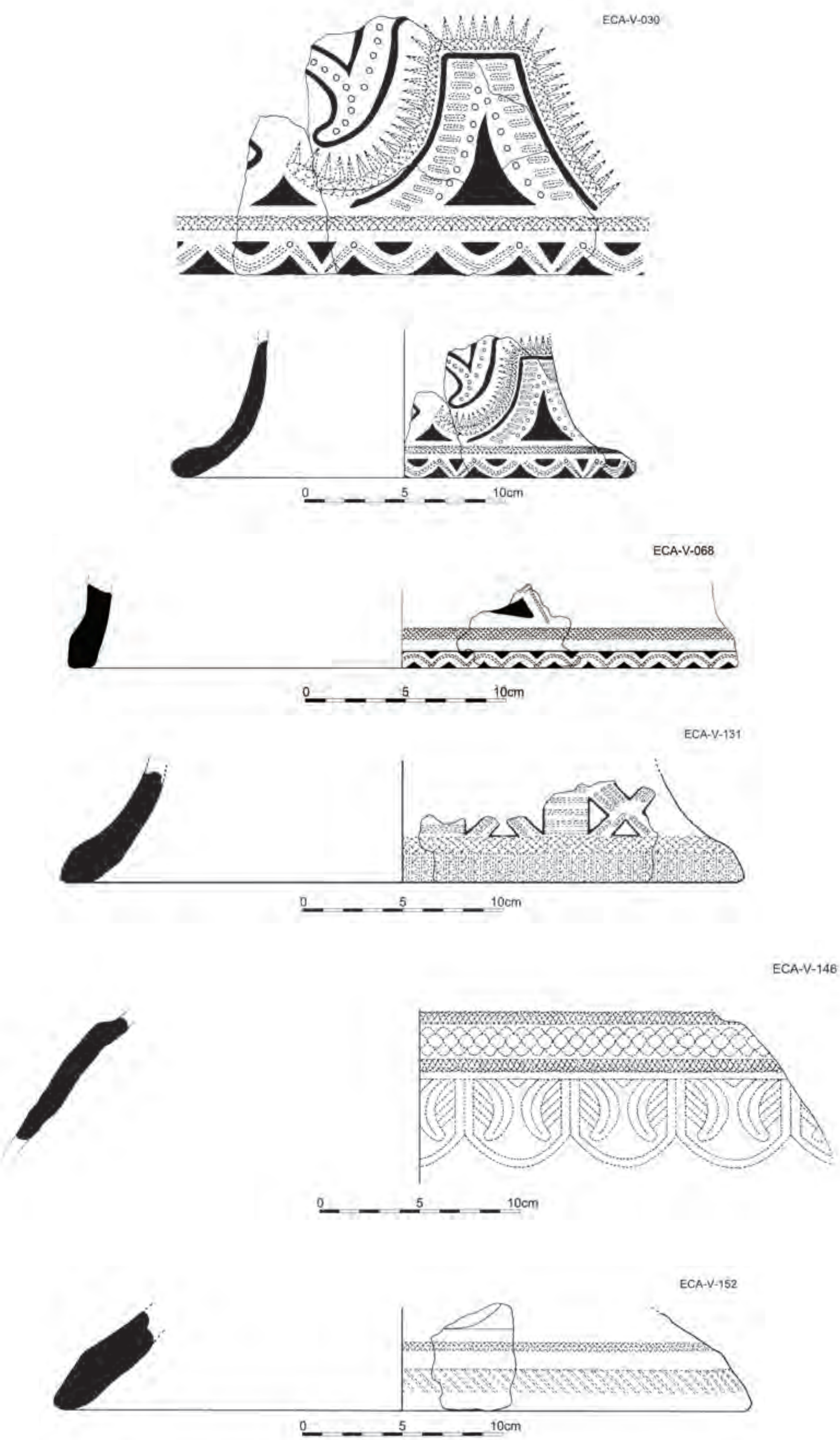


Figure 11.113. Reconstructed vessels of class IVB: ECA-V-030, -068, -131, -146, and -152. (Drawings by Lapita Pottery Online Database team.)

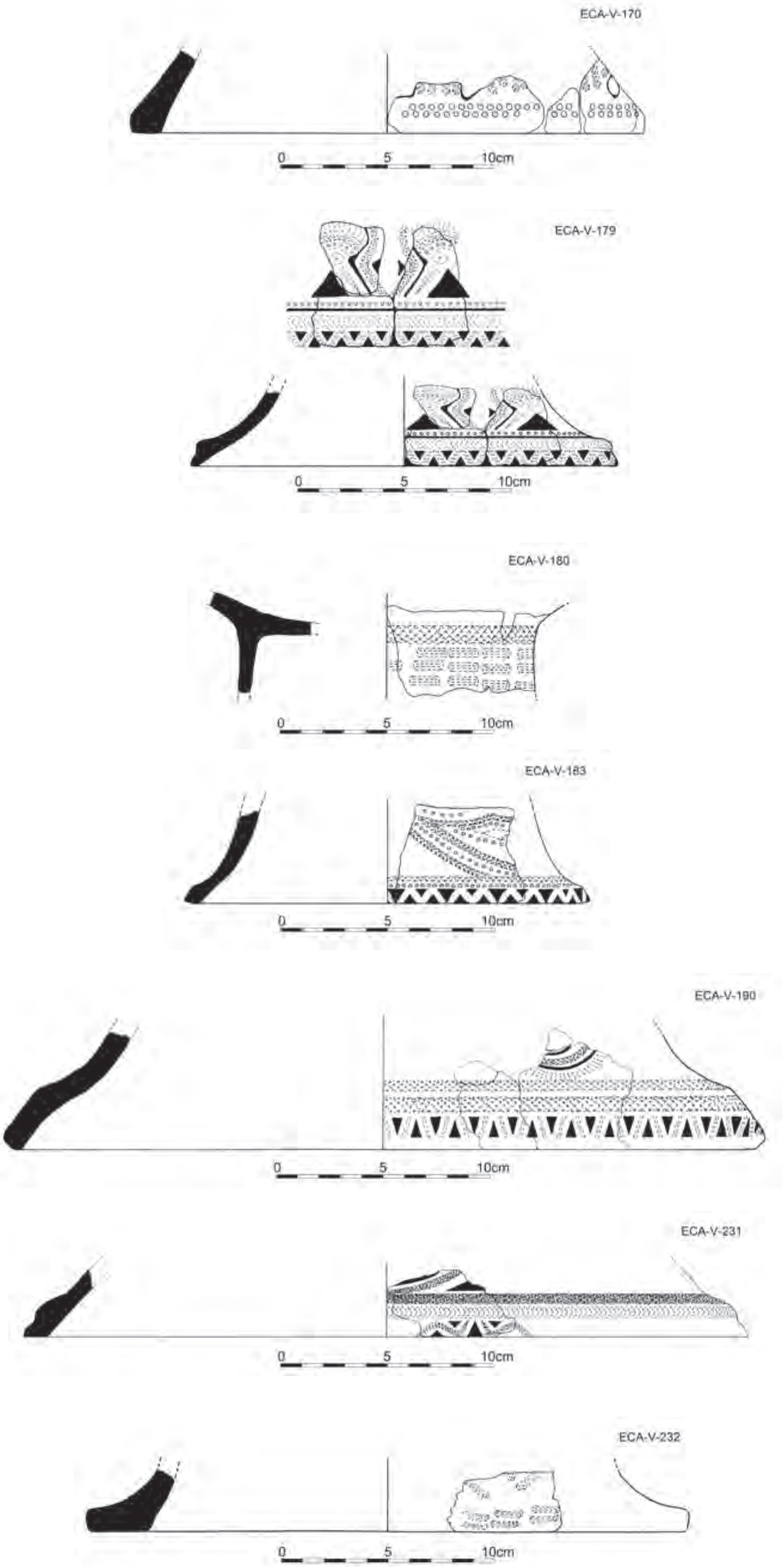


Figure 11.114. Reconstructed vessels of class IVB: ECA-V-170, -179, -180, -183, -190, -231, and -232. (Drawings by Lapita Pottery Online Database team.)

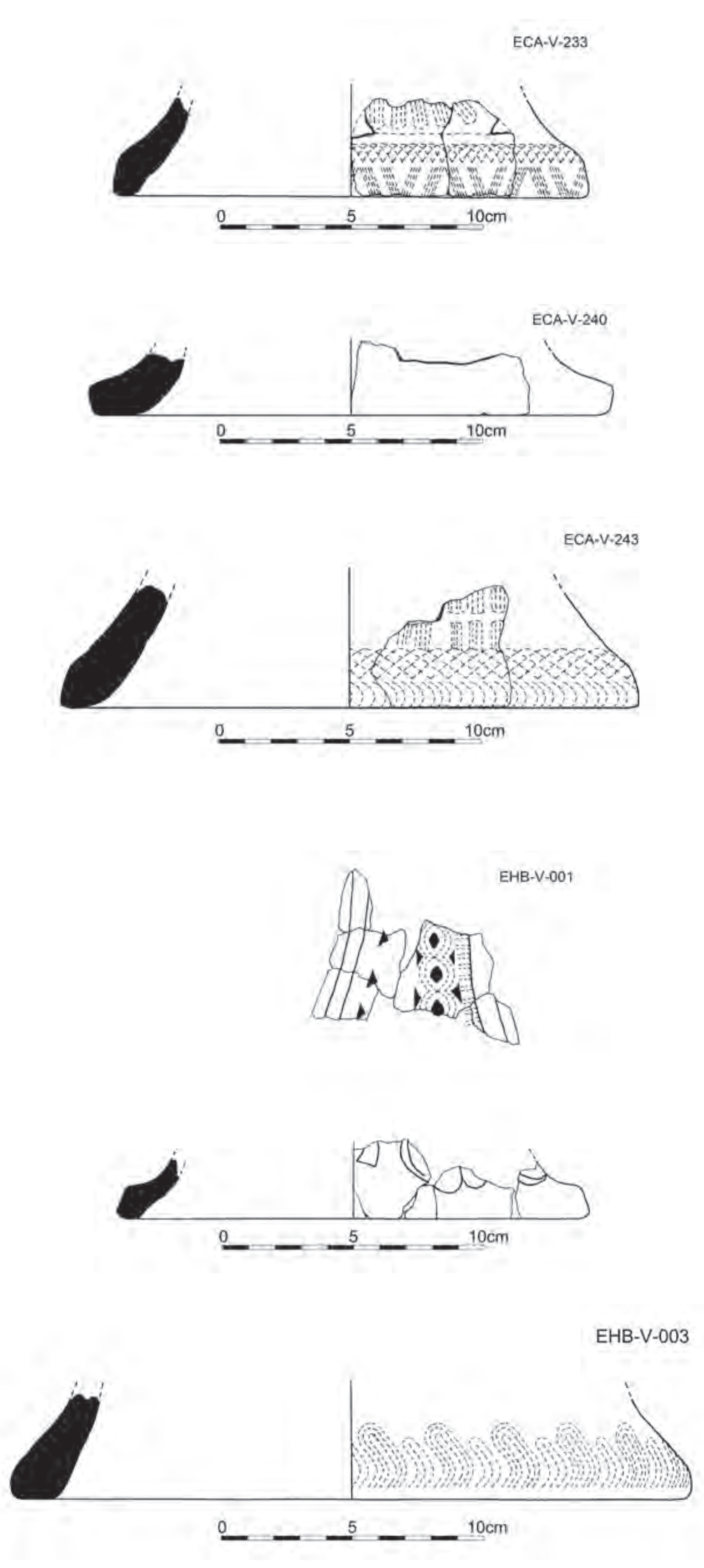


Figure 11.115. Reconstructed vessels of class IVB: ECA-V-233, -240, -243, EHB-V-001 and -003. (Drawings by Lapita Pottery Online Database team.)

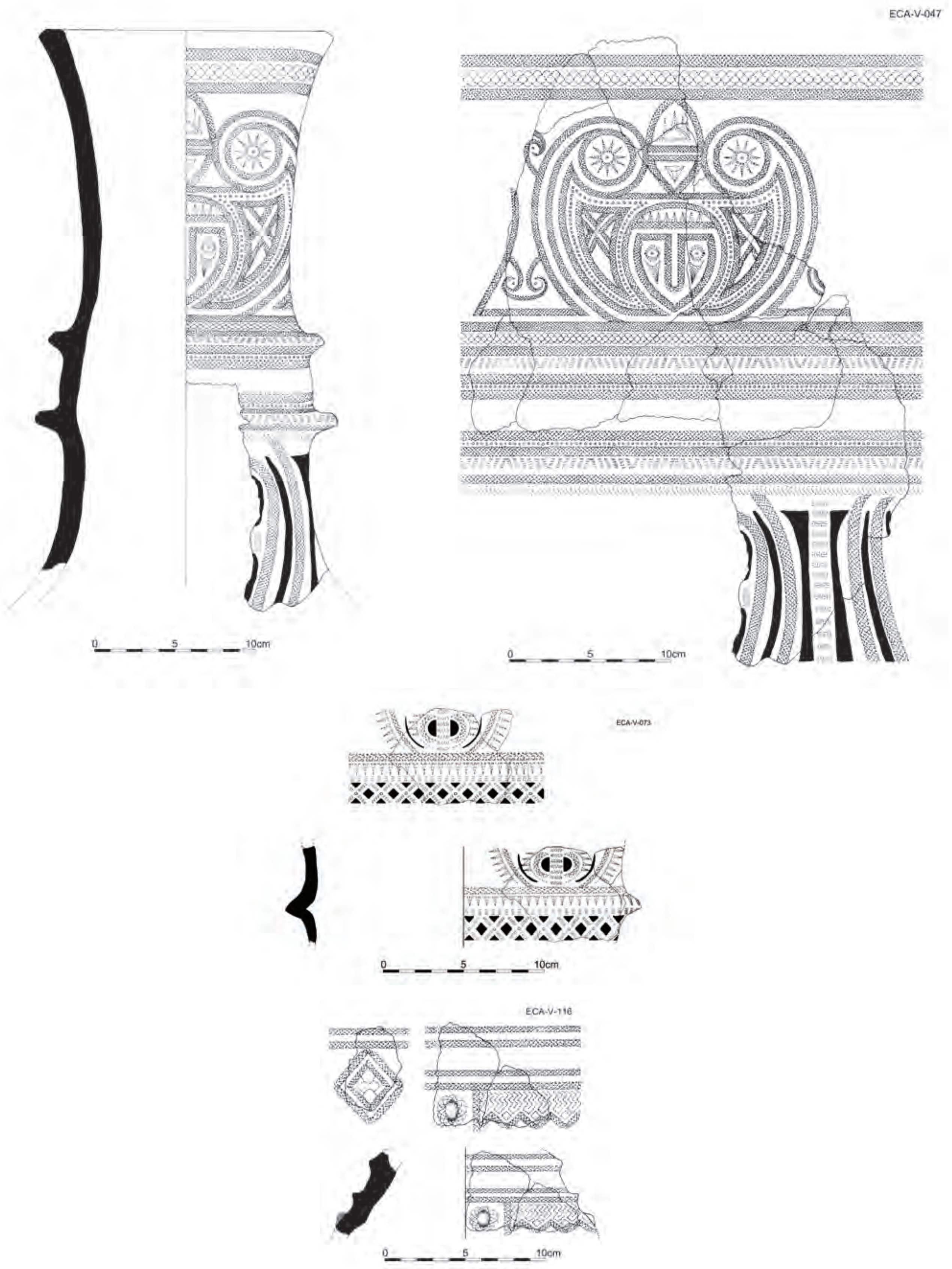


Figure 11.116. Reconstructed vessels of class V: ECA-V-047, -073, and -116. (Drawings by Lapita Pottery Online Database team.)

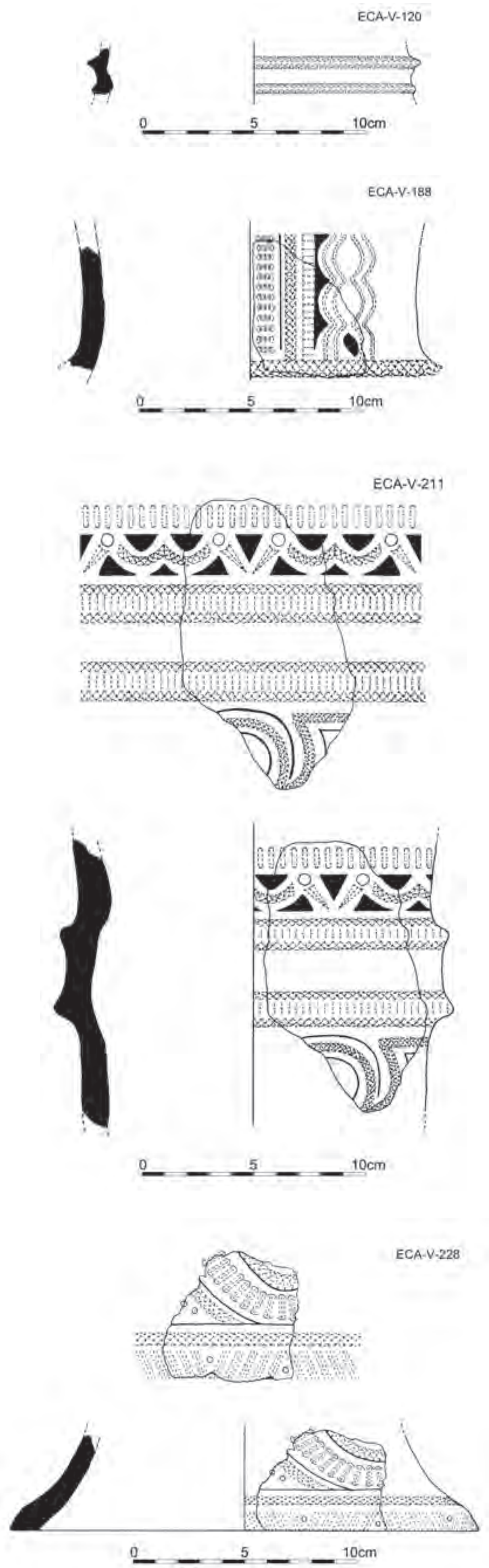
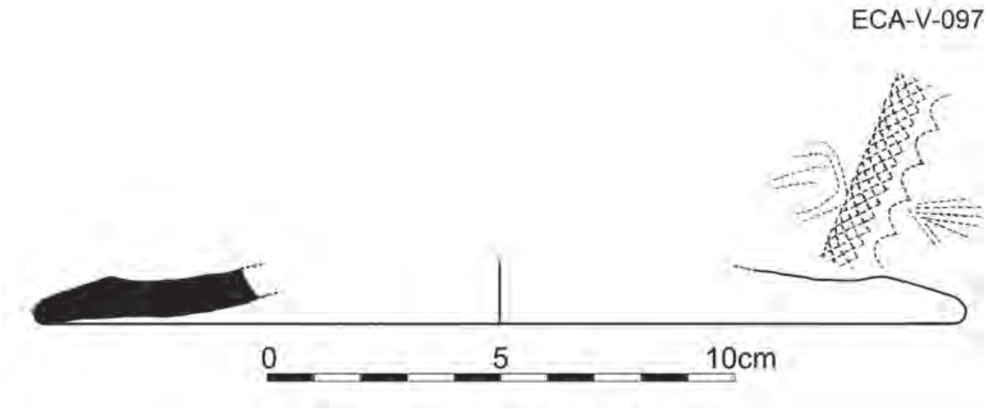
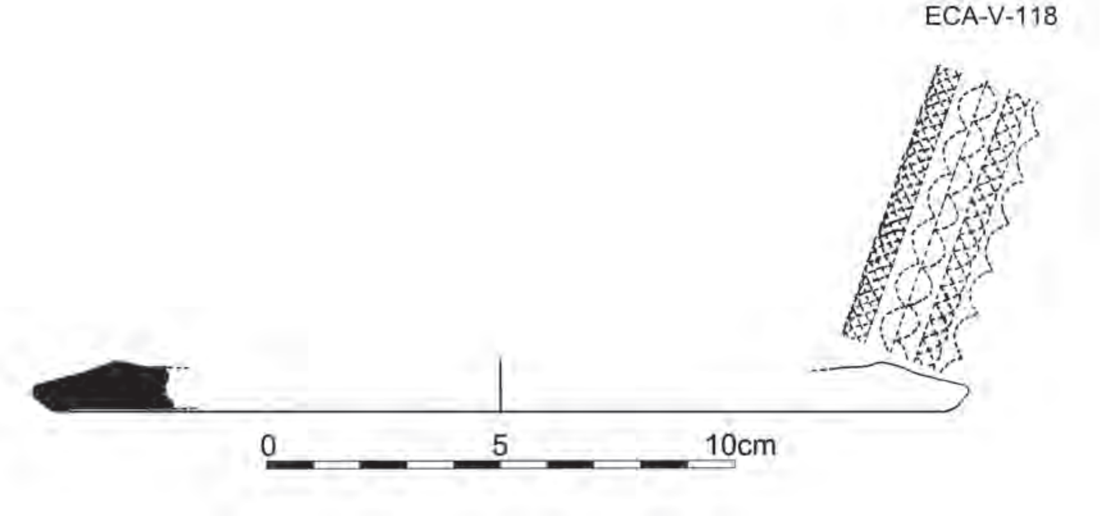


Figure 11.117. Reconstructed vessels of class V: ECA-V-120, -188, -211, and -228. (Drawings by Lapita Pottery Online Database team.)





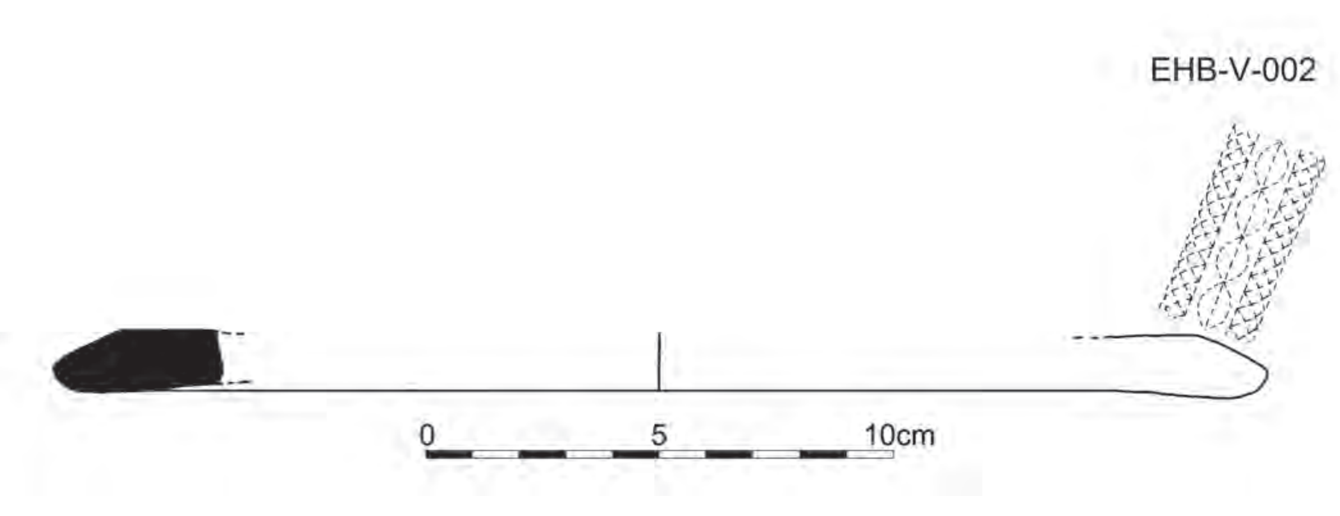


Figure 11.118. Reconstructed vessels of class VI: ECA-V-097, -118, and EHB-V-002. (Drawings by Lapita Pottery Online Database team.)

CHAPTER 12

Sand Tempers in Mussau Ceramics:

Evidence for Ceramic Transfer within the Bismarck Archipelago

William R. Dickinson

Archaeological sites on the coral islets of Eloaua and Emananus include the oldest dated Lapita sites known (Kirch and Hunt 1988; Kirch et al. 1991; Specht and Gosden 1997; Kirch 2001b), and are among the most prolific in terms of ceramic yield. Scanning electron microscopy (SEM analysis) of clay pastes in sherds from the Mussau Group implied that most of the sherd assemblage represents wares brought to Mussau from elsewhere (Kirch et al. 1991). Only 4% of 172 clay pastes closely match compositions of ceramic tiles prepared from local Mussau clays, with the remainder inferred to derive from islets near Manus Island in the Admiralty Group to the west, or from unknown locales also exotic to Mussau (Kirch et al. 1991:159).

Many Eloaua and Emananus sherds contain calcareous temper, composed of reef detritus, which is undiagnostic of specific geographic origin within tropical Oceania (Dickinson 1998b; Dickinson and Shutler 2000). Preliminary study of terrigenous (non-calcareous) tempers in 12 sherds from site ECA indicated that at least two temper types exotic to Mussau are present (Dickinson 2000). This chapter, based on petrographic examination of an additional 49 sherds (total sample of 61 sherds) in thin section, is a more definitive appraisal of the full array of Eloaua-Emananus temper types, which jointly document ceramic transfer to the Mussau Group from multiple unknown localities within the Bismarck Archipelago. The Mussau ceramic assemblage differs significantly in character from those of other known Lapita cultural centers within the Bismarck Archipelago, where most wares were made locally or transported only short distances from major islands to nearby offshore islets (Summerhayes 2000a; Thomson and White 2000).

The studied sherds include the full range of temper types separable megascopically in Lapita sherds from two localities with site ECA (the Area B Extension and Area C) on Eloaua Island, and from site EHB (Units TP1 and TP2) at Etapakengaroasa on Emananus Island (Kirch 1987a, 1988b; Kirch et al. 1991; Kirch 2001a). Sherds for thin-sectioning and petrographic analysis were selected in close consultation with Patrick Kirch during a visit by Dickinson to the Oceanic Archaeology Laboratory in December 2002. All diagnostic sherds from the Area B Extension and from Area C were first examined for macroscopic evidence of temper. Nine sherds from Area B Extension with evident calcareous sand temper (CST) were selected for petrographic study, as representative of the CST temper type. An additional 40 sherds with evident non-CST temper were then selected for thin-sectioning and petrographic study. The appendix to this chapter lists all of the 49 sherds sampled in 2002, with notes on sherd type and decoration.

The variety of apparently exotic temper types in sherds from sites ECA and EHB is far greater than for any other Lapita sites known from Pacific Oceania (Dickinson and Shutler 2000), providing physical evidence for systematic ceramic transfer to Mussau, whether by commercial trade or ceremonial exchange, on a scale undocumented elsewhere in the Lapita cultural sphere. Geological relations suggest that exotic wares were derived variously from islands of the Bismarck Archipelago lying in all possible compass directions (west to southeast) from Mussau, but exact places of origin cannot be specified with available geologic information. None of the tempers in Mussau sherds closely resemble presently known tempers in sherds from other archaeological sites within the Bismarck Archipelago.

Temper Types: Geologic Constraints

In the broadest sense, tempers in Mussau sherds embrace two end members: (1) volcanic sands composed of monocrystalline mineral grains and polycrystalline-polymineralic lithic fragments derived from volcanic and related igneous rocks exposed subaerially to erosion as terrigenous sources; (2) calcareous sands derived from offshore reef tracts. Some tempers are hybrid sands (Zuffa 1979), commonly termed mixed tempers in Pacific archaeological parlance, composed of admixtures in varying proportions of terrigenous and calcareous grains.

The temper sands are predominantly well-sorted aggregates of subrounded to rounded grains of beach origin. Distinct contrasts in size between temper grains and the coarsest silt particles imbedded within clay paste show that all were manually added temper, rather than natural temper enclosed within clay bodies. The prevalent use of beach sands as temper accords well with the coastal settings of all Lapita sites of any appreciable size within the Bismarck Archipelago (Gosden et al. 1989).

The islets of Eloaua and Emananus, where sites ECA and EHB occur, are composed entirely of Quaternary limestone and derivative sediment, flanked by beaches of exclusively calcareous sand. The subtidal waters of Malle Channel between Eloaua and Mussau effectively block transport of any sand derived from Mussau Island interior highlands from the strandlines of the high island to reefs and beaches surrounding the offshore islets. The bedrock of Mussau, which rises to a maximum elevation of 650 m at centrally located Mount Taleanuane, is more poorly known geologically than any other part of the Bismarck Archipelago (Dickinson 2000; Chapter 2, this volume). However, it is known that an island core of igneous rock is surrounded by elevated coastal terraces underlain by Neogene limestone.

The best current guide to the nature of Mussau bedrock is provided by rock samples collected by Kirch as controls for the interpretation of manuports in Mussau artifact collections (see Chapter 16). These control samples include plutonic diorite-gabbro, which is dominant in the collection, finer grained igneous rocks of volcanic or hypabyssal origin, and indurated limestone derived from the terraced plateaus flanking the island interior. The absence of any detectable plutonic detritus of coarse igneous texture in the tempers of any sectioned sherds from ECA or EHB argues against derivation of any significant component of the sherd assemblage from Mussau Island.

Calcareous tempers are predominant in ECA and EHB sherds (Kirch 1987a). On strictly petrographic grounds, such calcareous sands could have been collected locally near the ECA and EHB sites, but the SEM data for clay pastes imply that most calcareous-tempered Mussau wares are nevertheless exotic to the Mussau Group (Hunt 1989; see also Chapter 11). Because clay deposits suitable for ceramics are apparently absent on Eloaua and Emananus, any local wares must have been made with clay brought by canoe from nearby Mussau Island; however, the SEM data imply that only a minor fraction of the calcareous-tempered sherds contain clay pastes from Mussau (Hunt 1989; Kirch et al. 1991). As petrography cannot elucidate the origin of calcareous tempers, the focus of this temper analysis has been primarily on sherds with terrigenous tempers, and secondarily on those with hybrid tempers.

Temper Distribution in Sectioned Sherds

In summary, the percentages of fundamental temper categories displayed by the Mussau sherds examined petrographically in thin section can be extracted as follows from Table 12.1 indicating the provenience of all petrographically distinguishable temper types:

> 13% exclusively calcareous lacking any visible terrigenous grains;
> 23% predominantly calcareous but consistently containing rare terrigenous grains; 16% hybrid placer with terrigenous components dominated by opaque iron oxides;
> 5% opaque-rich placer sands lacking or with only traces of calcareous grains;
> 16% placer sands reflecting concentration of varied ferromagnesian minerals;
> 23% non-placer or only partially placered terrigenous (volcanic) sands; and
> 3% hybrid (calcareous-volcanic) sands of non-placer character.

The much higher proportion of volcanic and hybrid sand tempers among the sectioned sherds (nearly two-thirds), as compared to the sherd assemblage as a whole, reflects in part the restriction of a preliminary study (Dickinson 2000) to a dozen sherds (from ECA) with non-calcareous tempers potentially diagnostic of origin, and in part the deliberate selection in 2002 of sherds with both calcareous and non-calcareous tempers from various typological subsets of the ECA and EHB ceramic assemblages (Table 12.1), regardless of the relative abundance of those two temper categories in each subset.

Subsequent descriptions of Mussau temper types proceed in the following order: (1) calcareous sands (Types AB of Table 12.1; N = 22) for which the rare terrigenous grains in hybrid variants offer only cryptic clues to potential origins; (2) opaque-rich placer sands (Types CD of Table 12.1; N = 13), both hybrid and exclusively terrigenous, for which the general nature of parent bedrock can be inferred, but not detailed petrology; (3) volcanic sands (Types E–K of Table 12.1; N = 26), both non-placer and ferromagnesian placer, with some hybrid, for which the geologic character of bedrock sources can be inferred with confidence. Discussion of possible geographic sources for the various temper types is deferred until after descriptions of each type.

Calcareous Tempers

The exclusively calcareous tempers (Type A of Table 12.1; N = 8) display only chalky white to pale gray temper grains on sherd surfaces, and on broken or sawed sherd transects, and provide no diagnostic petrographic information. Approximately 64% of the tempers treated here as calcareous are actually hybrid sands (Type B of Table 12.1; N = 14), containing rare terrigenous grains, although the sparse non-calcareous temper grains are not reliably discernible megascopically. A microscopic census of the terrigenous grains present (Table S12.1) implies that all are admixtures of volcanic sand containing significant proportions of volcanic quartz grains, which are rare or absent in most of the non-calcareous volcanic sand tempers. The identification of quartz was quite conclusive, however, based upon obtaining a uniaxial positive interference figure for each quartz grain tabulated. Please see www.dig.ucla.edu/talepakemalai.

Although Type B tempers did not necessarily all derive from the same locale, the uniformly quartzose character of their terrigenous components encourages speculation that all are indeed variants of the same basic temper from some unknown cultural center. This inference is attractive because quartzose volcanic sand is uncommon as temper in Oceanian sherd suites (Dickinson 1998b; Dickinson and Shutler 2000). Summation of the various grain types present in all 14 sherds containing Type B tempers (Table S12.1) suggests derivation of the quartzose sand, with a *quartz index* (Dickinson 2001) of ~30, where QZi = 100 [qtz/(qtz + plg)], from an island (or islands) exposing a felsic suite of dacitic or rhyolitic volcanic rocks. Rhyolitic source rocks may be indicated by the presence of probable K-feldspar grains in two of the sherd tempers (Table S12.1), for K-feldspar occurs as phenocrysts of sand size in selected rhyolites but generally not in dacites.

Table 12.1. Temper types in subsets of Mussau sherds from sites ECA and EHB

Temper type	ECA (preliminary selection[1])	ECA Area C (typologically diagnostic)	ECA Area B Ext. (typologically diagnostic)	EHB TP1 & TP2 (typologically diagnostic)
A. calcareous (lacking terrigenous grains)	none	ECA-88-4-7 ECA-88-4-12 ECA-88-7-4	ECA-66-8-15 ECA-69-6-1 ECA-69-6-7	EHB-1-5-12 EHB-2-3-8
B. calcareous (with rare terrigenous grains)	none	ECA-87-5-6 ECA-87-5-7 ECA-88-4-4	ECA-66-3-7 ECA-66-3-16B ECA-66-7-3 ECA-66-8-24 ECA-67-5-5 ECA-67-6-23 ECA-68-1-24 ECA-68-3-5 ECA-69-5-7	EHB-1-4-19 EHB-1-9-6
C. hybrid placer (rich in opaque iron oxides)	ECA-16-8-17 ECA-17-6-20 ECA 17-6-30	none	ECA-66-7-16 ECA-66-7-19 ECA-66-8-9 ECA-67-6-12 ECA-68-7-6 ECA-68-7-27 ECA-69-1-4	none
D. opaque-rich placer (few calcareous grains)	ECA-19-1-29	none	ECA-67-2-10 ECA-67-2-14	none
E. hornblendic-feldspathic (pyroxene-free) volcanic	ECA-13-2-1 ECA-16-5-3 ECA-18-1-8	none	ECA-68-3-3	
F. hornblendic-feldspathic (pyroxene-bearing) volcanic	ECA-13-1-3 ECA-16-7-15	none	ECA-66-7-21 ECA-67-2-17 ECA-68-7-10	EHB-1-3-15
G. pyroxenic volcanic (largely placer sands)	ECA-16-6-17	ECA-87-6-1	ECA-67-5-7 ECA-67-6-29 ECA-68-1-42 ECA-69-7-19 ECA-69-2-6 ECA-69-7-27	EHB-1-6-5
H. hybrid non-placer	none	ECA-90-2-1	ECA-66-3-16A	none
J. quartzose-feldspathic volcanic (two subtypes)	none	ECA-90-4-9 ECA-92-3-3	none	none
K. feldspathic-pyroxenic volcanic (single temper)	ECA-17-5-6 ECA-17-7-43	none	ECA-67-5-11	none

[1] Subset of sherds initially chosen (without regard to typology) to exemplify non-calcareous temper types.

Opaque-Rich Tempers

Placer sands rich in opaque iron oxide grains (Table S12.2), which are judged from their equant forms to be largely magnetite, occur both as the terrigenous component of distinctly hybrid tempers (Type C of Table 12.1; N = 10), and as largely or exclusively non-calcareous tempers (Type D of Table 12.1; N = 3). Sherd surfaces display tiny black temper grains (the opaque grains), even where pale calcareous grains are more abundant. As both the hybrid and terrigenous variants are beach concentrates of opaque grains of especially high specific gravity (Dickinson 1994), the presence or absence of associated calcareous grains is probably serendipitous, dependent upon the exact collecting site for each sand rather than upon systematic generic differences in origin. There is no evident correlation between the intensity of placering and the percentage admixture of calcareous grains, suggesting that variably placered sands on beach faces were mixed unsystematically in variable proportions with calcareous grains washed onshore from offshore reef tracts.

The overall similarity in the character and proportions of constituent non-opaque grains suggests derivation of all the opaque-rich placer sands from the same island, or cluster of geologically related islands, exposing volcanic rocks of similar petrology. An overall quartz index (QZi) of ~25 suggests derivation of the terrigenous detritus in the opaque-rich placer sands from volcanic rocks more silicic than andesite. The observation that approximately two-thirds of the volcanic lithic fragments (VRF of Table S12.2) display either felsitic or vitric (glassy) internal textures, as opposed to microlitic, is compatible with that inference. The overall *pyribole index* (Dickinson 2001) of 70, where PYi = 100[cpx/(cpx + hbl)], implies derivation from a volcanic suite in which pyroxene is more abundant than hornblende, but in which both pyribole mineral species are consistently present. The scarcity of key mineral species (quartz, hornblende) in the more intensely placered opaque-rich sands (Table S12.2) probably reflects negative concentration, rather than absence from the parent (unplacered) sand aggregates from which the placer sands were derived through sedimentological processing.

Volcanic Sand Tempers

Volcanic sand tempers (Types EFG and JK of Table 12.1) include non-placer (N = 12), partially placered (N = 10), and placer (N = 4) variants, with the placered sands containing higher proportions of ferromagnesian mineral grains (either silicates or oxides or both) concentrated by sedimentological reworking of non-placer grain aggregates within beach systems. The intensity of placering reflected by the compositions of the various volcanic sand tempers is highly variable, giving rise to a gradational spectrum of temper types with only minimal compositional breaks between unplacered, partially placered, and placered types. Relative proportions of feldspar mineral grains, ferromagnesian silicate grains, and volcanic lithic fragments (VRF) are quantitatively similar in least placered volcanic sand tempers, with different proportions pertaining to more strongly placered temper types. Qualitatively, however, in terms of constituent grain types, selected non-placer and placer tempers are more closely related to one another generically than to other non-placer or placer tempers that contain contrasting grain types, or display different relative proportions of specific ferromagnesian silicate mineral species.

The surfaces of sherds containing volcanic sand tempers (Types EFG, JK) display varying proportions of pale plagioclase grains and dark ferromagnesian grains, but megascopic distinctions among the various temper types generally cannot be made with confidence. Hybrid volcanic-calcareous tempers (Type H) also display prominent chalky white calcareous grains, as well as both pale and dark terrigenous grains, but are difficult to distinguish megascopically from the opaque-rich hybrid tempers (Type C).

Hornblendic-Feldspathic Temper

In a preliminary study, all tempers dominated by plagioclase and hornblende mineral grains were grouped together (Dickinson 2000), but an expanded database and more detailed grain counting reveals that two generically different hornblendic-feldspathic temper types are present in Mussau sherds (Table 12.1): pyroxene-free (Type E) and pyroxene-bearing (Type F). Type F tempers include partially placered variants not present among Type E tempers (Tables S12.3, S12.4; Figure 12.1A).

Pyroxene-free hornblendic-feldspathic tempers (N = 4) contain only traces of quartz (QZi < 1), and internal textures of volcanic lithic fragments are variably microlitic, felsitic, and vitric (glassy). No grains of hypabyssal derivation with microgranular internal textures were observed, hence the dominant source rocks were felsic hornblende andesites of an exclusively or predominantly extrusive volcanic assemblage.

Pyroxene-bearing hornblendic-feldspathic tempers (N = 6) contain more quartz (QZi = 2–6) and significant proportions of clinopyroxene as well as hornblende (PYi = 30–45). The internal textures of most volcanic lithic fragments are also variably microlitic, felsitic, and vitric (glassy), but source rocks evidently included pyroxene andesites as well as hornblende andesites. Moreover, sparse

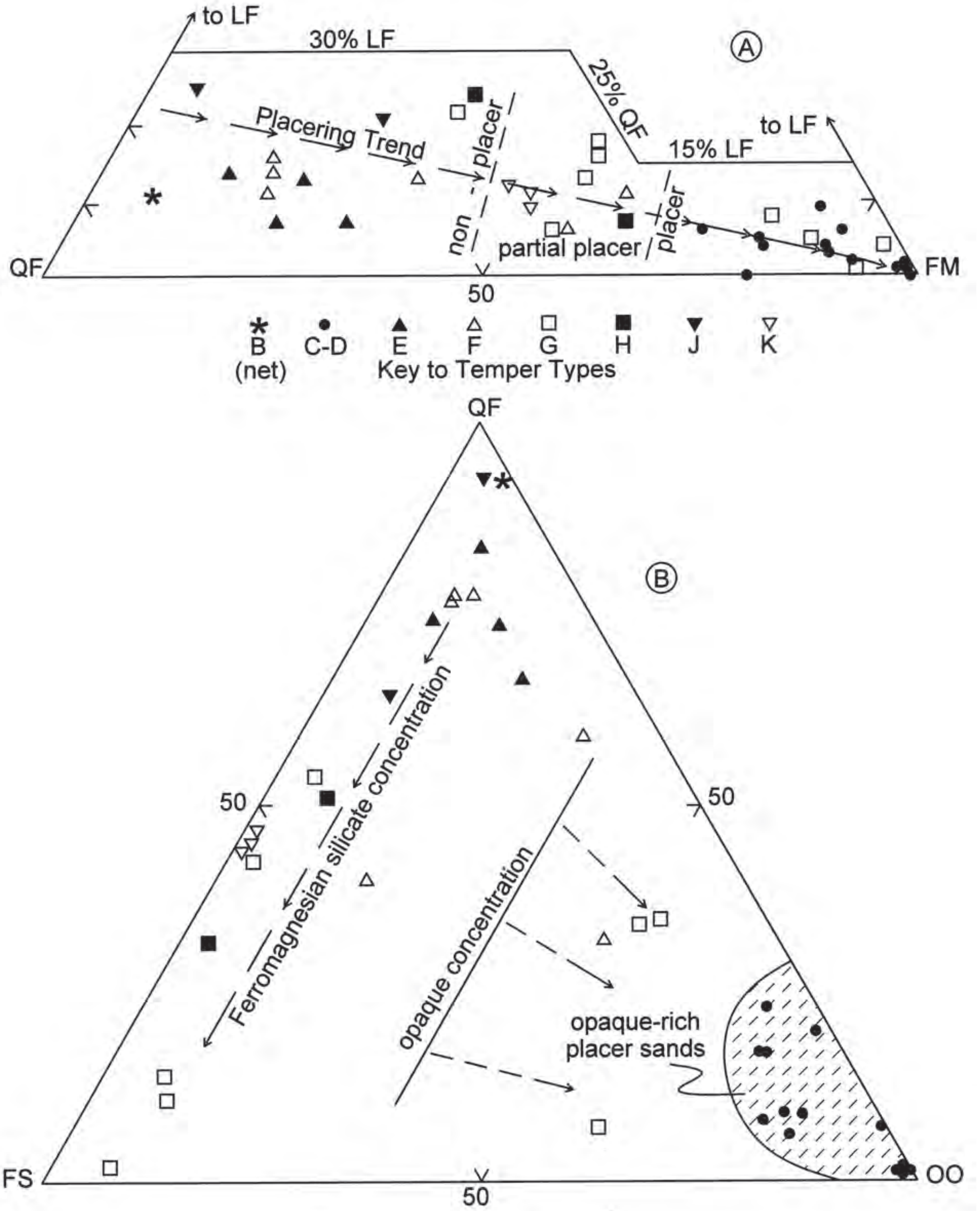
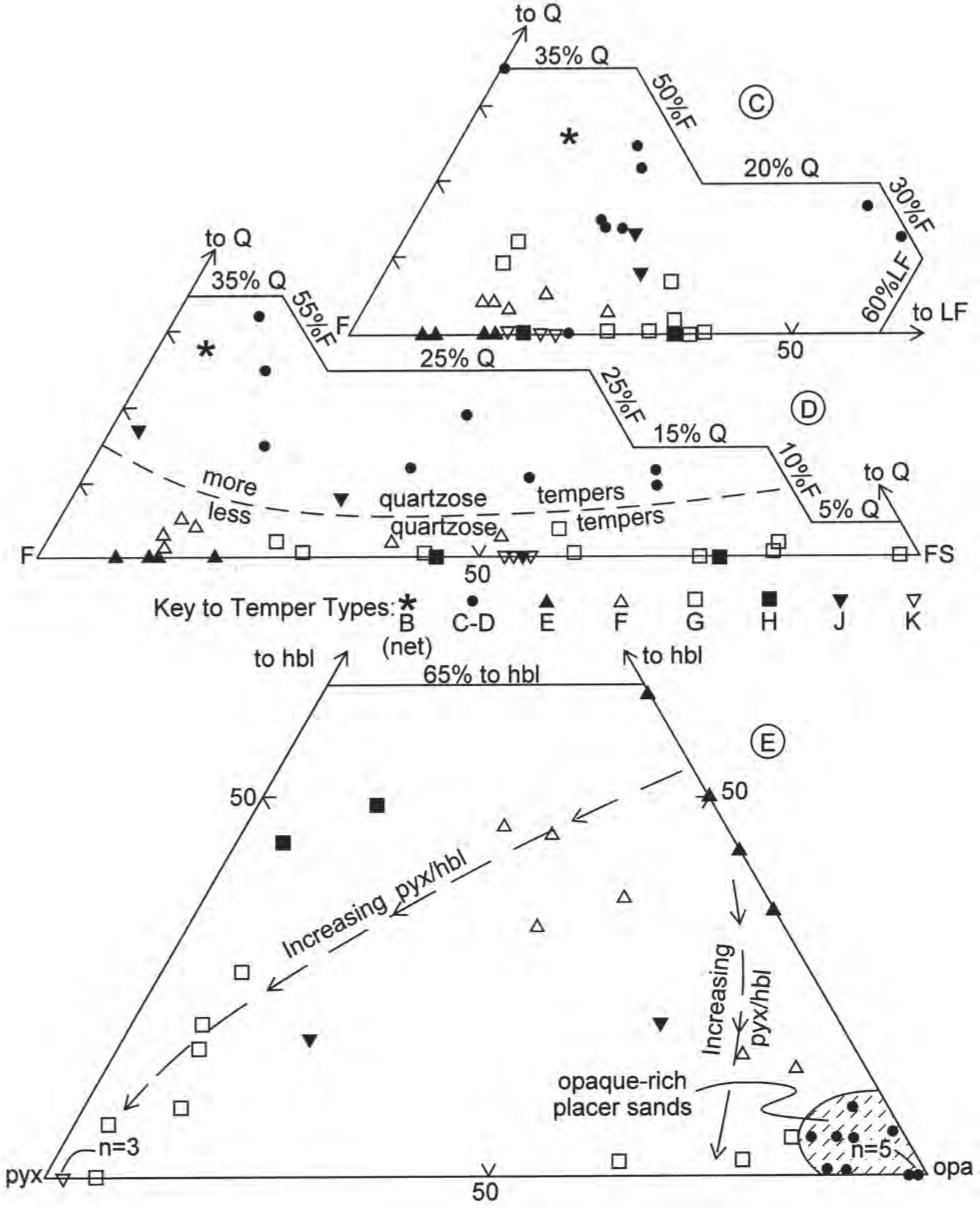


Figure 12.1. Triangular compositional diagrams (or segments thereof) for tempers observed in Mussau sherds: *a*: LF-QF-FM, where LF = lithic fragments (all volcanic), QF = quartz (Q) + feldspar (F) grains (almost exclusively plagioclase), and FM = ferromagnesian mineral grains (FS + OO); *b*: QF-FS-OO, where QF = quartz (Q) + feldspar (F) grains, FS = ferromagnesian silicate grains, and OO = opaque iron oxide grains; *c*: Q-F-LF, where Q = quartz grains, F = feldspar grains (almost exclusively plagioclase), and LF = lithic fragments (all volcanic); *d*: Q-F-FS, where Q = quartz grains, F = feldspar grains (almost exclusively plagioclase), and FS = ferromagnesian silicate grains (clinopyroxene, hornblende, oxyhornblende); *e*: hbl-pyx-opa (special diagram), where hbl = hornblende + oxyhornblende (lamprobolite), pyx = pyroxene (almost exclusively clinopyroxene), and opa = opaque iron oxide grains (= OO of standard triangular diagram of Figure 12.1B). (Diagram by W. Dickinson.)


to Q
35% Q
50%F
C
20% Q
30%F
60%LF
F
to LF
50
to Q
35% Q
55%F
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25%F
D
15% Q
10%F
to Q
5% Q
more
less
quartzose
quartzose
tempers
tempers
F
FS
50
Key to Temper Types:
* B (net)
● C-D
▲ E
△ F
□ G
■ H
▼ J
▽ K
to hbl
to hbl
65% to hbl
E
50
50
Increasing pyx/hbl
Increasing pyx/hbl
opaque-rich placer sands
n=3
n=5
pyx
50
opa

microgranular grains derived from hypabyssal intrusive rocks are also present (1–2% of total grain population; 12–18% of volcanic lithic fragments). The enhanced quartz content, in comparison to the pyroxene-free hornblendic-feldspathic tempers, can probably be ascribed to derivation of quartz from hypabyssal igneous rock (dikes, sills, or small stocks) forming an integral part of a composite volcanogenic assemblage of cogenetic extrusive and intrusive rock bodies. Quartz crystals of sand size can occur in subvolcanic hypabyssal intrusions of the same petrochemical character as extrusive volcanic rocks lacking any quartz of sand size.

Pyroxenic Volcanic Temper

Nine sherds contain pyroxenic tempers (Type G of Table 12.1) that are dominantly partially or strongly placered sands (Table S12.5; Figure 12.1A), with pyroxene consistently more abundant than hornblende (PYi > 70), and contain variable minor contents of quartz grains (QZi < 10). Either ferromagnesian silicate minerals or opaque iron oxides are dominant as placer concentrates (Table S12.5). Except in the three most opaque-rich temper sands, more than half (and typically two-thirds) of the volcanic lithic fragments are vitric (glassy) grains. Rare microgranular hypabyssal grains (1–2% of total grain populations) are present in two of the opaque-rich temper sands, but not in the other pyroxenic tempers. Pyroxenic (Type G) tempers are clearly more heterogeneous than either Type E or Type F hornblendic-feldspathic tempers, and may derive from multiple locales. Source rocks in each case, however, were andesitic volcanic assemblages in which pyroxene is more prominent than hornblende.

Hybrid Non-Placer Temper

Two sherds contain hybrid volcanic-calcareous tempers (Type H of Table 12.1) in which terrigenous fractions are quartz-free and display PYi of ~50 (Table S12.6), intermediate between the values for hornblendic-feldspathic and pyroxenic volcanic tempers. Approximately three-quarters of the volcanic lithic fragments are vitric (glassy) grains, with the remainder displaying closely related microlitic internal textures (hyalopilitic with sparse plagioclase microlites imbedded in volcanic glass). The dominant source rocks are interpreted as an extrusive andesitic assemblage in which pyroxene and hornblende are equally prominent. One of the hybrid tempers is unique among the volcanic sand tempers of Mussau sherds in its high content of oxyhornblende or lamprobolite (7% of total grain population; 22% of ferromagnesian silicate grains).

Quartzose-Feldspathic Temper

Two sherds contain quartzose-feldspathic tempers (Type J of Table 12.1), quite different from one another in detail (Table S12.7), with a higher proportion of quartz grains (QZi = 12–17) than any other volcanic sand tempers. Approximately a quarter of the volcanic lithic fragments are internally microgranular varieties derived from hypabyssal intrusions, which probably also contributed many or most of the quartz grains, with the remainder dominantly felsitic and vitric (glassy). The dominant source rocks are interpreted as an andesitic to dacitic extrusive assemblage cut locally by subvolcanic dikes, sills, or small stocks.

Feldspathic-Pyroxenic Temper

Three sherds contain feldspathic-pyroxenic temper (Type K of Table 12.1) that is both qualitatively and quantitatively indistinguishable from sherd to sherd (Table S12.8), and effectively represents the same identical sand. Pyroxene grains have a distinct greenish cast typical for clinopyroxene from somewhat alkalic associations of volcanic rock. The grains are faintly pleochroic (pale green to yellowish green), and display optic axial angles (2V) of > 75° typical of aegirine-augite, a pyroxene species more sodic than common augite (with 2V ~ 60°). The internal textures of the volcanic lithic fragments are consistently intersertal (twinned plagioclase laths separated by interstitial volcanic glass), most compatible with derivation from basalt (or feldspathoidal basanite-tephrite) source rocks. The internal textures of the lithic fragments are distinctly coarser grained than the microlitic to felsitic textures of volcanic lithic fragments in other volcanic sand tempers of Mussau sherds.

Graphical Comparisons

Figure 12.1 plots the volcanic sand tempers (and terrigenous components of hybrid tempers) individually on standard triangular compositional diagrams (Dickinson 1998b), as well as on a supplemental diagram displaying relative proportions of hornblende-oxyhornblende, clinopyroxene, and opaque grains (Figure 12.1E).

In LF-QF-FM space (Figure 12.1A), which includes all terrigenous temper grains, an overall placering trend among generally lithic-poor sands embraces arbitrarily defined groups of unplacered, partially placered, and placered temper variants. Several temper types include representatives of two or more of these arbitrary groupings. Placer tempers of pyroxenic Type G volcanic sand tempers (in part hybrid) plot with opaque-rich Type CD tempers (largely hybrid), but the FM pole is dominantly clinopyroxene for the former and opaque iron oxide grains for the latter.

In QF-FS-OO space (Figure 12.1B), which excludes all lithic fragments (LF), alternate trends of placer concentration are revealed. The opaque-rich Type CD placer sands plot near the OO pole, whereas placering of ferromagnesian silicate grains (FS) defines a trend near the leg of the diagram opposite the OO pole. For some volcanic sands, joint concentration of FS and OO components of the FM grain population gave rise to tempers (N = 4) plotting in an intermediate position between the arrays of opaque-rich and opaque-poor placer sands.

In Q-F-LF space (Figure 12.1C), which excludes all ferromagnesian grains (FM), nearly all the tempers plot in the feldspathic corner of the diagram (F > 50%), with the exception of two outliers of Type C hybrid opaque-rich placer temper containing more volcanic lithic fragments than plagioclase grains.

In Q-F-FS space (Figure 12.1D), which excludes all lithic fragments (LF) and opaque grains (OO), all the tempers plot in the low-quartz part of the diagram, but three temper types are consistently more quartzose than the others: (a) terrigenous fractions of sparingly hybrid calcareous tempers (Type B); (b) terrigenous fractions of opaque-rich placer tempers (Types CD); (c) quartzose-feldspathic tempers (Type J). These three temper types were probably derived from volcanic assemblages more silicic than andesite (in whole or in part).

In hbl-pyx-opa space (Figure 12.1E), which is restricted to the FM grain population, the wide range of hornblende/pyroxene ratio is well displayed for different temper types. Pyroxene-free Type E tempers plot along the hbl-opa leg of the diagram, feldspathic-pyroxenic Type K temper plots close to the pyx pole, and opaque-rich placer tempers plot near the opa pole. Pyroxenic Type G tempers plot either near the pyx pole or near the pyx-opa leg of the diagram, whereas other volcanic sand tempers (Types F, HJ) with intermediate FM composition plot within the interior of the diagram along trends that define increasing pyx/hbl ratio, with or without significant admixtures of opaque grains.

Potential Bismarck Archipelago Temper Sources

The terrigenous detritus in the tempers of all sectioned sherds from ECA and EHB is dominantly volcanic, and does not require derivation of any Mussau wares from outside the Bismarck Archipelago. Knowledge of Bismarck geology (Figure 12.2) provides a guide to speculation regarding the origins of the diverse temper types in Mussau sherds, but no close temper matches have been observed to date between any of the temper types in Mussau sherds and known indigenous tempers from elsewhere within the Bismarck Archipelago. As all the potential bedrock sources of terrigenous sand within the Bismarck Archipelago are predominantly volcanic, discriminations among different potential temper sources are largely dependent upon correlation between variations in volcanic petrology and in temper grain types.

The oldest rocks within the Bismarck Archipelago form a heterogeneous volcanogenic assemblage of extrusive volcanic rocks, together with associated subvolcanic intrusions and derivative volcaniclastic strata, of Eocene to Miocene age (Figure 12.2). The assemblage formed within the ancestral Vitiaz island arc along which Pacific seafloor was subducted downward to the southwest beneath the Melanesian region until mid-Late Miocene time (Dickinson 2001). Exposures occur on all the major islands (Manus, Lavongai or New Hanover, New Ireland, New Britain). Distinction between Eocene-Miocene sources of sand on the different islands is generally not feasible, however, because the present far-flung islands formed a compact landmass or superisland (Figure 12.2) prior to post-Miocene seafloor spreading, which opened the Bismarck Sea (Martinez and Taylor 1996) and dispersed the various islands to their present geographic positions. A similar array of volcanic successions, granitic intrusions, volcaniclastic beds, and limestone cover is accordingly present on each of the larger Bismarck islands (Exon and Tiffin 1984; Exon and Marlow 1988).

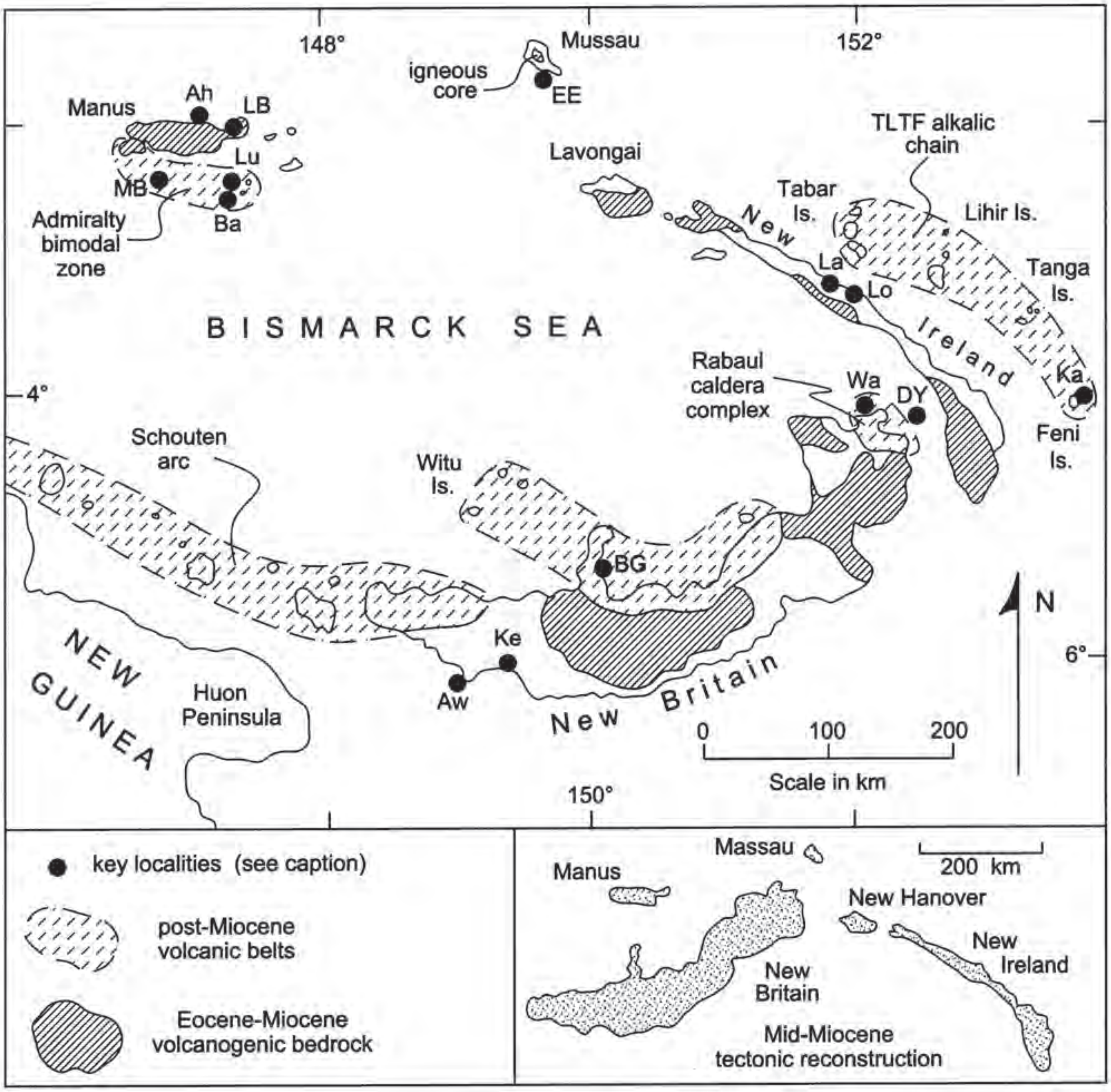

Figure 12.2. Sketch map of Bismarck Archipelago showing distribution of various kinds of volcanic sources for potential temper sands (unpatterned islands and island segments are underlain by Neogene limestones and related sedimentary strata); geologic relations after Johnson (1982), Page and Ryburn (1977), Johnson and Arculus (1978), Jaques (1981), Stewart and Sandy (1988), Francis (1988), Lindley (1988); inset on lower right shows configuration of major islands prior to Neogene seafloor spreading within the Bismarck Sea (after Dickinson 2000:176). Key localities of archaeological interest (see text for discussion): Ah, Ahus islet; Aw, Arawe Islands; Ba, Baluan Island; BG, Boduna and Garua islets; DY, Duke of York Islands; EE, Eloaua and Emananus islets; Ka, Kamgot (on Anir Is.); Ke, Kreslo; La, Lasigi; LB, Lombrum Bay; Lo, Lossu; Lu, Lou Island; MB, M'Buke Island; Wa, Watom Island. (Map by W. Dickinson.)

Five post-Miocene volcanic belts composed of active and extinct or dormant volcanic centers are superimposed on the older geologic framework of the Bismarck Archipelago (Figure 12.2). Each has a different petrologic character, which offers the possibility of drawing distinctions between derivative sands potentially available as temper in different parts of the Bismarck region:

(1) The Admiralty bimodal zone, erupted in response to crustal fracturing and magma ascent associated with formation of the igneous floor of the adjacent Bismarck Sea

by extensional tectonism, consists of volcanic edifices of either basalt or rhyolite (but not both conjoined), which form small islands south of Manus, and the southwesternmost peninsula of Manus itself (Johnson and Smith 1974; Johnson et al. 1978; Jaques 1981).

(2) The Schouten island arc, erupted in response to subduction at the New Britain Trench and its westward extension along the Markham suture belt, where the Huon Peninsula was attached to New Guinea (Dickinson 2000), forms an alignment of andesitic volcanic centers that trends into western New Britain from offshore New Guinea.

(3) The New Britain arc, erupted in response to continuing subduction along the New Britain Trench to the south, forms a belt of andesitic volcanic centers along the north coast of New Britain, extending northwestward into the Witu Islands (Johnson and Arculus 1978).

(4) The Rabaul caldera complex of northeasternmost New Britain is a discrete volcanic center active in association with segmentation of the Gazelle Peninsula by lateral displacements along strands of a transform fault system displacing New Ireland northwestward (relative to New Britain), as the Bismarck Sea has opened between New Britain and Manus (Dickinson 2000).

(5) The TLTF (Tabar-Lihir-Tanga-Feni) alkalic chain northeast of New Ireland (Johnson et al. 1976; Wallace et al. 1983) is composed of Pliocene-Pleistocene (3.7–0.35 Ma) non-arc or post-arc volcanic centers probably erupted along the trend of a fracture system related to breakup and dispersal of the pre-Pliocene Bismarck superisland.

Inferred Origins of the Mussau Ceramic Wares

Mussau is the most isolated segment of the Bismarck Archipelago, with no other islands visible on any horizon (Figure 12.2). The closest landmass, distant 100 km to the southeast, is Lavongai (New Hanover), which is nearly contiguous with the northwestern tip of New Ireland. Manus and the islands of the Admiralty bimodal zone lie 250 km to the west and southwest. The northwest tip of the TLTF alkalic chain lies the same distance (250 km) to the southeast, but ready access from the TLTF chain to nearby New Ireland suggests that any wares taken to Mussau from New Ireland or the TLTF chain could transit by way of Lavongai, which can perhaps be regarded as a potential "gateway" for ceramic transfer to Mussau from any islands in the eastern Bismarck Archipelago.

The distance from Mussau southward to the New Britain arc is 350 km, either to the Witu islands or to the tip of the Williamez Peninsula on northernmost New Britain, and the Schouten arc lies still farther away (~ 450 km). Close cultural ties between Mussau and islands of the southern Bismarck Archipelago thus seem inherently less likely than ties with the northern or eastern islands. Ceramic transfer from the north coast of New Britain is disfavored in any case by the observation that tempers in sherds from islets (Arawe, Boduna-Garua, Watom) off the coast of New Britain (Figure 12.2) contain variable but significant proportions of orthopyroxene (Dickinson 2000), a mineral that is absent or rare in all the tempers of Mussau sherds. Provisional correlation of Mussau temper types with potential bedrock sources in the Admiralty Group (Manus and nearby islands), Lavongai (and nearby northwest New Ireland), and the TLTF chain to the east of New Ireland encourages dismissal of more distant origins for the Mussau wares. Comparative study of other Bismarck sherds reinforces that perspective.

This perspective for ceramic transfer to Mussau clearly does not apply, however, to obsidian, which was evidently imported to Mussau from both the Williamez Peninsula of New Britain and from the Admiralty Group (Kirch et al. 1991; see Chapter 14, this volume). As obsidian is both less bulky and less fragile than pottery, movement over greater distances by down-the-line transfer may have been more prevalent during prehistory.

Quartz-Rich Mussau Tempers

For the origin of the most quartzose terrigenous fractions in Mussau tempers (Types BCD), attention is drawn to the Admiralty bimodal zone where a rhyolitic to rhyodacitic eruptive suite (TLP suite of Smith and Johnson 1981) is widely exposed to the exclusion of andesitic-dacitic rocks. Exclusively calcareous tempers (Type A) in some Mussau sherds may be indicative of local indigenous origin, but most of the sherds containing predominantly calcareous tempers display sparse terrigenous grains suggestive of ceramic transfer from some locale or locales within the Admiralty bimodal zone.

The presence of Admiralty Islands obsidian at Mussau, in increasing proportions relative to other sources over time (Kirch et al. 1991), seemingly reflects long-continued cultural ties across the northern Bismarck Archipelago that are supportive of ceramic transfer from the Admiralty Group as well. Obsidian sources on Lou Island (Figure 12.2) and the tiny nearby Pam Islands were especially significant during prehistory (Fullagar and Torrence 1991; Fredericksen 1997a, 1997b). The presence in selected sherds from ECA of clay pastes that are indistinguishable geochemically from clay bodies used by contemporary potters of Mbuke Island (Hunt 1989; Kirch et al. 1991), lying within the Admiralty bimodal zone, adds support to the suggestion from temper analysis of ceramic transfer to Mussau from the Admiralty Group.

Quartz-bearing felsitic tempers derived from Lou, or a nearby smaller island of similar geology, occur in sherds (N = 4) from Lou, Baluan, and Mbuke (Figure 12.2). Their quartz index (QZi = 11–32) is comparable to that of Type CD tempers in Mussau sherds (QZi = 14–33). Internal textures of volcanic lithic fragments in the Lou felsitic tempers are dominantly felsitic or glassy, as are most volcanic lithic fragments in Type CD tempers. Although known Lou felsitic tempers are more lithic-rich (39 ± 10% VRF) than the terrigenous fractions of Type BCD Mussau tempers (< 10% VRF), which are typically placer sands (Table S12.2), origin of the latter from somewhere within the Admiralty bimodal zone is suggested by temper analysis. The basaltic edifices (Baluan, Mbuke, southwest Manus) of the Admiralty bimodal zone (Figure 12.2) apparently do not yield attractive temper sands, for no basaltic tempers are present in ten representative sherds from Baluan and Mbuke, to which wares were evidently brought from Lou and Manus (Dickinson 2000).

Andesitic Mussau Tempers

The dominant volcanic sand tempers in Mussau sherds (Types EFGHJ), with highly variable pyribole index (PYi), were apparently derived mainly from andesitic-dacitic volcanic rocks, associated in some instances with cogenetic subvolcanic hypabyssal intrusions. Geologic relations on both Manus to the west and Lavongai (and adjacent parts of New Ireland) to the south are broadly compatible with detritus of the observed character. Petrographic study alone does not allow a clear choice between Manus or Lavongai as most attractive potential source of the temper sands, nor does it document how many specific locales on Manus or Lavongai, or both, may have been involved. On the one hand, indications (see above) that the more quartz-rich Mussau tempers (Types BCD) probably derive from the Admiralty Group favor Manus by association. On the other hand, Lavongai lies much closer to Mussau, and indications (see below) that alkalic pyroxenic temper (Type K) in Mussau sherds probably derives from the TLTF chain favors Lavongai as a "gateway" for ceramic transfer to Mussau from the southeast.

The variety of volcanic temper sands in Mussau sherds implies multiple sites of origin, but their respective distances from one another (on Manus, Lavongai, New Ireland, or all those islands) cannot be judged with any certainty from petrography. Tempers in limited sherd collections known or inferred to derive from Manus (N = 10) and New Ireland (N = 12) are generically similar to quartz-free or quartz-poor volcanic sand tempers in Mussau sherds, but provide no close temper matches (Dickinson 2000). A few specific analogies and apparent distinctions can be drawn as follows, although no data exist for any Lavongai sherds.

The range (32–88) of pyroxene index (PYi) in nine partially placered Manus tempers (containing 33 ± 5% plagioclase) in sherds from Manus (N = 5), Lou (N = 3), Mbuke (N = 1) and Baluan (N = 1) is similar to the range (35–92) in ten comparably placered Mussau tempers (35 ± 7% plagioclase) of Types FGH. Comparably placered tempers (37 ± 9% plagioclase) in non-Lapita sherds (N = 3) from Anir in the Feni Islands of the TLTF chain (Figure 12.2), but thought probably to derive from nearby New Ireland, display a similar range (43–76) in PYi index. More feldspathic New Ireland tempers (56 ± 6% plagioclase) in sherds from Lasigi (N = 3) and Lossu (N = 4) display PYi indices (52–97) falling in the upper part of the range for partially placered tempers in Manus and Mussau sherds, but somewhat above the range (30–45) for comparably feldspathic (~ 65% plagioclase) Type F Mussau tempers (N = 3). None of these similarities or differences in PYi are conclusive of origin, but show that Manus and New Ireland (or Lavongai) temper sands could well be present in Mussau sherds.

No known tempers from Manus and New Ireland (or New Britain) are as exclusively hornblendic (PYi ~ 0) as Type E tempers in Mussau sherds, but both hornblende and pyroxene andesites occur on Manus (Francis 1988) and Lavongai (Stewart and Sandy 1988), meaning that local occurrences of pyroxene-free sands derived from Manus or Lavongai bedrock can be anticipated without undue forcing of geologic interpretations. Sparingly quartzose detritus of hypabyssal origin in Type FG Mussau tempers, and in Type J quartzose Mussau tempers, could derive from local intrusions on either Manus or Lavongai (or nearby New Ireland). Bismarck tempers with quartz contents (6–12%) comparable to Type J Mussau quartzose-feldspathic tempers are presently known only from New Britain (Dickinson 2000), where nine sherds with quartzose tempers at Kreslo (Figure 12.2) contain 6–16% quartz and seven sherds with quartzose tempers at Watom (Figure 12.2) contain 7–11% quartz. In both cases, however, the quartz in the New Britain tempers is inferred to derive from pre-Pliocene volcanogenic assemblages intruded by hypabyssal intrusions, and analogous bedrock assemblages are exposed on Manus, Lavongai, and New Ireland (Figure 12.2).

In sum, derivation of most volcanic sand tempers in Mussau sherds from either Manus or Lavongai (or adjacent New Ireland), or both, seems a robust geologic interpretation, but specifying particular sites of origin is impossible with available information. Clay analysis has indicated that selected non-Lapita sherds from an archaeological site on Mussau Island itself contain clay pastes that are indistinguishable from clay bodies used by contemporary potters on Ahus Island (Figure 12.2) off the north coast of Manus (Hunt 1989; Kirch et al. 1991). Although this observation calls attention to the Manus region, the only sherds (N = 4) studied in thin section from Ahus Island contain exclusively calcareous tempers undiagnostic of origin, and there is at present no comparative data for potential clay pastes from either Lavongai or New Ireland.

Hybrid beach sand from Lombrum Bay (Figure 12.2) on Los Negros Island off the eastern tip of Manus is composed dominantly of calcareous (45%) and opaque iron oxide (40%) grains, but the remainder of the sand (15%) consists of the following relative percentages of ferromagnesian silicate mineral grains (N = 500): clinopyroxene, 80%; orthopyroxene, 3%; hornblende, 16%; oxyhornblende, 1%. Those proportions are broadly commensurate with the proportions of the same minerals in the volcanic sand tempers of Mussau sherds, but the overall composition of the modern beach sand is not a close match for any known Mussau tempers.

Alkalic Mussau Temper

The sodic nature of the clinopyroxene in feldspathic-pyroxenic Type K temper suggests derivation from the highly sodic, silica-undersaturated lavas (Kennedy et al. 1990) of the TLTF chain east of New Ireland. More than half the TLTF rock samples used for petrochemical studies (Wallace et al. 1983) are varied alkalic types of basaltic rock (basanite, tephrite, trachybasalt) which could yield the intersertal volcanic lithic fragments observed in Type K temper. Although the soda content of selected clinopyroxenes from the Feni Islands has been reported as too low for aegerine-augite (Heming 1979), clinopyroxene phenocrysts in all TLTF volcanic assemblages are described as distinctly greenish (Wallace et al. 1983), comparable in coloration to the aegirine-augite in Type K temper.

Tempers in Lapita sherds from the Feni and Tanga Islands (Summerhayes 2000b, 2001a; Garling 2003) near the southeast end of the TLTF chain (Figure 12.2) do not closely resemble Type K temper (Dickinson 2006:76–79), being either less feldspathic and lithic (more strongly placered, N = 28) or more feldspathic or lithic (less placered; N = 40), and are consistently finer grained. The clinopyroxene in the Feni-Tanga placer tempers is nevertheless aegirine-augite with optical properties similar to the clinopyroxene in Type K temper (faint pale green to yellowish green pleochroism with 2V > 75°). The similarity of the clinopyroxene properties encourages continued speculation (Dickinson 2000) that Type K temper derives from somewhere along the TLTF chain, which is unique within the Bismarck Archipelago in the alkalinity of its eruptive suite. Perhaps the K tempers derive from farther north along the TLTF chain than the Feni and Tanga Islands, but no comparative ceramics are currently available from the Lihir or Tabar Islands near the northwest end of the TLTF chain (Figure 12.2).

Summary and Conclusions

Petrographic study shows that the temper sands of 61 selected Lapita sherds from sites ECA and EHB on Eloaua and Emananus islets lying just south of the high island of Mussau include ten different calcareous, hybrid, and volcanic temper types, nearly all of which are exotic to the Mussau Group and reflect prehistoric ceramic transfer from other islands in the Bismarck Archipelago. Within the Mussau ceramic assemblage as a whole, exclusively calcareous tempers are undiagnostic of origin, but hybrid and volcanic sand tempers are consistently exotic to Mussau. Geologic considerations imply that three hybrid and opaque-rich temper types derive from small islands of the Admiralty Group to the west-southwest, that one distinctive volcanic sand temper derives from the TLTF island chain to the east-southeast, and that the other five non-calcareous temper types derive either from Manus to the west or from Lavongai and nearby New Ireland to the south, but distinction between those alternate sources of exotic wares is indeterminate with present information. The prevalence and variety of exotic temper types in the Mussau sherd collection is atypical for Lapita sites elsewhere, and reflects ceramic transfer from multiple distant locales to Mussau on a scale otherwise unknown within Pacific Oceania.

Acknowledgments

Sherds from non-Mussau sites in the Bismarck Archipelago were provided by Wal Ambrose (Ahus, Baluan, Muke, Lou), Dimitri Anson (Watom), Jack Golson (Lasigi), Chris Gosden (Arawe), Jean Kennedy (Manus), Richard Shutler, Jr. (Watom), Jim Specht (Boduna, Kreslo, Watom), Glenn R. Summerhayes (Kamgot), Robin Torrence (Garua), and J. Peter White (Anir, Duke of York, Lossu). Through the intercession of Dr. Hugh L. Davies of the University of Papua New Guinea in Port Moresby, a sample of modern beach sand from the point on the northwest side of Lombrum Bay on Los Negros Island was collected in mid-1996 by Major Murphy Kila of the Papua New Guinea Defence Force, and kindly provided for petrographic study by Lt. Col. Peter Ila, Commanding Officer of the Lombrum Naval Base.

Appendix: Notes on Sherds Sampled for Petrographic Analysis in 2002 (by P. V. Kirch)

Sherds marked with an asterisk in the following list were subsampled for petrographic sectioning by breaking off a piece of the sherd with pliers, part of the sherd (usually that with the catalog number written on it) being retained by Kirch for further study.

Site ECA, Area B Extension

*ECA-68-03-002, -003, two rejoined sherds, forming the base carination of a flat-bottom dish with flaring sides. Triangular cutouts along the upper side of the carination with a broad crisscross zone marker above that. There is only a trace of the main motif, executed in medium-sized dentate stamping. This sherd is typical of "middle-phase" in the ECA decorative sequence.

*ECA-68-03-005, a portion of the base and complete side of a flat-bottom, flaring-sided vessel. Exterior and lip decorated; no decoration on interior. Medium to coarse dentate stamping. The main motif is a vertical "scroll" which may be highly stylized anthropomorphic design; flanked top and bottom by zone markers. Large fragments of shell or coral temper visible on interior surface.

*ECA-68-01-042, sherd from the vessel wall of a possible "cylinder stand" type, with pronounced horizontal ledge or band. Red slipped. Decorated in relatively fine dentate stamping. Only zone-marker motifs are visible, with the main motif missing.

*ECA-68-01-024, somewhat weathered (water-rolled?) sherd from the side and rim of a flaring-sided vessel. Coarse dentate stamping. Main motif consists of vertical zigzags.

ECA-67-06-029, small fragmentary sherd from a vessel wall, with relatively fine dentate stamping in curvilinear style.

*ECA-67-06-023, neck sherd from a large globular vessel with an everted rim, evidently plainware, only part of rim being present (lip missing). There are traces of paddle impressing on the exterior. Pronounced unfired carbon core.

*ECA-67-05-011, rim sherd from a flaring-sided vessel (bowl or flat-bottom dish), with particularly fine dentate stamping. The lip is decorated by carving and with small circular stamps. The main motif is of vertical zigzag type. The style is representative of the early part of the ECA ceramic sequence.

ECA-67-06-012, a small vessel wall fragment with fine dentate stamping: parallel rows of lines with a row of small circles. This sherd appears to be a fragment of a zigzag type of main motif.

*ECA-67-05-005, small body sherd with a portion of a main motif executed in medium-sized dentate stamping. The motif consists of opposing semicircles.

*ECA-69-07-027, rim (base?) from a plain, exceptionally thick (17.5 mm) walled vessel, which is either a pedestal base or, more likely, a fragment from a ceramic drum.

*ECA-69-07-019, wall sherd from another exceptionally thick (21 mm) vessel, also plain, again quite likely a fragment of a ceramic drum.

*ECA-69-06-001, rim and body sherd, from a bowl (quite probably a pedestal-foot bowl). The lip is decorated with fine dentate stamping (circles and line) interspersed with carved, lime-infilled triangles. The exterior surface is decorated with fine dentate stamping with a main motif of closely interlocked zigzags, under a zone marker and DE1 hanging motif.

*ECA-69-06-007, lip and rim sherd from a large globular vessel with an everted rim, plain except for notching on the lip. The notching is from both inner and outer edges of the lip, evidently made with a small tool pressed into the clay.

ECA-69-01-004, small rim and neck sherd from a globular pot with an everted rim, plain but appears to have had red slip applied. Some traces of paddle impression are evident on the exterior surface.

*ECA-69-05-007, small rim sherd, rather worn (eroded), with traces of notching on the lip, otherwise plain.

ECA-69-02-006, small eroded sherd with traces of dentate stamping on the exterior. The paste is an unusual reddish color throughout.

*ECA-68-07-027, base sherd from a large pedestal as indicated by cross-section profile. Somewhat waterworn, but with traces of both medium dentate stamping and curvilinear carving on the exterior. This sherd is unusually thick for a pedestal base (19 mm).

ECA-68-07-010, rim and neck sherd from a globular pot with an everted rim, plain except for notching along the lip (both interior and exterior edges notched). Pronounced firing core.

*ECA-68-07-006, rim and body sherd from a bowl (probably pedestal type). The lip and exterior are decorated with fine to medium dentate stamping.

*ECA-66-08-024, base sherd from large pedestal with cutouts and decorated with fairly coarse dentate stamping. Very thick and massive (22.5 mm).

*ECA-67-05-007, rim and body sherd from a bowl (probably pedestal type), decorated with medium-sized dentate stamping. The lip is both carved and stamped (somewhat eroded). The main motif is a stylized anthropomorph.

*ECA-67-02-010, rim and body sherd from a bowl, decorated with relatively fine but crudely executed dentate stamping. The lip is dentate stamped; the main motif consists of parallel zigzags. 23 mm down from the lip there is a hole (4–5 mm diam) purposefully "drilled" through the body of the vessel, probably for suspension or for lashing a lip to the bowl.

*ECA-67-02-014, body sherd from what appears to be a bowl (with pronounced curvature but lacking a definite carination). Decorated with medium to coarse dentate stamping. The bottom of the main motif is visible and appears to be an interlocked zigzag design.

*ECA-67-02-017, rim and neck sherd from a large globular vessel with an everted rim. The decoration is restricted to notching of the lip, consisting of closely spaced notches made with a tool impression. Pronounced carbon core.

ECA-66-07-016, rim sherd, broken off at the neck, presumably from a globular vessel with an everted rim. The sherd is somewhat eroded (water-rolled). The decoration is limited to notching of the lip (from both inner and outer edges). Abundant CST temper evident.

ECA-66-08-009, small pedestal base sherd decorated with fine dentate stamping, lime-infilled. This sherd is characteristic of the early phase at ECA.

ECA-66-07-021, small rim sherd, plain except for notching of the lip (from both inner and outer edges).

ECA-66-07-019, small body sherd fragment with fine dentate stamping.

ECA-66-08-015, rim sherd (broken off at neck) from a globular pot with an everted rim. Entirely plain including lack of decoration on the lip. Unusually thin-walled (5.2 mm). Abundant very fine-grained CST temper evident.

*ECA-[66]-03-016 (note missing part of catalog #, grid unit 66 inferred), body sherd with concave curvature; decorated with unusual incised design, curvilinear motif, possibly part of an anthropomorph.

*ECA-66-03-007, body sherd from a vessel with concave inflection, like ECA-66-03-016 is decorated with incised lines, but in this case with a rectilinear rather than curvilinear motif.

ECA-66-03-016, rim sherd with everted lip (somewhat eroded). The exterior is decorated in classic Lapita style, but executed entirely with fine incising rather than dentate stamping. There are traces of decoration on the inner edge of lip (small circles and triangular lines) but these are rather eroded and hard to make out.

ECA-66-07-003, small fragment of a large, thick pedestal stand, decorated with coarse dentate stamping and with cutout holes (very similar to ECA-66-08-024).

Site ECA, Area C

ECA-87-06-001, out-turned rim sherd.

ECA-87-05-006, -007, two joined body sherds, incised.

ECA-88-04-012, body sherd with fine incised lines.

ECA-88-04-007, rim sherd with thickened lip, parallel notched lines on rim.

ECA-88-04-004, classic Lapita rim sherd with dentate stamping and cutout designs; shows signs of being water-rolled.

ECA-88-07-004, incised body sherd.

*ECA-90-02-001, large rim sherd with notched rim and rocker stamping (shell edge).

ECA-90-04-009, decorated body sherd, non-dentate, stamped?, distinctive.

ECA-92-03-003, decorated body sherd, parallel incised lines in sets of three.

Site EHB, Test Pits 1 and 2

EHB-1-4-019, red-slipped decorated rim sherd, everted rim, notched, with CST.

EHB-1-05-012, body sherd with fine dentate stamping, CST.

EHB-1-09-006, rim sherd with notching, red slip, CST.

EHB-1-06-005, plain rim sherd, out-turned rim, red slip, non-CST, probably pyroxene (stands out as first sherd to be found in tray that is non-CST).

EHB-1-03-015, fine dentate-stamped, pedestal foot fragment, very fine-grained "sparkling" inclusions, non-CST.

EHB-2-03-008, out-turned rim with incised decoration, CST.

CHAPTER 13

Non-Ceramic Portable Artifacts from Talepakemalai and Other Mussau Sites

Patrick Vinton Kirch

In his pioneering synthesis of Lapita, Roger Green noted that while the distinctive dentate-stamped pottery had dominated scholarly discourse regarding the Lapita cultural complex, nonetheless "the Lapita cultural complex exhibits a full range of [non-ceramic] portable artifacts typical of many Oceanic assemblages" (1979a:39). Green enumerated and illustrated a range of Lapita non-ceramic objects, including adzes of stone and shell, obsidian and chert flake tools, shell scrapers and peelers, assorted files or abraders, anvils, polishers, gaming discs, one-piece fishhooks and net sinkers, a diversity of shell rings, bracelet units, and beads, as well as bone needles, awls, tattooing chisels, and spear points (1979a:39–40, figures 2.4, 2.5). In subsequent writings, Green (1991b, 1992) continued to emphasize that Lapita is more than just pots (cf. Terrell 1989). However, in assessing the non-ceramic component of Lapita, Green pointed to two problems: (1) "the bias towards [the] definition [of these non-ceramic artifacts] on the basis of sites from Remote Oceania; and (2) "that in comparison to the pottery, analysis and classification of these items beyond rather broad descriptive categories is often minimal" (1992:16).

The archaeological assemblages we recovered in our excavations in Mussau are remarkable for their diversity and richness, and include 1,073 non-ceramic portable artifacts, plus an additional 8,805 obsidian and other lithic artifacts, and 120 unworked manuports (Table 13.1). This is the most extensive set of non-ceramic portable artifacts yet recovered from Lapita contexts in either Near or Remote Oceania, providing an opportunity to redress the problems lamented by Green (1992).

This chapter provides a descriptive analysis and classification of Lapita as well as post-Lapita non-ceramic artifacts from the Mussau sites. The lithic assemblages are also briefly enumerated and described, while more detailed analyses of the obsidian assemblages are provided in Chapters 14 and 15. A geological analysis of unmodified stone manuports is provided in Chapter 16.

Archaeologists have long debated the criteria by which portable artifacts should be classified, some preferring to

Table 13.1. Distribution of non-ceramic portable artifacts by site

Artifact Class	ECA	ECB	EHB	EHK	EHM	EHN	EKE	EKL	EKO	EKP	EKQ	EKS	EKU	Other Sites*	Totals
Tools															
Stone adzes	2						1					1	1		5
Tridacna-shell adzes**		1	3	4			4	19				1	22	27	81
Terebra-shell adzes**				5			26	5			11	13	15	45	120
Tridacna-shell chisels	2	1													3
Cassis- and *Cypraecassis*-shell chisels	1		1									1			3
Coral abraders	6														6
Stone abraders	6	1													7
Whetstones	3														3
Hammerstones	2	2	1												5
Fishing gear															
Angling Hooks	18	1									1				20
Trolling Hooks	4	1									3				8
Hook blanks and preforms	199	20	15		2	11			1		9				257
Net sinkers	2			18			1								21
Net gauge	1														1
Food preparation															
Cypraea-shell scrapers	102	6	4									2			114
Cypraecassis-shell scraper		1													1
Pearl-shell peeling knives	17						3								20
Anadara-shell scrapers	2	2	1		6				7			3			21
Exchange valuables															
Long units (A)	3														3
Rectangular nits (B)	6														6
Conus-shell rings (C1)	186	17	3									2			208
Tridacna-shell rings (C2)	14	7													21
Trochus-shell rings (C3)	3					10	2		5		2	28			50
Disks (D)	4	1													5
Conus-shell beads (E1)	38	1													39
Spondylus-shell beads (E2)	9										1				10

Artifact Class	ECA	ECB	EHB	EHK	EHM	EHN	EKE	EKL	EKO	EKP	EKQ	EKS	EKU	Other Sites*	Totals
Pearl-shell beads (E3)	5														5
Shell pendants (F)	9														9
Polinices-shell pendants	3														3
Other shell ornaments	2						1								3
Tooth/tusk pendants	9								2						11
Bone ring	1														1
Anthropomorphic image	1														1
Inlay disks	8								1						9
Flaked stone															
Obsidian	5901	1233	405		2		408		6	5	697		87		8744
Chert	16	1					1				2				20
Other flaked stone	23	15	2								1				41
Manuports	69	24	8				15			1	1		2		120
Totals	6677	1335	443	27	10	21	462	24	22	6	728	51	127	72	10,005

* These represent surface collections from sites EHC, EKC, EKK, EKN, EKR, EKV, EKW, and EKZ.

** Includes incomplete adzes and adze fragments.

privilege raw material (stone, shell, bone, etc.), others formal attributes of morphology, technology, or style, while yet others organize classes according to inferred functional categories. In Oceania, where there is direct historical continuity between the archaeological and ethnographic records, a reasonable case can be made for functional classification, and there is a long tradition among Oceanic archaeologists of using such systems. Oceanic examples of functionally based classes include the artifact classifications of Green (1974), Kirch (1988a), Kirch and Yen (1982), and Suggs (1961); classifications based primarily on raw material classes include Gifford and Shutler (1956) and Poulsen (1987). The functional-class approach is adopted here; the broad functional categories into which I have divided the Mussau non-ceramic portable artifacts are essentially those that I used in earlier studies of material culture assemblages from Tikopia (Kirch and Yen 1982) and Niuatoputapu (Kirch 1988a). This reflects my view that the majority of objects in the Mussau assemblages can be unambiguously assigned to one of several major functional groups, such as fishing gear, manufacturing tools, or food preparation equipment. Of course, there is always a residuum of objects (often incomplete, broken, or unfinished specimens) for which no functional assignment is possible. However, given that most of the artifacts recovered from our sites have direct equivalents in the ethnographic record of Oceanic material culture, to my mind it is reasonable to use such functional categories, rather than to arbitrarily separate a group of objects—adzes, for example—simply because some are made of shell while others are of stone.

Tools

Adzes, along with ceramics, fishhooks, and certain kinds of ornaments, have been among the most important classes of portable artifacts for archaeological "systematics" in Oceania. Although adzes combine both functional and stylistic features in often complex ways, they nonetheless have been shown to display non-random patterns of spatial distribution and time-sensitive morphological changes. The representation of adzes (of both stone and several different kinds of shell) in the Mussau collection is not as great as for some other southwestern Pacific sites (e.g., Tikopia, see Kirch and Yen 1982:206–237); indeed, adzes were fairly rare in Lapita contexts in Mussau. Nonetheless, they exhibit important chronological changes, as described below.

Stone Adzes

Two fragments of small stone adzes were recovered from the Area B excavation at Talepakemalai; both are made of a fine-grained, greenish-gray stone, possibly metamorphosed sandstone. One is the butt section of an adze (ECA-35-8-37) with an ovoid to quadrangular cross section, well ground and polished except for the poll, which retains some traces of flaking (Figure 13.1, a; Figure 13.2, a). This specimen has a width of 30.3 mm and thickness of 15.1 mm; the extant portion is 40.2 mm long; when whole the adze probably had a length of around 80 mm. The second partial adze (ECA-53-3-3) is a bevel fragment, again with an ovoid cross section, well ground and polished on the front; the bevel is curved (Figure 13.1, b; Figure 13.2, b). For this adze the width is 41.8 mm, thickness is 11.6 mm, and bevel width is 42.2 mm.

From the surface of site EKU we collected a nearly complete stone adze (EKU-0-0-18), made from a very dense, fine-grained stone, possibly metamorphosed sandstone (Figure 13.2, c). The adze is well ground and polished overall, with an ovoid cross section; it is complete except for the bevel, which appears to have been damaged through use. The adze measures 100.3 mm long, and has a width of 38.3 mm and thickness of 22.3 mm. From the surface of the EKS site we also collected the curved bevel of a small stone adze (Figure 13.1, c), while from site EKE we excavated what appears to originally have been a stone adze that was later modified through use as a hammerstone (Figure 13.1, d).

Tridacna-Shell Adzes

Although the Mussau collection includes 81 adzes, adze fragments, or adze preforms made of *Tridacna* shell, only eight of these are from excavated contexts: two from Lapita site EHB, and three each from the post-Lapita sites of EKE and EKU. The remaining *Tridacna*-shell adzes (including fragments and preforms) are all from surface contexts, primarily from sites on the offshore islets (Table 13.1).

As I pointed out in my study of shell adzes from Tikopia Island, an important distinction must be made between adzes manufactured from the thick hinge portion of these large bivalves, and those made from the thinner ventral margin (Kirch and Yen 1982:209–210). The more massive adzes made from the hinge are known to be associated with Lapita contexts. In post-Lapita contexts, *Tridacna*-shell adzes were more commonly made from the thinner ventral margin. In some cases, however, it can be difficult to discern whether an adze was made from the hinge or from a particularly thick ventral margin of the large species *Tridacna gigas*. Some of the Mussau adzes were clearly made from *T. gigas*, although the majority were made from the smaller species *Tridacna crocea*.

Surprisingly, given its extensive excavation, Talepakemalai did not yield any *Tridacna*-shell adzes. The EHB site, however, produced an adze made from the hinge of a large *Tridacna*, probably *T. gigas*, in level 5 of TP-2, in association with Lapita pottery (Figures 13.3; 13.4, b; 13.5, b). This adze has a ridge running down the back, a remnant of the hinge morphology. The bevel is slightly curved and extensively battered; the thick poll is rounded. This adze is 136 mm long, has a bevel width of 60 mm, and thickness of 33.5 mm. A surface find from site ECB (ECB-0-0-23), displaced from its original context by gardening activity, is also of the hinge portion of a large *Tridacna* shell, extensively chipped along both sides and ground and polished smooth on the front and back (Figures 13.4, a; 13.5, a; 13.6). This adze has a straight bevel and a distinctly pointed poll. It measures 131.5 mm long, has a bevel width of 58 mm, and thickness of 24.1 mm. These adzes demonstrate that hinge-section *Tridacna*-shell adzes were a part of the Lapita tool kit in Mussau. In addition to these finished adzes, a thick *Tridacna gigas* shell from site ECA (ECA-37-8-28) has been extensively chipped around its ventral margins, and probably represents the first stage in the manufacture of a hinge-portion adze (Figure 13.7).

One complete adze surface collected at site EKU may be from a *Tridacna* hinge, although it is so extensively ground and polished on all surfaces that it is impossible to tell whether it is from a hinge or from a very thick portion of ventral margin of a large *T. gigas*. This adze, which was beautifully finished, has a curved bevel and tapers to a pointed poll. It has a length of 92.2 mm, bevel width of 45.6 mm, and thickness of 22.5 mm. Three other adze fragments

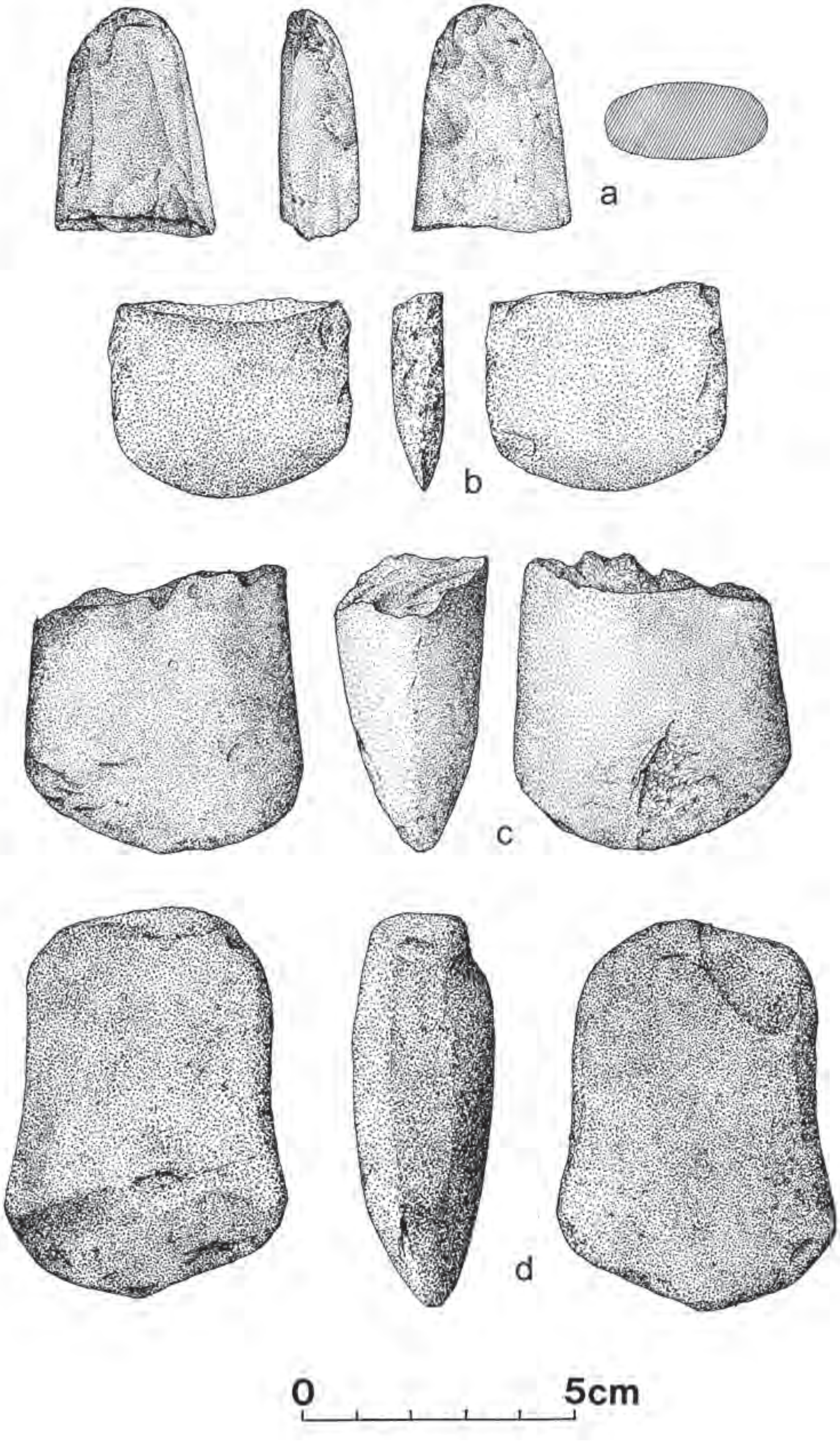

Figure 13.1. Stone adzes from Mussau sites: a, butt fragment from ECA (ECA-35-8-37); b, bevel fragment from ECA (ECA-53-3-3); c, bevel fragment from site EKS (EKS0-0-37); d, adze reworked as a hammerstone from EKE (EKE-12-1-4). (Drawings by Margaret Davidson.)

Figure 13.2. Stone adzes from Mussau sites: a, butt fragment from ECA (ECA-35-8-37); b, bevel fragment from ECA (ECA-53-3-3); c, adze from EKU (EKU-0-0-18).

may have been made from *Tridacna* hinge portions but this cannot be determined with certainty; all are surface finds.

Seventy-four adzes (including fragments and preforms) were made from the ventral margins of *Tridacna* valves, in all cases apparently from *T. crocea*. Ventral margin adzes were manufactured by first chipping out a preform, as seen in the two examples in Figure 13.8. Examples of finished *Tridacna* ventral-margin adzes are illustrated in Figure 13.9. A single ventral-margin preform comes from Lapita site EHB, while the others are all from post-Lapita sites, mostly as surface finds. Straight bevels are the most common, but there are five examples with distinctly curved bevels; this difference in bevel shape presumably had functional significance. Of adzes with intact polls, 24 are distinctly pointed and four are rounded. The preference for pointed polls is a stylistic trait seen in other adze assemblages, such as that from the Sinapupu Period in Tikopia (Kirch and Yen 1982:226), and in adzes from post-Lapita contexts in Vanuatu (Garanger 1972).

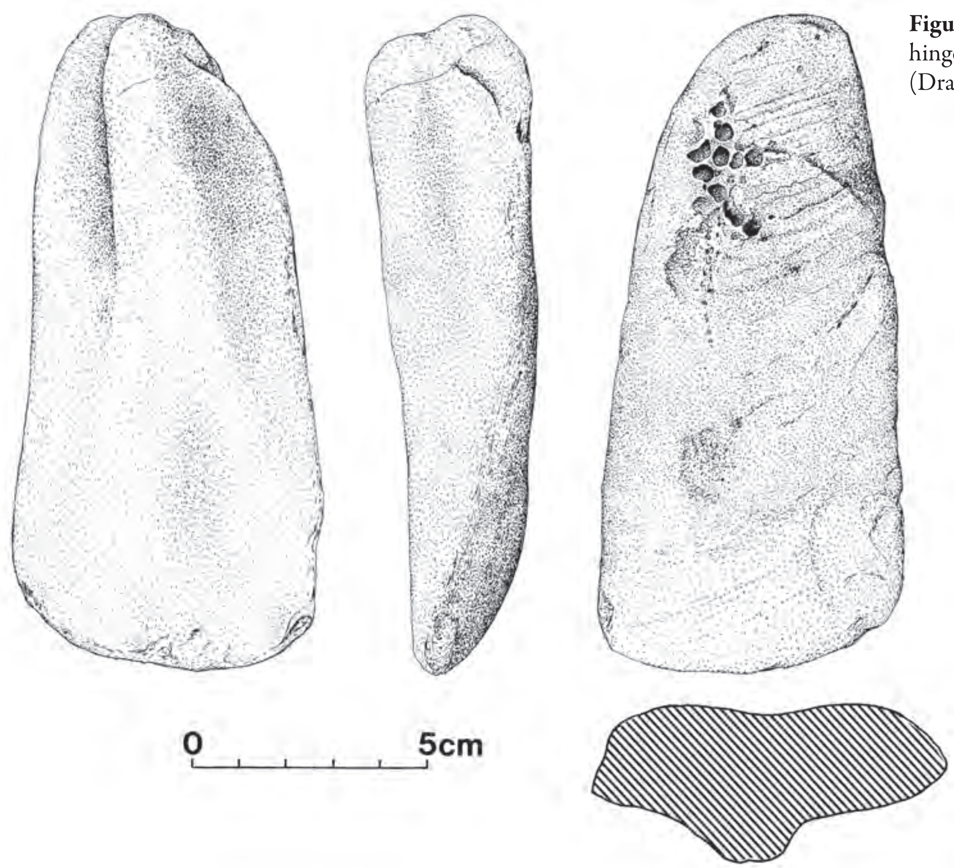

Figure 13.3. Adze of *Tridacna* shell hinge from EHB (EHB-2-5-1). (Drawings by Margaret Davidson.)

Figure 13.4. Adzes from Lapita sites ECB and EHB, front views: *a*, *Tridacna* hinge adze, ECB-0-0-23; *b*, *Tridacna* hinge adze, EHB-2-5-1; *c*, *Cassis* shell adze, EHB-3-2-4.

Figure 13.5. Adzes from Lapita sites ECB and EHB, back views: *a*, *Tridacna* hinge adze, ECB-0-0-23; *b*, *Tridacna* hinge adze, EHB-2-5-1; *c*, *Cassis* shell adze, EHB-3-2-4.

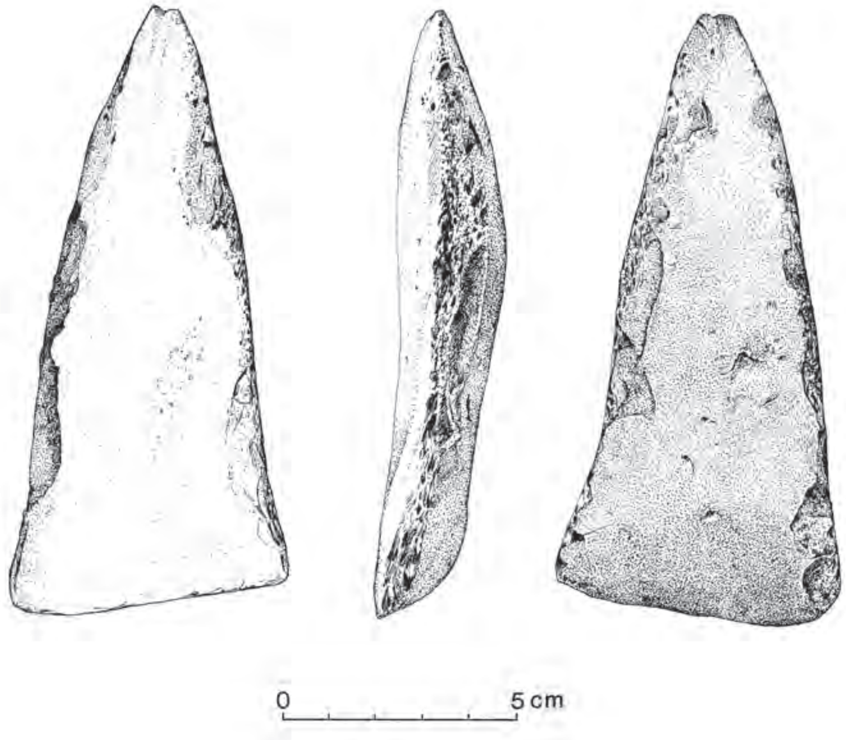

Figure 13.6. Large *Tridacna*-shell adze from ECB (ECB-0-0-23). (Drawings by Margaret Davidson.)

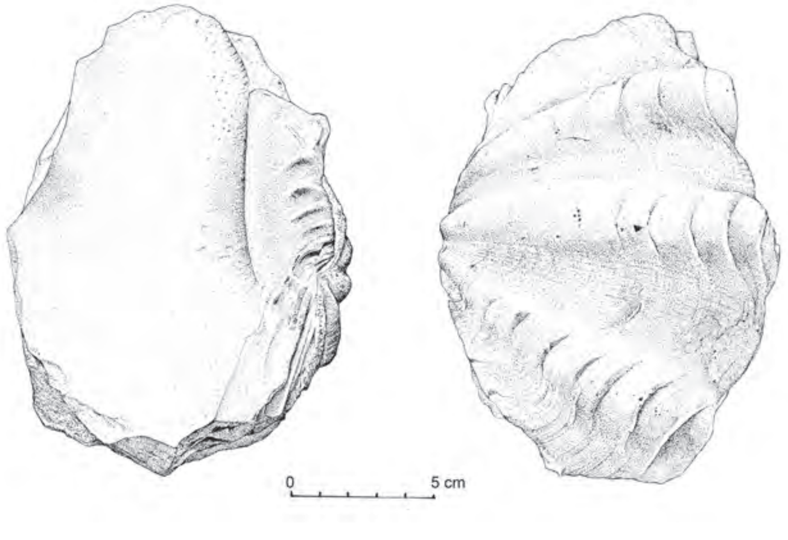

Figure 13.7. Worked *Tridacna gigas* shell from ECA, probably the first stage in production of a hinge-portion adze (ECA-37-8-28). (Drawings by Margaret Davidson.)

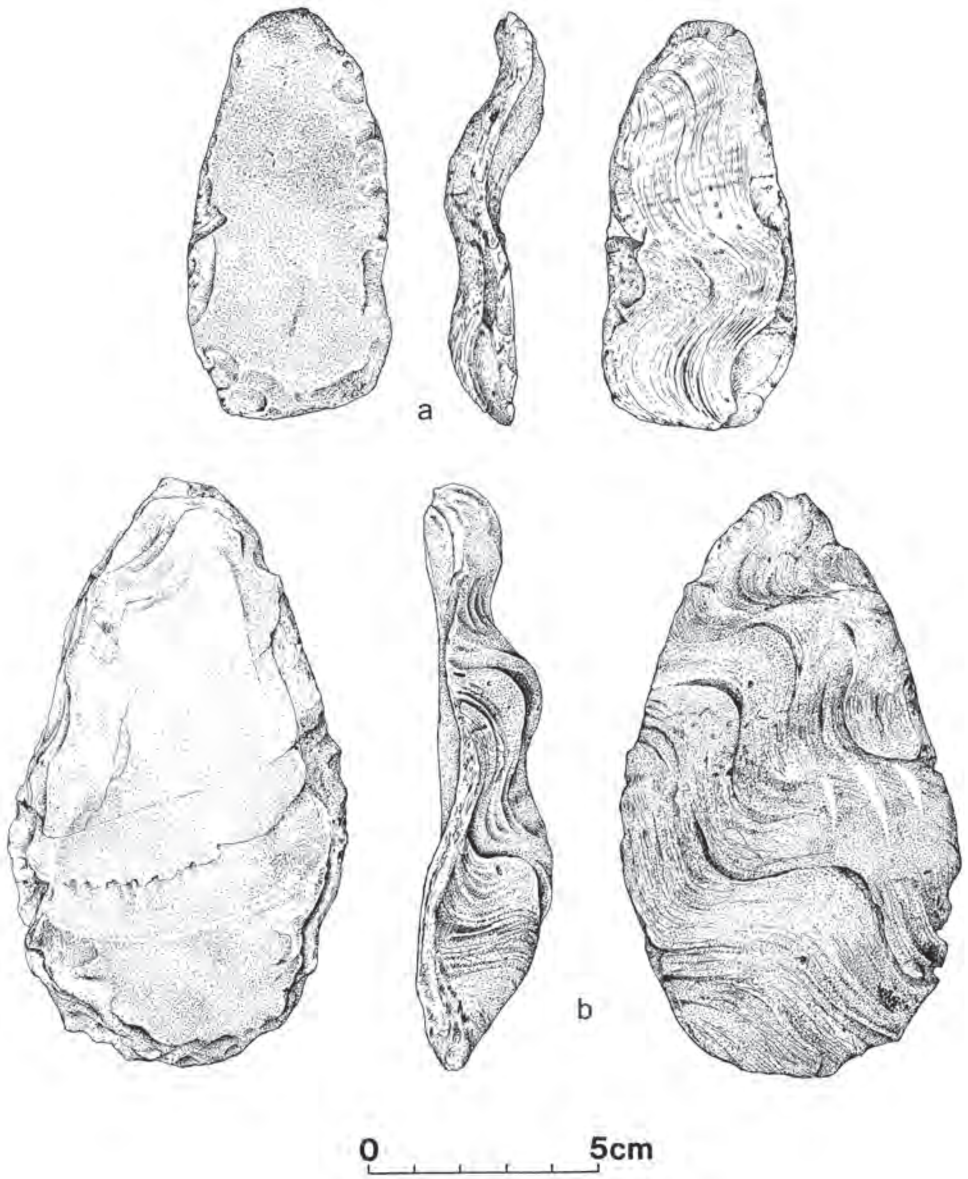

Figure 13.8. Preforms of *Tridacna* ventral margin adzes: *a*, EKS-0-0-36; *b*, EHB-3-1-2. (Drawings by Margaret Davidson.)

Figure 13.9. *Tridacna*-shell ventral margin adzes from EKU: *a*, EKU-0-0-27; *b*, EKU-0-0-26; *c*, EKU-0-0-13.

Table 13.2. Dimensions of *Tridacna*-shell adzes of ventral margin type

Dimension	N	Minimum	Maximum	Mean ± s.d.
Length	26	59.5	124.1	81.2 ± 14.6
Bevel width	37	29.2	76.3	45.3 ± 9.9
Thickness	52	6.4	34	11.9 ± 4.9

Ventral margin adzes are constrained in their size range by the size limits of *Tridacna crocea* valves. Table 13.2 presents statistical data on the dimensions of ventral margin adzes in the Mussau collection (the table excludes smaller fragments that could not be accurately measured). Most ventral margin adzes range between 60 and 100 mm in length; these would have been suitable for various woodworking tasks, such as carving bowls or small canoe hulls, or preparing house timbers such as posts and rafters.

Lastly, from the landowner of the Sinakasae site (EKU), we obtained a very unusual object of *Tridacna* shell, which may have functioned as an adze but might also have been a ritual object or exchange valuable (Figure 13.10). Measuring 252 mm long and shaped rather like an adze, this artifact has a curved bevel edge and distinctly pointed butt. It bears no traces of the original shell exterior, and must have been manufactured from an especially large *Tridacna* valve, probably of *T. gigas*.

Figure 13.10. Large *Tridacna*-shell adze or possible ritual object from site EKU.

Tridacna-Shell Chisels

During the 1985 field season at Talepakemalai, while reconnoitering a recently gardened part of the site in the general vicinity of Area A, two distinctively shaped objects of *Tridacna* shell were discovered. In part because they had been heavily eroded by their exposure on the surface and through contact with the humic acids of the upper garden soil (they had presumably been brought to the surface at some point by burrowing land crabs, see Chapter 3), I was initially uncertain as to their possible function. When in the following field season, however, we excavated a beautifully preserved, unweathered example from site ECB, I realized that these objects represent a class of small micro-adzes or chisels, an artifact class not previously known from Lapita sites. The three objects are shown in Figure 13.11.

Whether these objects should be functionally classified as adzes or chisels is a point that cannot be resolved without knowing how they were hafted (i.e., as an adze with a wooden handle at right angles to the orientation of the adze blade, or as a chisel with a straight shaft in the same axis as the bevel), or indeed, whether they were hafted at all. As described below for the specimen from ECB, considerable damage to the poll suggests the possibility that this "chisel" could have been hand-held and used with a small hammerstone.

The specimen from site ECB (Figure 13.11, c) had been carefully prepared, by grinding and polishing, from a massive block of *Tridacna* shell, probably *T. gigas*. It measures 54.4 mm long, has a maximum width of 9.1 mm (minimum width of 3.6 mm), and maximum thickness of 14.3 mm. In cross section it is "reversed" trapezoidal with the narrower side of the trapezoid forming the back of the chisel. The bevel, which is straight and exactly 5 mm wide, has been formed by grinding from both the back and front sides. The poll or butt is slightly reduced by grinding on one side, but has been extensively battered, exhibiting many small step fractures. If the implement were hafted, such damage to the poll would seem unlikely, raising the possibility that the tool was hand-held, lightly tapped with a small hammerstone. It presumably could have been used for fairly fine carving or woodworking, such as making a narrow groove. Such a tool could have been useful in the fine work of fitting planks, gunwales, or washstrakes on canoes.

The two examples from ECA are of similar form, although the chemical decomposition of their surfaces has obscured fine details such as are visible on the specimen from ECB. One of the ECA chisels (ECA-0-0-2) is of almost identical dimensions to the ECB artifact, measuring 54.5 mm long, 7.3 and 3.6 mm wide (max and

Figure 13.11. *Tridacna*-shell chisels: *a*, ECA-0-0-1; *b*, ECA-0-0-2, *c*, ECB-12-5-2.

min), and 16.2 mm thick. It too, has a reversed trapezoidal cross section. Although weathered, battering damage is still evident over its poll. The third specimen (ECA-0-0-1) is somewhat longer, 74.5 mm, but roughly the same size in width (6.8 mm) and thickness (16.3 mm). It has a rectangular cross section, but is sufficiently weathered that traces of former damage to the poll, if they were present, have been completely obliterated.

Terebra-Shell Adzes

The elongated, spire-shaped shells of *Terebra maculata* (synonym *Oxymeris maculata*) were used in various parts of Micronesia and Melanesia as adzes, and are well represented in post-Lapita contexts in Mussau, with 120 specimens, mostly from surface contexts (Table 13.1). These sturdy shells with thick walls were converted into adzes by first chipping away the aperture and part of one side of the shell, then grinding the exposed shell wall and columella smooth; the upper end of the spire is typically left untouched. This results in a distinctly curved, concave bevel that follows the contour of the main body whorl, thus resembling a gouge more than a typical adze with a straight bevel. Examples of *Terebra*-shell adzes from the EKU site are illustrated in Figure 13.12, and from the EKE site in Figure 13.13. Ethnographic specimens, however, indicate that these modified *Terebra* shells were hafted in the same manner as other adzes of shell or stone. Nevermann (1933) illustrated such an example from Mussau. The curved bevels range from 25 to 33 mm in width, and would have been well suited to carving out the interiors of wooden bowls, or even small canoe hulls. Complete *Terebra*-shell adzes have overall lengths of between 70 and 108 mm. On many specimens, the bevels are chipped or partly broken from use.

Cassis- and *Cypraecassis*-Shell Chisels/Adzes

Far less common than *Tridacna*- or *Terebra*-shell adzes in the western Pacific, but nonetheless represented from several sites in the Solomon Islands (e.g., Anuta, Nendö) and western Micronesia, are adzes or chisels made from the thickened apertural lip of helmet shells (*Cassis cornuta* and *Cypraecassis rufa*). The lips of these shells are both massive and elongated, making it a material well adapted to adze/chisel manufacture, requiring only some grinding and polishing of the detached lip and grinding of a sharp bevel. A chisel or gouge from the massive lip of a *Cassis cornuta* shell was excavated at site EHB, and has a pronounced, concave bevel that would have made it suitable to carving out the interior of a bowl or a narrow canoe hull (Figures 13.4, c; 13.5, c). One complete example of an adze or chisel of *Cypraecassis rufa* was recovered from the proto-historic, aceramic EKS site (Figure 13.14, b). Measuring 133 mm long with a maximum width of 27 mm, this adze or chisel has a bevel about 14 mm wide, which has been quite blunted, presumably through use. The sides of the specimen have also been well ground, eliminating any roughness.

From site ECA we also recovered what may be an unfinished preform of such a *Cypraecassis* -shell adze/chisel (Figure 13.14, c). This piece of apertural lip measures 115 mm long, and has been chipped at both ends and along the margin where it was detached from the body whorl of the shell, seemingly in preparation for grinding.

Figure 13.12. *Terebra*-shell adzes from site EKU: *a*, EKU-0-0-21; *b*, EKU-0-0-23; *c*, EKU-0-0-39; *d*, EKU-0-0-30; *e*, EKU-0-0-31.

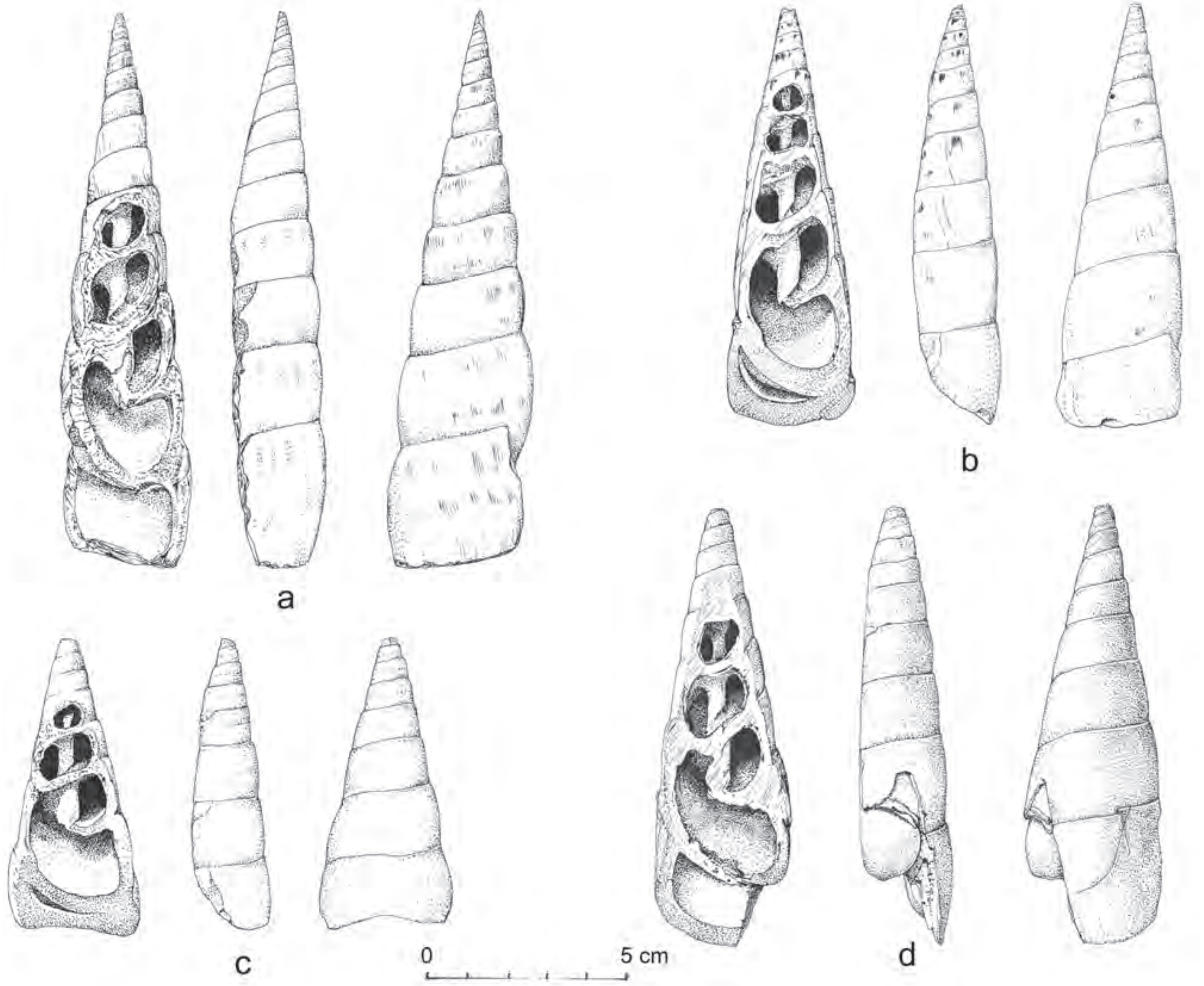

Figure 13.13. *Terebra*-shell adzes from site EKE: *a*, EKE-11-6-1; *b*, EKE-0-0-1; *c*, EKE-1-1-1; *d*, EKE-1-8-1. (Drawings by Margaret Davidson.)

Coral Abraders

Six pieces of branch coral (*Acropora* sp.) exhibit signs of having been used as abraders, presumably in the manufacture of shell fishhooks or other shell objects (Figure 13.15). In one case (ECA-43-6-3) the branch tip has been abraded on two sides, creating a V-shaped section (Figure 13.15, a). In another case, one side has been smoothed, while in the other four examples the tips have been abraded through a circular action, possibly from enlarging a perforation in a *Trochus*-shell fishhook preform. Four additional pieces of branch coral were also collected, but are most likely simply waterworn. All of the *Acropora* coral abraders are from Talepakemalai.

Stone Abraders

Seven objects have been classified as stone abraders, six from site ECA and one from site ECB (Figure 13.16). Four are relatively short, shaft-like pieces of stone (most likely andesite) with angular wear facets indicating their use as abraders, probably for working shell. Another specimen (ECA-17-3-1) is slightly longer with a distinct square cross section and grinding on all four facets. The sixth specimen from ECA (ECA-16-8-2) is different in being a small cobble with a circular end ground down through abrading action, probably by grinding a circular perforation in a shell artifact such as a rotating fishhook or shell ring (Figure 13.16, g). The abrader from

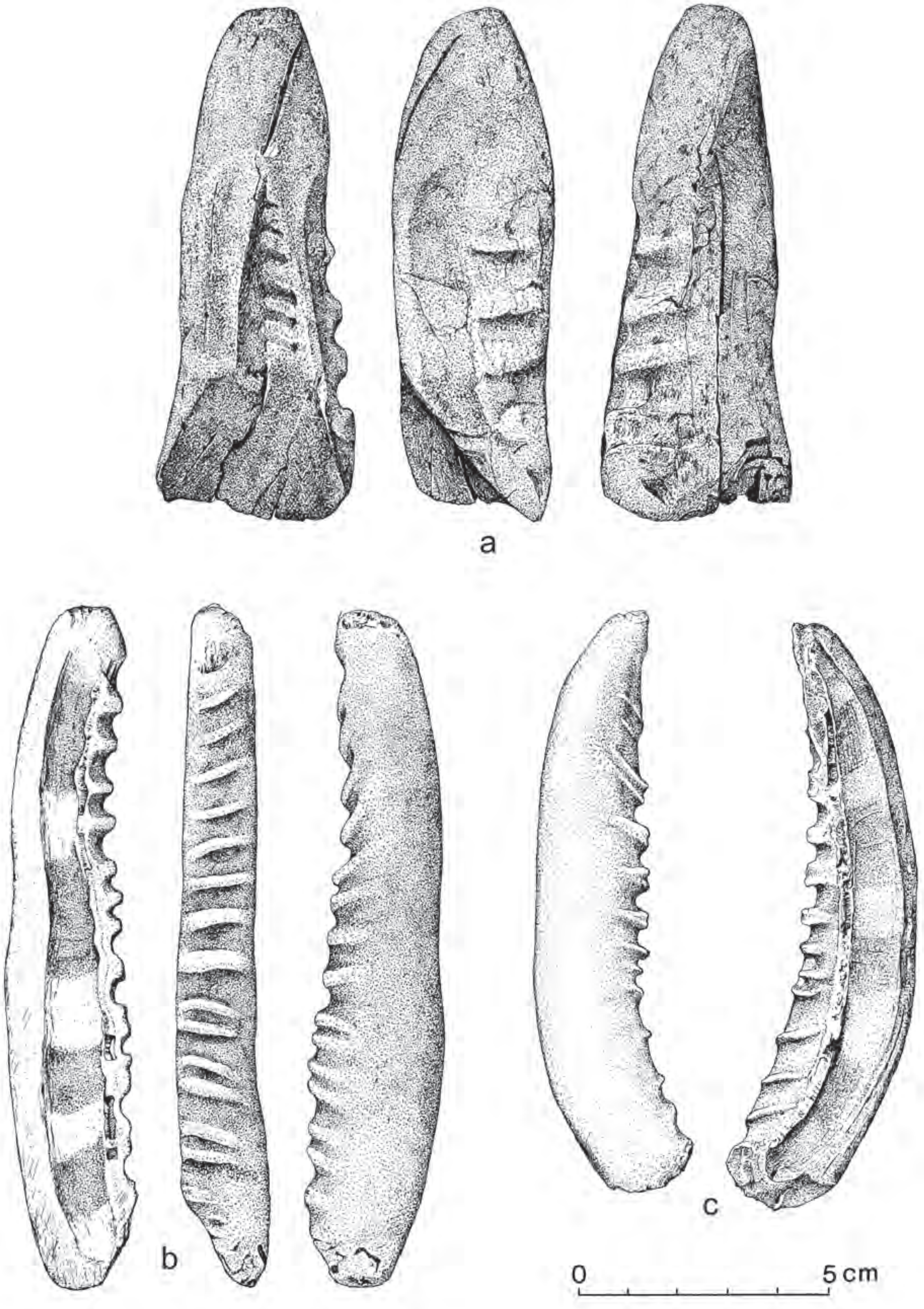

Figure 13.14. *Cassis*- and *Cypraecassis*-shell adzes: *a*, adze or gouge of *Cassis cornuta* shell, EHB-3-2-4; *b*, adze of *Cypraecassis rufa*, EKS-0-0-3; *c*, adze preform of *Cypraecassis rufa*, ECA-54-3-4. (Drawings by Margaret Davidson.)

Figure 13.15. Abraders of *Acropora* branch coral: *a*, ECA-43-6-3; *b*, ECA-34-1-18; *c*, ECA-39-5-8.

ECB (ECB-18-1-1) is elongated, tapering with an elliptical cross section, made from a porphyritic stone in which harder, dark inclusions stand out against the softer matrix, giving the surface a rasp-like quality (Figure 13.16, a).

Shaped Stone of Unknown Function

A unique stone object recovered from Unit W200N120 at site ECA consists of a small cobble of light gray stone (ECA-18-8-5), probably andesite that has been heavily pecked on

Figure 13.16. Stone abraders: *a*, ECB-18-1-1; *b*, ECA-18-8-5; *c*, ECA-41-7-9; *d*, ECA-51-6-3; *e*, ECA-18-4-2; *f*, ECA-23-2-5; *g*, ECA-16-8-2.

two sides. The other two sides are smooth, probably remnants of the original waterworn surface. It is possible that the object was being shaped for use as an abrader, but this function is not certain. The object measures 57.6 mm long and 20.3 mm wide.

Whetstones or Grindstones

Three artifacts from Talepakemalai consist of tabular pieces of stone that have been ground smooth on one or both flat surfaces (Figure 13.17). From Area B we recovered such a stone (probably andesite) ground smooth on two sides (ECA-37-9-54); the stone is roughly rectangular, with a maximum length of 77.0 mm, width of 52.8 mm, and thickness of 16.5 mm (Figure 13.17, c). From excavation Unit W200N160 we recovered a small tabular block of greenish-gray mudstone (ECA-57-6-1), ground smooth on one side; the block measures 50.8 x 48.8 mm and has a thickness of 20.2 mm (Figure 13.17, b). The third whetstone comes from Unit W160N140 (ECA-65-5-1) and is of a slightly porphyritic stone (probably andesite) with one side ground flat; it appears to have been broken off of an originally larger piece (Figure 13.17, a). This whetstone has a maximum length of 101.0 mm and thickness of 30.5 mm.

Hammerstones

Five objects have been classified as hammerstones, two from site ECA, two from ECB, and one from EHB (Figure 13.18). The first from ECA is a dense, fist-sized cobble of porphyritic stone (ECA-62-6-7) with pecked indentations (finger grips) on four sides and signs of battering on the ends. The second ECA hammerstone (ECA-89-7-1) is similar, a light grayish ovoid cobble (probably andesite) with lightly pecked finger grips and battering around the edges and especially on the ends (Figure 13.18, c). From ECB we recovered an ovoid cobble, probably of andesite (ECB-16-4-9), with pecked finger grips on two sides

Figure 13.17. Whetstones: *a*, ECA-60-5-1; *b*, ECA-57-6-1; *c*, ECA-37-9-54.

and clear evidence of battering around the circumference (Figure 13.18, a). The second hammerstone from ECB was found on the surface (ECB-0-0-1), a biconvex cobble with battering on the two flattened ends (Figure 13.18, b). The specimen from EHB, also a surface find (EHB-0-0-5), is a rounded cobble of dense light gray stone (probably andesite) with faintly pecked finger grips and some signs of battering around the circumference. None of these hammerstones show signs of heavy-duty use such as would indicate hard-hammer action against other igneous rocks. The probable functions of these tools include: (1) light flaking of shell (as in chipping out preforms for shell adzes or fishhooks); (2) breaking open shellfish for meat extraction; and, (3) opening the hard-shelled nuts of *Canarium indicum* in order to extract the edible kernel (see Chapter 10).

Fishing Gear

Artifacts inferred to have been used for fishing are of two main classes: fishhooks and net weights. The former include both one-piece angling hooks and trolling hooks, extending our knowledge of the use of fishhooks by Lapita peoples back to the earliest time period for Western Lapita. This is of considerable importance given faunal evidence for extensive fishing (see Chapter 7), as well as in relation to historical linguistic reconstructions of Proto-Oceanic terms for a range of fish (including pelagic species probably taken by trolling) and for some items of fishing gear (Walter 1989).

Material and Manufacture of Fishhooks

The preferred material from which to make both angling and trolling hooks in Mussau was the large shell of *Trochus*

Figure 13.18. Hammerstones: *a*, ECB-16-4-9; *b*, ECB-0-0-1; *c*, ECA-89-7-1; *d*, EHB-0-0-5.

niloticus (see Chapter 8), with most of the finished hooks being of this species. However, pearl shell (*Pinctada margaritifera*) was also used, primarily for smaller angling hooks. There is also a single unfinished one-piece fishhook (from site EKQ) made from *Turbo marmoratus* shell; this is of interest as the use of this species is known from Lapita sites farther to the east (especially with the early Tikopia fishhook assemblages, which are dominated by *T. marmoratus* shell; see Kirch and Yen [1982:238]).

Both angling and trolling hooks were made from the broad, flat basal whorl of *Trochus niloticus*, using the same techniques. The first stage in manufacture was to remove a suitable basal whorl, by chipping or flaking laterally along the shell between suture lines, leaving remnant or discard debris as seen in Figure 13.19. This flaking probably was done with hammerstones of either stone or hard shell (such as *Tridacna*). It is possible that the area to be flaked was first “softened up” by the application of a heated fire

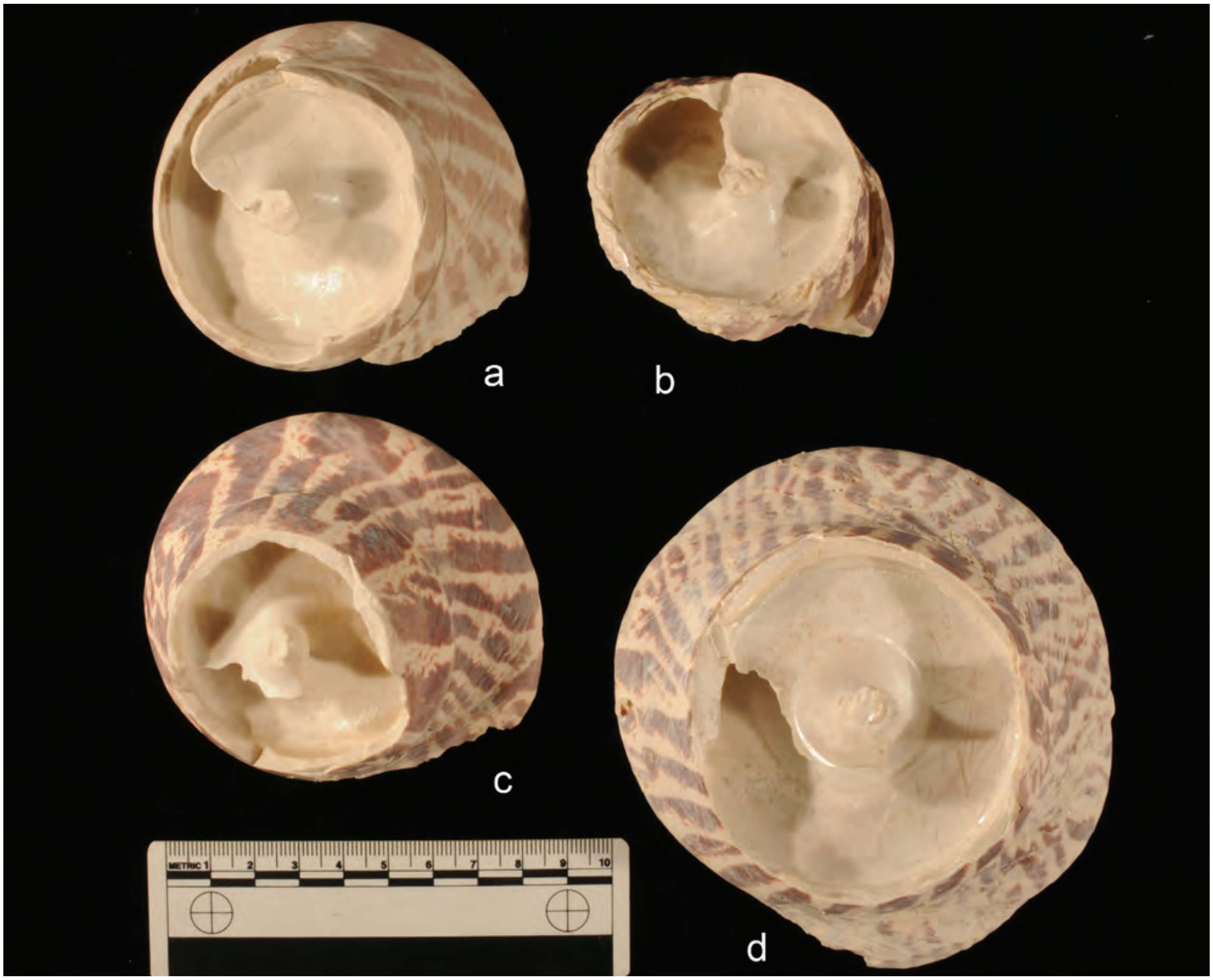

Figure 13.19. Initial stages of reducing *Trochus niloticus* shells for fishhook manufacture: *a*, ECA-46-3-9; *b*, ECA-62-9-7; *c*, ECA-43-5-27; *d*, ECA-46-4-76.

stick, which would have the effect of calcining the calcium carbonate. This method was ethnographically observed by Patrick McCoy and Paul Cleghorn in Nendö Island (Eastern Solomons), for the production of *Trochus*-shell armrings (P. C. McCoy, personal communication, 18 September 2018).

Once a suitably sized piece of *T. niloticus* basal whorl had been extracted, this was further chipped to form a preform or tab, examples of which are illustrated in Figure 13.20. These hook preforms all have a remnant section of outer shell wall along one side, which was worked to become the fishhook shank, while the flat and slightly thinner base of the whorl (the portion of the shell connecting the outer wall to the columella) was reduced and shaped to become the bend and point. Stages in the sequence of fishhook manufacture are illustrated in Figures 13.21 and 13.22. A specimen from Area B of site ECA (Figure 13.21, d) shows that an opening was first made in the center of the flat portion of the tab, perhaps again by initially burning with a fire stick, and then enlarging the opening by abrading the inner edges. (Abrasion marks are clearly visible on the inner edges of the specimen shown in Figure 13.21, d.) At the same time, the outer surfaces of the preform were ground flat, possibly using a stationary anvil-type grindstone or whetstone. Eventually the central opening was enlarged to separate the point from the shank (as seen in Figure 13.21, e), with grinding and polishing continuing until the final shape was achieved.

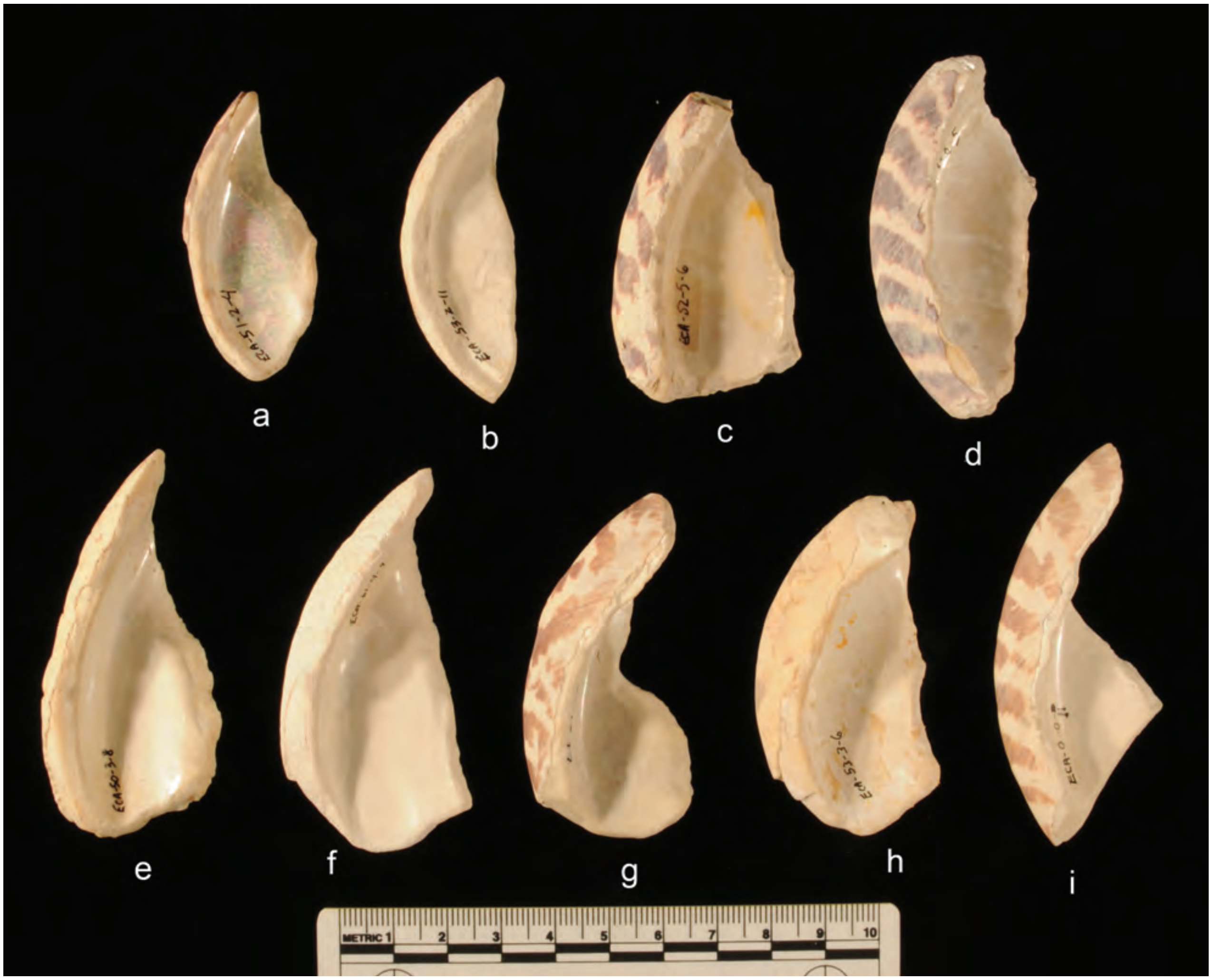

Figure 13.20. Fishhook preforms of *Trochus niloticus* shell: *a*, ECA-51-2-4; *b*, ECA-53-2-11; *c*, ECA-52-5-6; *d*, ECA-57-8-5; *e*, ECA-50-3-8; *f*, ECA-61-4-9; *g*, ECA-78-7-3; *h*, ECA-53-3-6; *i*, ECA-0-0-11.

One unresolved issue concerns the nature of the tools used to abrade and polish the preforms. A stationary grindstone would work well for the flat outer surfaces, but the inner sides and edges would have required a smaller, hand-held tool. There are several abraders made from *Acropora* branch coral at ECA (see above), but the total sample size of six abraders from ECA seems insufficient for working the substantial quantities of shell in evidence at the site. The obvious implication is that there were other kinds of abrasive tools that have not survived in the archaeological record. One possibility would be wooden shafts covered with highly abrasive shark or ray skin, as known from ethnographic examples. An alternative would be the use of rough lianas (such as rattan).

During the 1985 and 1986 field seasons we did not differentiate chipped *Trochus niloticus* shell that may have been fishhook manufacture debris separately from shell midden, recording this material in aggregate by weight (see Chapter 8). By the 1988 season, however, I had become aware that the production of shell fishhooks was likely to have been a major activity at ECA, and therefore decided to separate out all chipped and worked *T. niloticus* shell for more detailed counting by shell part. As reported in Chapter 3, the distribution of worked *Trochus* shell across the horizontal extent of the W250 transect displays a high frequency between Units N90 and N120, suggesting that a great deal of shell-working was going on in the stilt houses situated in this vicinity.

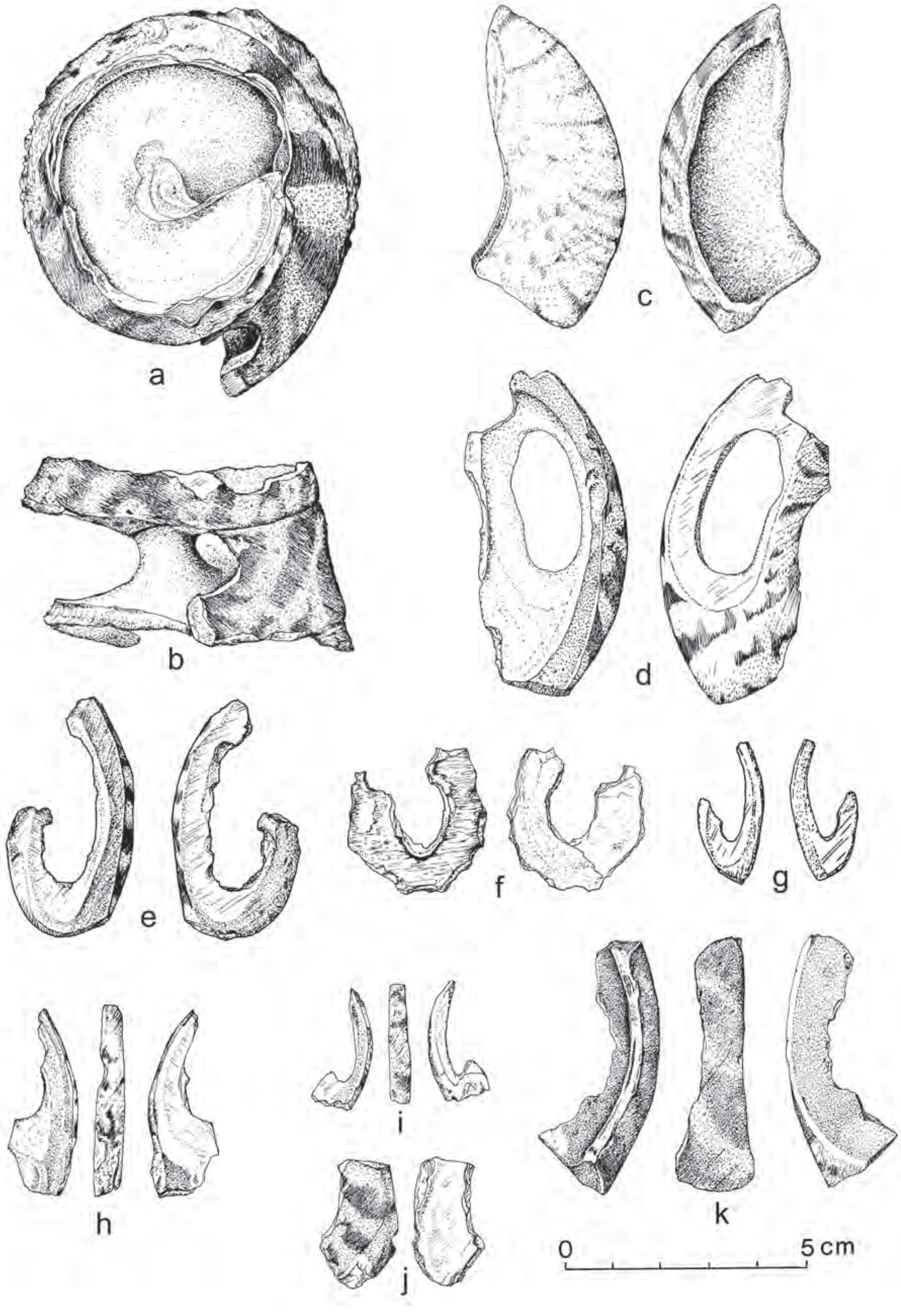

Figure 13.21. Stages of fishhook manufacture: *a*, *b*, worked *Trochus niloticus* shell, EKQ-1-23-2; *c*, fishhook preform, EKQ-1-7-15; *d*, fishhook preform with perforation, ECA-67-3-4; *e*, unfinished fishhook, ECA-39-8-33; *f* to *k*, unfinished fishhook fragments, *f*, EKQ-1-8-7, *g*, ECA-40-7-21, *h*, EKQ-2-11-4, *i*, EKQ-1-8-5, *j*, *k*, catalog data missing. (Drawings by Margaret Davidson.)

Figure 13.22. Stages in the sequence of fishhook manufacture: *a*, *Trochus* shell rough-out, ECA-52-5-6; *b*, *Trochus* shell preform, ECA-50-3-8; *c*. preform with perforation, ECA-67-3-4; *d*, unfinished fishhook, ECA-39-8-33.

In sorting the worked *Trochus* shell from the W250 transect in 1988, we divided the material according to three morphological classes: (1) chipped remnant columellar sections, which would be the detritus resulting from removal of the prized basal whorl, that section of the shell which was turned into hook blanks and preforms; (2) chipped basal whorls separate from the columella; and (3) miscellaneous smaller chipped fragments. The counts of worked *Trochus* shell from all W250 transect units by these categories are shown in Table 13.3. These data indicate the considerable extent of *Trochus* shell-working at ECA. As there is also far more detritus than would be expected for the relatively small number of finished hooks recovered from the site (since it takes just one base section, corresponding with one columella, to make a single hook tab), these data also suggest that a significant number of finished hooks were not used at Talepakemalai itself, but were exported to other communities. A likely possibility is that fishhooks were items of exchange or trade that were moving out of Mussau, against other imported material goods such as ceramics and obsidian.

Table 13.3. Worked *Trochus niloticus* shell from the W250 transect, site ECA

Type of Material	N	Percent
Chipped columellae	503	78
Chipped basal whorls	30	5
Chipped fragments	112	17
Hook preforms	2	0.3
Total	647	

Table 13.4 summarizes the distribution, by site, of fishhook blanks, preforms, unfinished hooks, and finished (including broken) hooks. *Blanks* are defined here as roughed-out basal whorl sections of *Trochus* shell, whereas *preforms* have been sufficiently worked by chipped and/or preliminary grinding so that the overall outline of the intended fishhook is evident. Unfinished hooks have been further worked into the specific shape of the intended hook, and have had considerable chipping and grinding. Not included in counts given in Table 13.4 are small fragments of worked *Trochus* shell, which were quite common, and which were not generally separated from *Trochus* shell midden.

Table 13.4. Distribution of fishhook blanks, fishhook preforms, unfinished fishhooks, and finished fishhooks from Mussau Lapita sites

Site	Fishhook Blanks	Fishhook Preforms	Unfinished Fishhooks	Finished Fishhooks
ECA	183	16	5	17
ECB	11	9	0	2
EHB	10	5	0	0
EHM	2	0	0	0
EHN	11	0	0	0
EKO	1	0	0	0
EKQ	7	2	1	4
TOTALS	225	32	6	23

Angling Hooks

Angling hooks are more frequently represented in the Mussau assemblages, with 19 specimens for which diagnostic features can be ascertained (i.e., either whole or complete finished hooks, or unfinished hooks that display measurable traits). These fishhooks are listed in Table 13.5 with their metric attributes and notes on morphology. A selection of 12 angling hooks, including all of the more complete specimens, are illustrated in Figure 13.23.

As noted earlier, most angling hooks are of *T. niloticus* shell, although a few are of pearl shell (e.g., Figure 13.23, j, k). The larger *Trochus*-shell hooks (Figure 13.23, a–g) display minor variations in certain features, but as a set are fairly consistent in morphology. The shank, formed from the outer shell whorl, is fairly thick and has a distinct inward curvature. The shank head was modified for line-lashing by filing two to four (but usually three) grooves, about 0.75–2 mm deep, on the outer side of the shank. The base of the hook (bottom of the bend) is either rounded or, in some specimens, distinctly flattened. Where present, the points are all incurved, so that the hooks would be classified as "rotating hooks" (Emory et al. 1959:10, 14). Jabbing hooks (in which projection of the point angle does not cross the shank) are also present, represented by a fine example from ECA (ECA-68-6-4). Two smaller hooks exhibit two exterior shank grooves for their lashing devices (Figure 13.23, i, j), with the grooves spaced more widely apart than in the larger hooks.

Although the sample size is small, a considerable range in fishhook sizes is evident. Of 14 hooks with measurable shank lengths, the smallest hook had a shank length of 15.5 mm, and the largest of 63.5 mm; the mean is 41.2 ± 14.9 mm. It is likely that there were functional differences between the smaller and larger hooks, as argued also for a similar range in hook sizes in the larger sample of archaeological hooks from Tikopia (Kirch and Yen 1982:239–243, Figure 96). The smaller hooks may have been intended for use on the shallow reef flats or at the reef margins, whereas the larger, more massive hooks would have been suitable for hand-lining in deeper waters off the reef edge (presumably from canoes), and for catching such fish as large groupers (Serranidae).

Trolling Hooks

One unfinished and seven finished (whole or broken) trolling hooks were excavated from sites ECA (4 specimens), ECB (1 specimen), and EKQ (3 specimens), as illustrated in Figures 13.24, 13.25, and 13.26. These hooks were made exclusively of *Trochus niloticus* shell, and were one-piece hooks (i.e., the shank, bend, and point were all of a single piece of shell). (Because these were one-piece hooks, they are not referred to as trolling "lures," as the term *lure* properly applies to the separate shank component of a two-piece trolling hook.) However, they probably were the prototype for two-piece trolling lure-hooks known from later Oceanic sites and from the ethnographic record (e.g., Reinman 1967:135, Figure 7). The principal difference between these

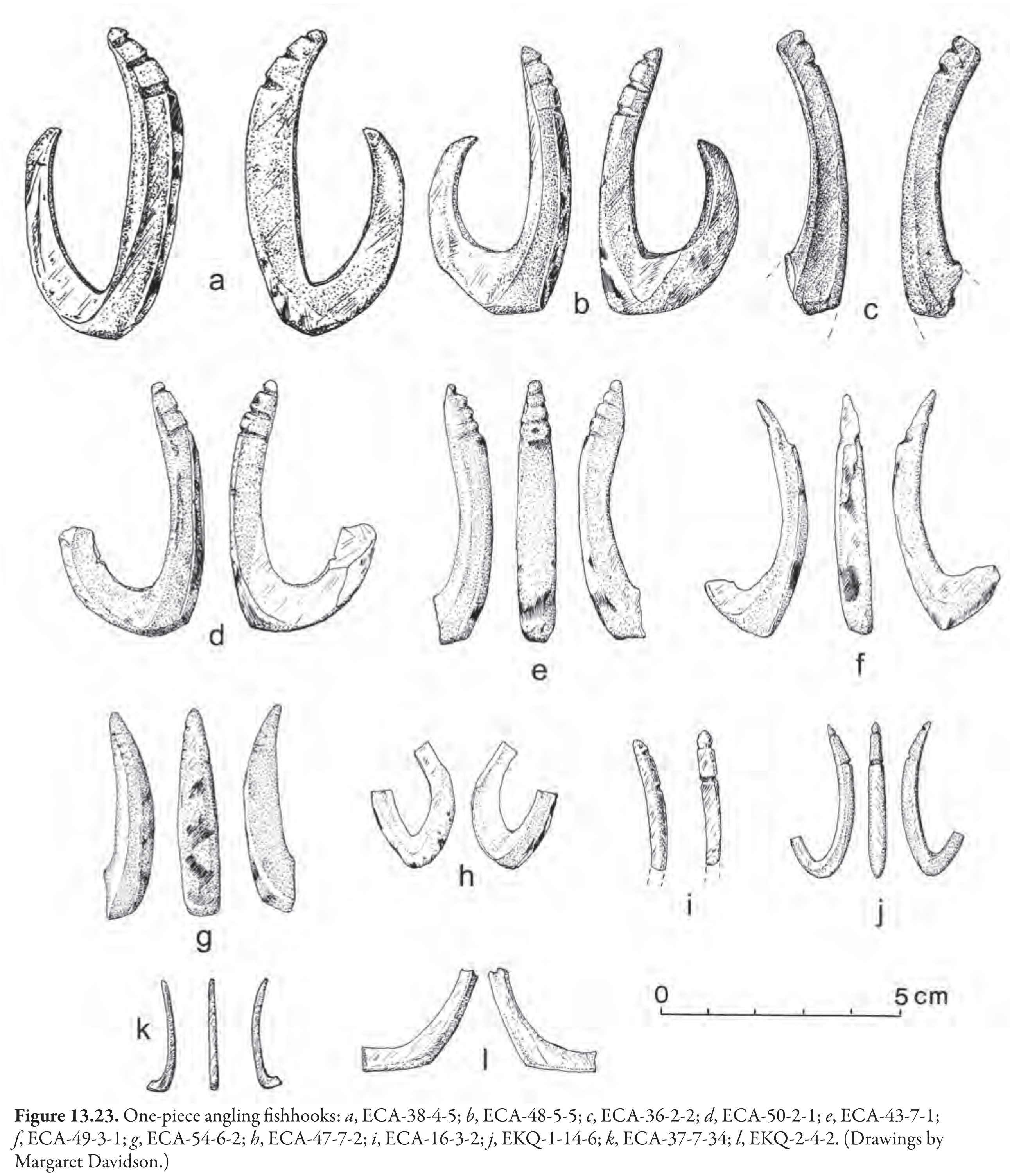

Figure 13.23. One-piece angling fishhooks: *a*, ECA-38-4-5; *b*, ECA-48-5-5; *c*, ECA-36-2-2; *d*, ECA-50-2-1; *e*, ECA-43-7-1; *f*, ECA-49-3-1; *g*, ECA-54-6-2; *h*, ECA-47-7-2; *i*, ECA-16-3-2; *j*, EKQ-1-14-6; *k*, ECA-37-7-34; *l*, EKQ-2-4-2. (Drawings by Margaret Davidson.)

trolling hooks and the angling hooks just described is that the former have a fusiform shank when viewed in profile, a design feature that would have allowed them to "plane" when towed or pulled through the water on the end of a line. This shape is in marked contrast to the angling hooks, which are distinctly squared-off or blunt when viewed from the side. A second key feature identifying them as trolling hooks (and distinguishing them from the angling hooks) is a groove (or grooves) at the base of the point, presumably for the attachment of hackles (such as pig bristles).

Table 13.5. Description of angling-type fishhooks from Mussau Lapita sites (SL = shank length, W = width, PL = point length)

Catalog No.	SL (mm)	W (mm)	PL (mm)	Weight (g)	Comments*
ECA-16-3-2					Head and partial shank; pearl shell?
ECA-36-2-2	57.5			8	Shank only; flattened base; lashing device consists of 2 grooves
ECA-37-7-34	22.5			0.1	Pearl shell; very slender shank
ECA-38-4-5	63.5	33.5	44+	16	Complete except for point tip; point incurved (rotating hook); lashing device consists of 3 deep grooves
ECA-39-8-33	49	26	27+	7	Unfinished preform, partly ground; appears to be rotating form
ECA-40-7-21	30+	13.5		1	Nearly finished, broken; pointed base
ECA-43-7-1	53.5			6	Shank only; flattened base; lashing device consists of 4 grooves
ECA-47-7-2		18		1	Bend only
ECA-48-5-5	55	31	37	13	Complete hook; incurved point (rotating); lashing device consists of 3 grooves
ECA-49-3-1	49+			4	Shank and bend only; head broken
ECA-50-2-1	52	30		8	Point tip missing; lashing device consists of 3 grooves
ECA-50-4-6				7	Unfinished hook; ground but broken specimen
ECA-54-6-2			41	4	Point only
ECA-67-3-3				1	Partial shank only; 2 line-lashing grooves evident
ECA-68-3-1			25	1	Point only; thin and delicately worked
ECA-68-6-4	15.5+	8	8	0.1	Delicate jabbing-type hook; pearl shell; head missing
ECA-90-3-1	36.1			3.2	Unfinished hook with point broken; partially ground
ECA-91-2-2	36.7			1.6	Shank and bend only; lashing device consists of 2 deep grooves
ECB-16-4-3				2	Partial shank only
EKQ-1-14-6	31.5	14.5+		1	Pearl shell; shank and bend; lashing device consists of 2 grooves
EKQ-2-11-4	24.5+			1	Unfinished, broken

*All hooks of *Trochus niloticus* shell unless otherwise noted.

The most complete trolling hook (missing only the point tip) from Mussau is a specimen from W250N100 of site ECA, shown in Figures 13.25 and 13.26. The lanceolate shape of the shank is evident, as is the pronounced V-shape of the bend. Note the protruding lug with three fine grooves at the distal base of the shank (shown in the figure inset), presumably for lashing hackles onto the shank. The trolling line itself would have been attached to the proximal end of the shank by means of the two deep grooves. The hook, measuring 70 mm overall, is finely executed and polished.

Other trolling hook specimens are illustrated in Figure 13.24. An unfinished hook from ECA (Figure 13.24, f) can be distinguished as a trolling hook from its fusiform shape and the acute angle (V-shaped) of the shank-point bend; the overall length of this hook is 64 mm. Another specimen from ECA (Figure 13.24, b) is missing the point, which has broken off at its base, but is otherwise complete. This hook is 50 mm long, and has a single groove at the point base, along with two grooves for line-lashing near the proximal shank end. Similar shank ends with dual

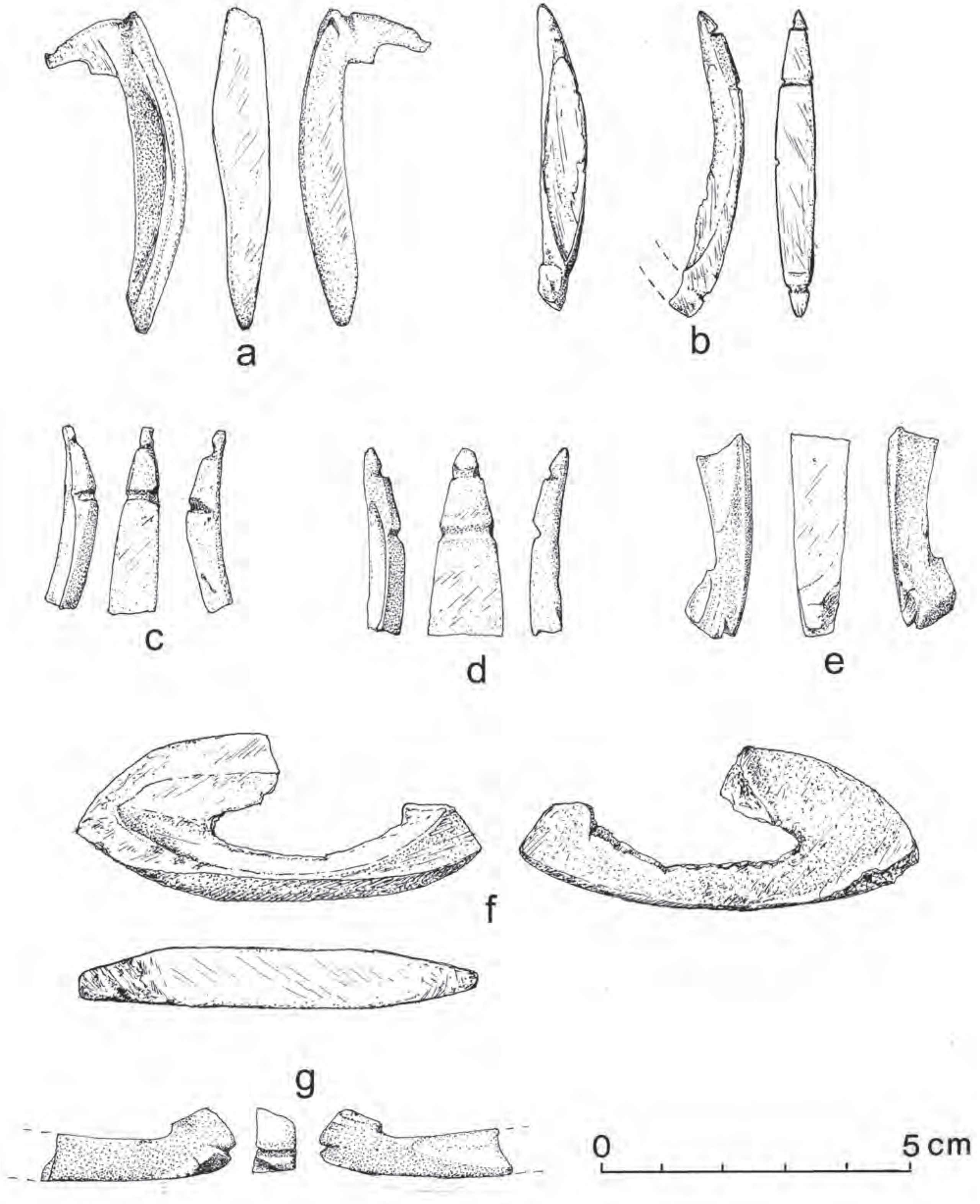

Figure 13.24. Trolling hooks: *a*, EKQ-2-9-2; *b*, ECA-49-4-2; *c*, EKQ-2-13-3; *d*, ECA-44-5-2; *e*, ECA, catalog data missing; *f*, ECA-52-2-3; *g*, EKQ-1-8-4. (Drawings by Margaret Davidson.)

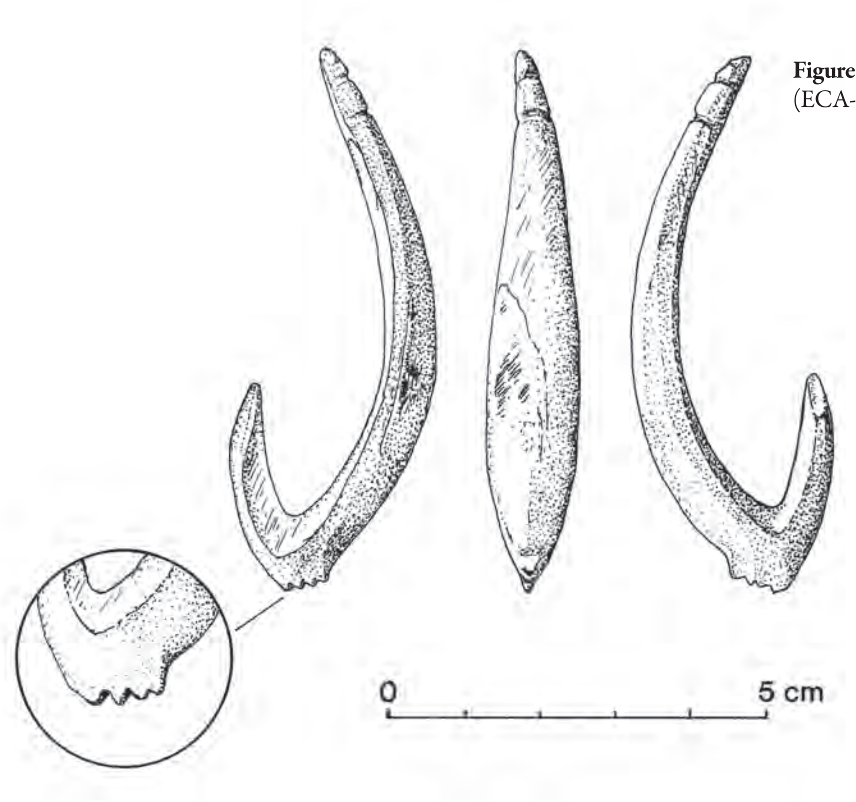

Figure 13.25. Complete trolling hook from site ECA (ECA-74-5-1). (Drawing by Margaret Davidson.)

Figure 13.26. Photograph of complete trolling hook from site ECA (ECA-74-5-1).

line-lashing grooves were also found at ECA and EKQ (Figure 13.24, c, d). Two incomplete, distal-shank fragments from ECB and EKQ also display single grooves for hackle-lashing at the shank tip (Figure 24, g).

The final specimen, from site EKQ (Figure 13.24, a) also has a missing point but is otherwise complete, and displays an entirely different form of line-lashing device. This hook, which measures 51 mm long overall, has a pronounced, stepped lug or limb at the proximal end of the shank, standing up 17.5 mm from the shank base. This lug is grooved completely around its base, and there is a second small groove on the exterior surface of the lug just below its tip.

Net Weights

Two shell artifacts that most likely functioned as net weights both came from Unit W200N145 at ECA. The first (ECA-67-1-1) is a complete valve of *Tridacna crocea* (160 mm long) with a circular hole 35 mm in diameter chipped (and partly ground on the exterior surface) through its center (Figure 13.27). The second specimen (ECA-67-1-2) is a slightly smaller piece of *Hyotissa hyotis* shell (85 mm long) with a similarly chipped, circular hole (14 mm diameter) in the center. Figure 13.28, a, illustrates a complete valve of *Spondylus* shell from the Boliu site (EKE), where it was in a post-Lapita context. This shell also has a roughly chipped hole 18–23 cm in diameter. At the Elunguai site (EHK), Araho recovered 18 *Anadara antiquata* shells that had roughly chipped or pecked perforations through them, which he interpreted as net sinkers. These EHK net sinkers are also in post-Lapita contexts.

Possible Net Gauge

A widespread artifact class associated with nets and netting throughout Oceania is a gauge, often made of bone, used to assure uniformity in mesh size during the process of knot tying (Buck 1957:290–291). A bone plaque from Area B of site ECA may well have served this function. The plaque, which is rectangular, was carefully worked from sturdy bone, almost certainly turtle plastron (Figure 13.28, b). It measures 51 by 25 mm, and has a corner that was broken off, possibly during excavation.

A flat "plaque" of heavy bone, probably turtle plastron, was recovered from Area B of site ECA (ECA-55-9-8). This specimen is 60 mm long, has a maximum width of 31 mm, and maximum thickness of 9 mm; its cross section is slightly elliptical. It may be the preform stage for an artifact of unknown type, or possibly for a net gauge.

Chronological Distribution of Fishing Gear

All of the angling and trolling hooks from the Mussau sites, including all obvious blanks and preforms, are from exclusively Lapita contexts. At Talepakemalai, hooks are represented from contexts on the elevated beach terrace (the complete trolling hook from W250N100), from Area B, and from later contexts in Area C. The trolling hooks

Figure 13.27. Perforated *Tridacna crocea* shell, possibly a net weight (ECA-67-1-1).

from site EKQ also extend the temporal range of trolling hooks into the early first millennium BC, based on our radiocarbon chronology.

Although the sample size is small, it is possible to infer a change, from early to late Lapita phases, in the form of the line-lashing device on trolling hooks. The hooks from ECA all have dual grooves on the base of the shank at its proximal end, whereas the nearly complete hook from EKQ has an upright lug or limb. This latter kind of lashing device is similar to that found on trolling hooks in Lapita contexts from Tikopia (Kirch and Yen 1982:243–244, Figure 97), and from Nendö Island in the Santa Cruz group of the eastern Solomon Islands (McCoy and Cleghorn 1988:110, Figure 6); these also date to the early first millennium BC. It seems possible that during the several centuries represented by the Lapita record in Mussau there was a shift in the form of the trolling hook lashing device to the upright limb type, which had become prevalent by the time of the Lapita expansion eastward out of the Bismarck Archipelago into Remote Oceania.

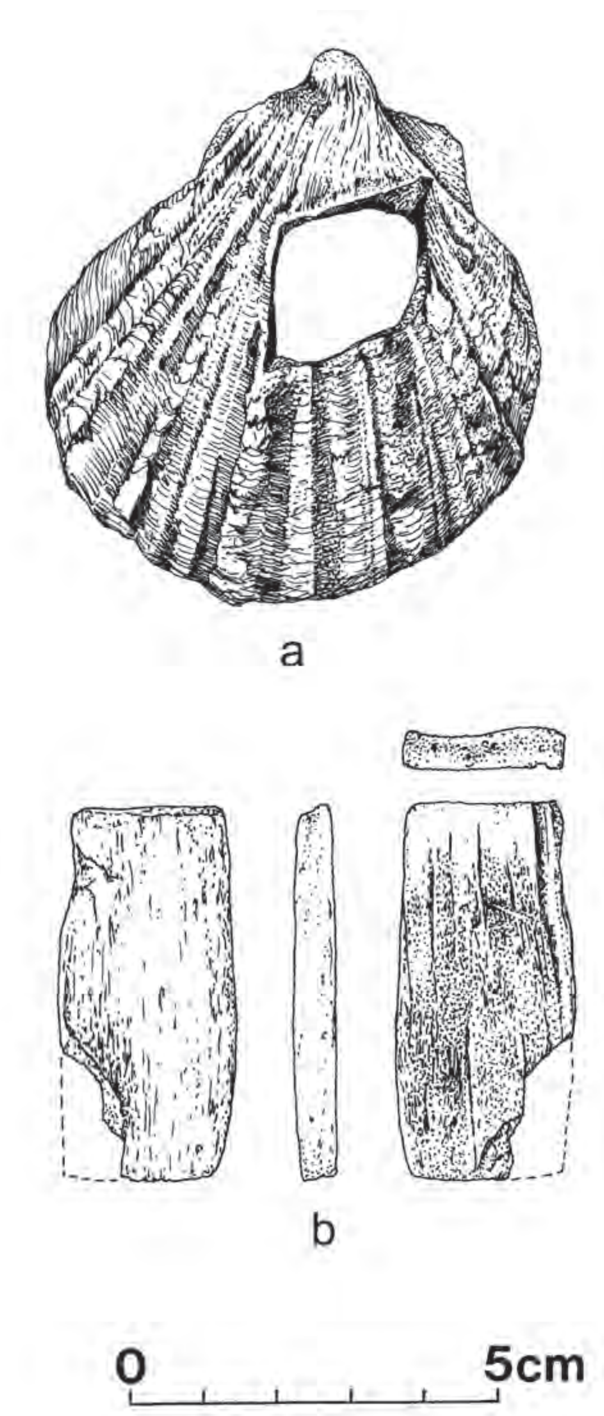

Figure 13.28. Fishing gear: *a*, probable net weight of *Spondylus* shell, from site EKE; *b*, possible net gauge of bone, from site ECA. (Drawings by Margaret Davidson.)

It is significant that not a single fishhook was recovered from any of the post-Lapita site excavations. Parkinson (1907:327) reports that he did not see any fishhooks during his visit, although he describes nets in some detail. However, some of the Mussau prisoners Parkinson interviewed in Kokopo told him that hooks of shell and turtle shell were used. Nevermann (1933:89–90, Figure 31) describes and illustrates some rather crude-looking one-piece hooks of turtle shell from Eloaua and Emira, quite unlike our Lapita-period specimens in shape or form. Chinnery (1925) describes several methods of fishing in use at Emira (with nets, baskets, and using poisons), but none involving hooks. The extent to which hooks were a part of the technological repertoire of the Mussau fisherman in post-Lapita times is thus uncertain. The archaeological record suggests that hooks, if known, were uncommon, and this is in congruence with the minimal ethnographic data.

Net sinkers, while not common in our sites, are represented in both Lapita and post-Lapita contexts (sites ECA, EKE, EHK), and suggest that nets were in use throughout the entire sequence. For the ethnographic period, Chinnery (1925:184) mentions that Mussau nets (called *uben*) were weighted with "shell or stone sinkers" (called *atu uben*), confirming Parkinson's earlier statement that nets were weighted with stones, coral lumps, or shells (1907:326). The Mussau term *uben* for net is of interest, since this is clearly a cognate reflex of the Proto-Oceanic term **kupenga* (Kirch 1997:Table 7.1).

Food Preparation Equipment

Cypraea-Shell Scrapers

The most common type of scraper in the Mussau collection consists of the dorsal "cap" of the large cowrie shell *Cypraea tigris* (N = 114), which were present at sites ECA (102 specimens), ECB (6 specimens), EHB (4 specimens), and EKS (2 specimens). These scrapers can be divided into two subtypes, those exhibiting a purposefully ground scraping edge (N = 28) and those lacking a ground edge but with significant edge wear (N = 86). After removing the dorsum of a large *C. tigris* shell, one edge was ground against an abrasive surface (probably a large stone) to create an arc-shaped bevel that could be used to scrape the rounded surfaces of tubers such as taro or yam, or of breadfruit (Figure 13.29, b, d; Figure 13.30). Probably all of these scrapers originally had such prepared scraping surfaces, but over time and with extensive use in the majority of cases the bevel has been worn away, leaving only a smoothed edge. Some of the scrapers evincing the great degree of edge wear (rounding and polish) are also the smallest, suggesting that they were used over extended periods of time until they became quite reduced in size. Two of these cowrie-shell scrapers also have small holes drilled through, perhaps for the attachment of a line or cord.

Cypraecassis-Shell Scraper

At site ECB we found one scraper made of the large shell of *Cypraecassis rufa* (Figure 13.29, a; Figure 13.31) As with the cowrie-shell scrapers just described, this has a purposefully ground arc-shaped bevel that would have been very effective at scraping the skin of tubers or of breadfruit.

Pearl-Shell Peeling Knives

Another kind of implement for removing the outer skin of tubers or root crops was made by trimming and grinding the edges of the large, relatively thin valves of the pearl oyster (*Pinctada margaritifera*) to create sharp cutting edges (Figure 13.29, c, e, f; Figure 13.32). Such pearl-shell peeling knives are still used by the Mussau people to cut away the outer skins of taro, yams, and manioc prior to cooking; these implements are called *gaulu* in the Mussau language. I use the term "knives" here because the action applied to these implements is not one of scraping, but rather of grasping the thick, hinge portion of the bivalve in the hand and then pushing the ground, sharpened edge into and through the flesh of the tuber. We recovered twenty of these pearl-shell peeling knives, mostly from site ECA (N = 17), but also three at EKE. Several of the specimens were very carefully prepared, with squared off and well-ground, sharp edges.

Anadara-Shell Scrapers

A final category of scraper is that of the valves of *Anadara antiquata*, whose naturally serrated ventral margin is well suited to the task of scraping. Although hundreds if not thousands of *Anadara* shells were recovered in our excavations, we distinguished as scrapers only those displaying considerable edge damage or wear to their ventral margins. These scrapers were most common at sites EHM (N = 6) and EKO (N = 7), but were also present at ECA, ECB, EHB, and EKS. While the scraping of tubers is one possible use of these *Anadara* shells, they might also have been used to scrape non-food items, such as wooden artifacts (e.g., to smooth the insides of bowls, or of spear shafts).

Ornaments and Exchange Valuables

Beginning with Gifford and Shutler's excavations at the type site of "Lapita" (Site 13) on the Foué Peninsula of New Caledonia, the non-ceramic components of Lapita assemblages have been known to include a significant diversity of shell objects (see, for example, Gifford and Shutler 1956:Plates 6–8). These include a variety of objects that have often functionally been classified as "ornaments," including "beads," "pendants," "bracelets" or "armrings," and similar items, made primarily from *Conus*, *Trochus*, *Spondylus*, and *Tridacna* mollusk shells, but occasionally from other taxa as well. While some of these objects probably did function (at times) as items of personal ornamentation or bodily adornment, many of these Lapita shell objects are also either identical with, or strikingly similar to, ethnographically documented shell objects that functioned as valued items of exchange. Often such items were only incidentally worn as objects of bodily adornment, but were more typically displayed at feasts or other occasions at which exchanges were made. The classic ethnographic examples are, of course, the *Conus*-shell "armrings" (*mwali*) and *Spondylus*-shell necklaces (*soulava*) made famous by Bronislaw Malinowski in his study of the Kula Ring in the Massim region (Malinowski 1922:86–87; Campbell 1983). While Malinowski used the English terms "armring"

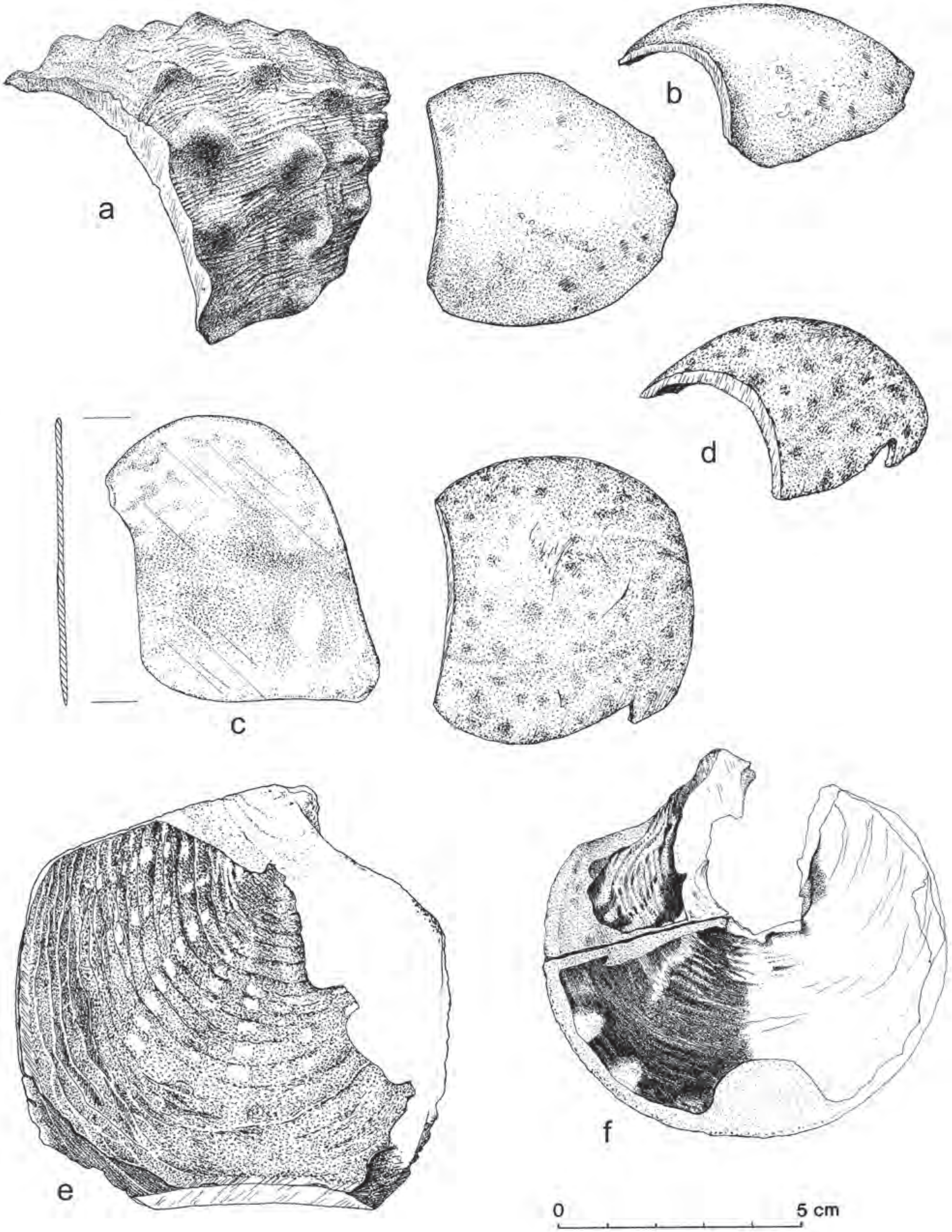

Figure 13.29. Scrapers and peeling knives: *a*, scraper of *Cypraecassis rufa* shell, ECB-10-5-4; *b*, *Cypraea*-shell scraper, ECA-32-3-18; *c*, pearl-shell peeling knife, ECA-31-10-24; *d*, *Cypraea*-shell scraper, two views, ECA-33-0-01; *e*, pearl-shell peeling knife with ground edge, ECA-46-7; *f*, pearl-shell peeling knife, ECA-40-8-9. (Drawings by Margaret Davidson.)

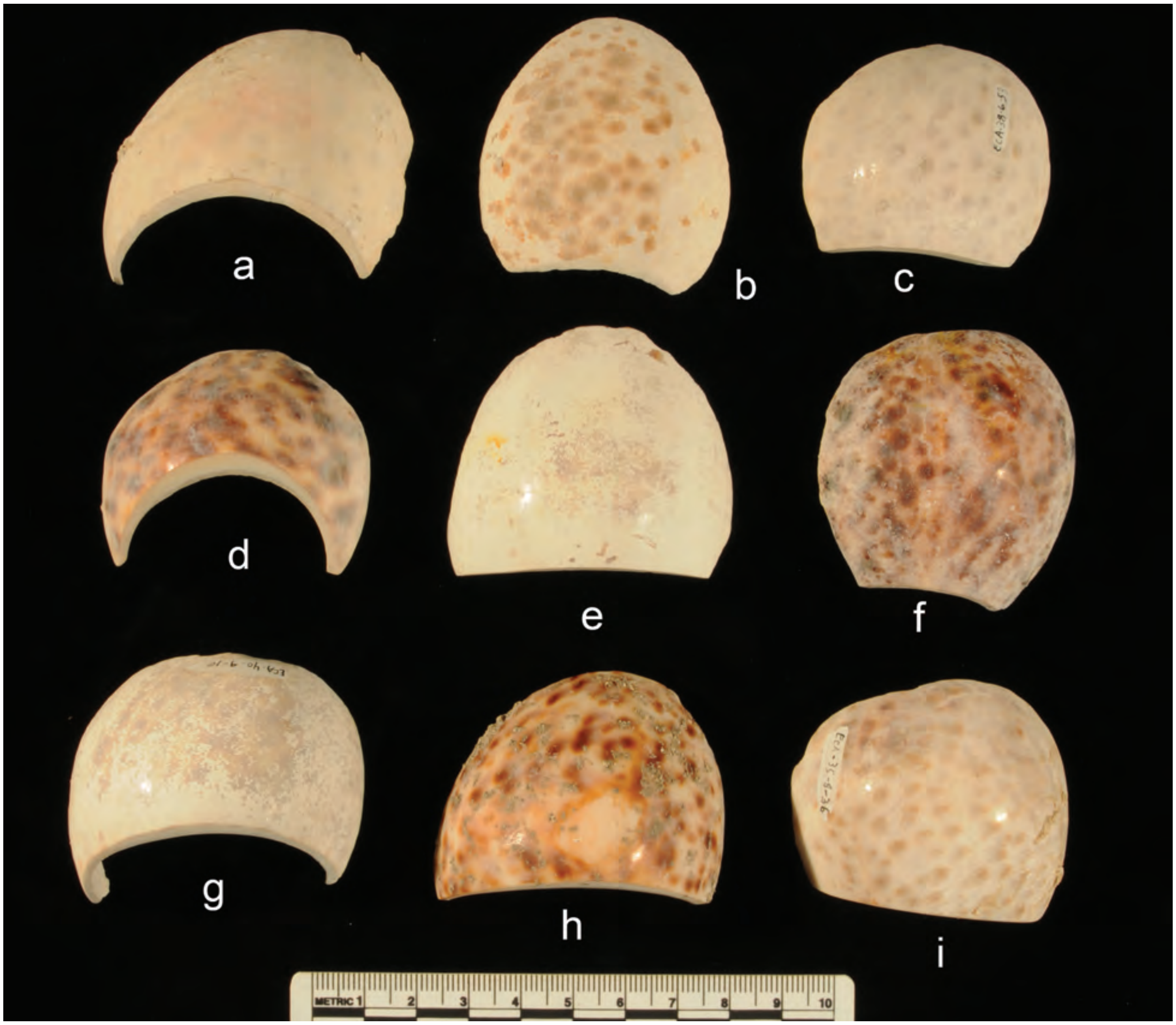

Figure 13.30. *Cypraea*-shell scrapers: *a*, ECA-63-3-1; *b*, ECA-17-7-7; *c*, ECA-38-6-53; *d*, ECA-51-4-1; *e*, ECA-48-7-15; *f*, ECA-54-5-3; *g*, ECA-40-9-10; *h*, ECA-9-3-5; *i*, ECA-35-8-36.

and "necklace" to describe these highly valued, counter-circulating objects, it is well known that the principal functions of these were not bodily ornamentation (although they might occasionally be worn for display purposes at ceremonial prestations). Rather, these *mwali* and *soulava* are better characterized as "exchange valuables." Other examples of such shell exchange valuables include shell armrings and larger *Tridacna*-shell rings in the New Georgia group of the western Solomons (Walter and Sheppard 2017:135), and the shell necklaces as well as *Tridacna*-shell rings of the Ulawa and Malaita region of the southeastern Solomons (Ivens 1927:Plates V and VI).

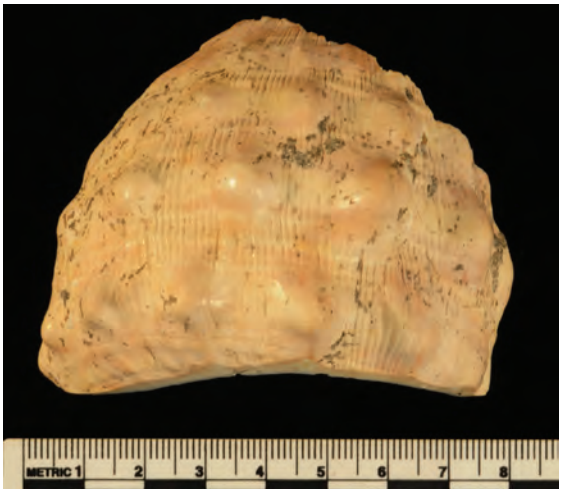

Figure 13.31. Scraper of *Cypraecassis rufa* shell, ECB-10-5-4.

Figure 13.32. Pearl-shell peeling knives: *a*, ECA-34-5-79; *b*, ECA-46-7-3; *c*, ECA-17-9-8; *d*, EKZ-0-0-1; *e*, ECA-31-10-24.

After completing our first two field seasons in Mussau, I became increasingly intrigued by the similarities displayed between many of the shell objects from Talepakemalai and other sites and ethnographically documented exchange valuables. Since we already had abundant evidence that Lapita communities were involved in extensive external exchange networks (from analyses of obsidian, ceramics, and other materials), it seemed likely that many, if not most, of the shell objects from Lapita sites had also functioned primarily as exchange valuables, much like their ethnographic counterparts. I advanced this hypothesis in a paper (Kirch 1988c) in which I reviewed the extant archaeological evidence for the distribution—both of finished shell objects, and of manufacture detritus—at ten Lapita sites. The evidence indicated that while finished shell objects were present at many sites, only a few sites in a region yielded evidence for the manufacture of certain shell artifact classes. From this analysis, I tentatively concluded the following:

> We can identify *Conus* rings and *Conus* beads as relatively common items, which were also widely manufactured. This suggests that *Conus* rings and beads played a role in high-frequency exchange transactions, such as would occur between local lineage groups in marriage and death transactions. Other object classes, such as rectangular *Conus* units, *Spondylus* long units and beads, and *Tridacna* rings, occur less frequently and were produced only by one or two manufacturing centers. These objects were probably prestige valuables analogous

> to the *kula*-ring armshells (*mwali*) involved in long-distance and in less frequent transactions between [more] distant exchange partners [Kirch 1988c:112].

Mussau was identified as one such Lapita community where there was substantial evidence for the manufacture of the full range of shell objects, including the *Conus*-shell rectangular units and *Spondylus*-shell long units and beads. I therefore suggested that the Mussau Lapita communities may have specialized in the production of shell exchange valuables, which they exported into a wider regional exchange network, partially to offset the importation into Mussau of such exotic materials as obsidian, chert, and pottery.

Additional evidence supporting a model of shell object production for exchange was obtained during the 1988 field season in Mussau. It is first necessary, however, to present a formal classification of these objects. Table 13.6 is a *paradigmatic* classification (see Dunnell 1971:70–76) of these items, in which each cell represents an ideational class created by the intersection of two main sets of defining criteria: (1) morphology or shape of the object; and (2) mollusk taxon. (Not included in this table are certain classes of detritus resulting from the manufacture process.) This simple classification (an earlier version of which was first presented in Kirch 1988c:Table 1) has proved to encompass the full range of variability within our Mussau assemblage, although some cells in the paradigmatic classification are empty (that is, they are not represented by any real objects). The classification could, of course, readily be expanded to encompass additional morphological or taxonomic variants.

Class A: "Long Units"

Poulsen coined the term "long unit" (1987:258–261), using it to refer to elongated, parallel-sided, generally round or oval-sectioned shell units, with drilled perforations at both ends, found by him in Tongatapu Lapita sites. The Tongatapu examples, described in further detail in Poulsen (1987:198–199, Plate 70), are all of *Tridacna* shell, here designated Class A1. We have no examples of this class from Mussau, but do have three specimens made from *Spondylus* shell, which I have designated Class A2.

The first of these, shown in Figure 13.33, d, is an oval-sectioned "bar" originally greater than 30 mm long (it probably measured about 34 mm before breaking across one of the drilled perforations), and 7 mm in diameter. It has a biconically drilled perforation at each end, as well as five notches or grooves along one side. These grooves are not evenly spaced, but rather are distributed with one near each end, and a cluster of three grooves near the center of the bar. The unit is finely polished overall.

A second specimen (Figure 13.33, e) differs in some respects from Poulsen's typical "long unit," and is only provisionally included here in Class A2. Made of *Spondylus* shell, it is 26 mm long and flattish in cross section, with a deep groove running along one face. It has two small, biconically drilled perforations, one near one end and the other about midway along the shaft. There is also a carefully filed semicircular notch cut out of one face.

The third specimen (not illustrated) appears to be a broken fragment of a "long unit," heavily weathered but probably of *Spondylus* shell. Its original dimensions cannot be determined, but it was somewhat longer than 31 mm. The remaining fragment has a biconically drilled perforation near the tip; the cross section is subrectangular.

Class B: Rectangular Units

The term "rectangular unit" was also coined by Poulsen (1967:263); Best (1984:473) used the term "broad unit" for the same kind of object, made from large *Conus* shells. In his later monograph on Tongatapu, Poulsen (1987:196–197, Plate 70) used the term "broad bracelet" as well. As there is no indication that these objects were ever worn as "bracelets," I prefer the functionally neutral term "rectangular unit," even though it is admittedly not the most visually evocative term. Indeed, these objects are only "rectangular" in one plane, since they are made from the curved body whorl of large species of *Conus*, particularly *C. leopardus* and *C. litteratus*. They might better be labeled "curved plates" of *Conus* shell, also morphologically characterized by having drilled perforations at their corners or along their margins, presumably for line attachment. The larger of these are not unlike the ethnographically famed *mwali* exchange valuables from the Massim region also made from the body whorl segments of large *Conus* shells. Although Malinowski referred to *mwali* as "armshells" and indicates that they were worn on occasion, these shell valuables were frequently suspended from thick rope circlets and displayed on poles carried between two men (Malinowski 1922:Frontispiece, Plates XVII and LXI). My hypothesis is that like *mwali*, the Class B rectangular unit *Conus*-shell objects from Talepakemalai and other Lapita sites were items of prestige display and exchange. The perforations may well have served to combine them with other kinds of shell objects, such as *Spondylus*-shell beads and pendants, or *Conus*-shell beads, making up complex, composite artifacts.

We recovered six examples of Class B rectangular units, all from Talepakemalai, along with another four artifacts that may be preforms. A complete example of a Class B object from Area B is illustrated in Figure 13.33, a. This consists of a section cut from a *Conus*-shell body whorl with an original diameter of about 80 mm, and having a width of 45 mm. The curved band or plate was removed from that portion of the outer shell whorl just below the spire, as the inner surface of the object still reveals a slight "shelf" that was not entirely eliminated during manufacture, where the whorl attached to the columellar spire. In each corner of the band is a single drilled perforation, 3–4.5 mm in diameter; all of these were biconically drilled except for one that was from the outer surface only. The entire outer surface had been carefully ground and polished.

A second complete Class B object was found in the Area C excavations in 1988. This is again a large band or plate from the outer whorl of a cone shell with an original diameter of about 70 mm. The superior margin of this specimen is marked by a 5 mm deep groove which cut more than halfway through the 8 mm thick shell, which had then been snapped or fractured to separate this object from the rest of the parent shell. Interestingly, there was no further effort to grind away or even smooth off the ragged margin left after this stage of manufacture. However, the anterior margins of the shell have been extensively ground and smoothed. Two sets of two perforations are found on either side of the curved anterior margin, 7 mm and 4.5 mm apart in each case; these were drilled only from the exterior surface.

What may be a preform for a large Class B object was found on the site surface at Area B (where it had probably been brought to the surface by burrowing land crabs). It is a rectangular band (45 mm wide) from a particularly large *Conus* shell, with an original diameter of 90 mm. Lacking drilled perforations, it may not have been finished. The specimen is weathered and chalky from exposure to the elements and probably also to humic acids.

From the Area B extension units excavated in 1988 we recovered a broken piece of what appears to have been a fairly large Class B *Conus*-shell unit, with a width of 38 mm but indeterminate original diameter (its length, broken, is

Table 13.6. A paradigmatic classification of Lapita shell exchange valuables

Morphology	Material (Mollusk Genus)				
	Tridacna	*Spondylus*	*Conus*	*Trochus*	*Pinctada*
A. Elongate bar with end perforations	A1	A2			
B. Rectangular unit with corner perforations			B		
C. Rings or "circlets"					
Diameter < 5 cm			C1		
Diameter > 5 cm	C2			C3	
D. Disks with central perforation		D2	D1		D3
E. Beads		E2	E1		E3
F. Pendants	F1	F2	F3		F4

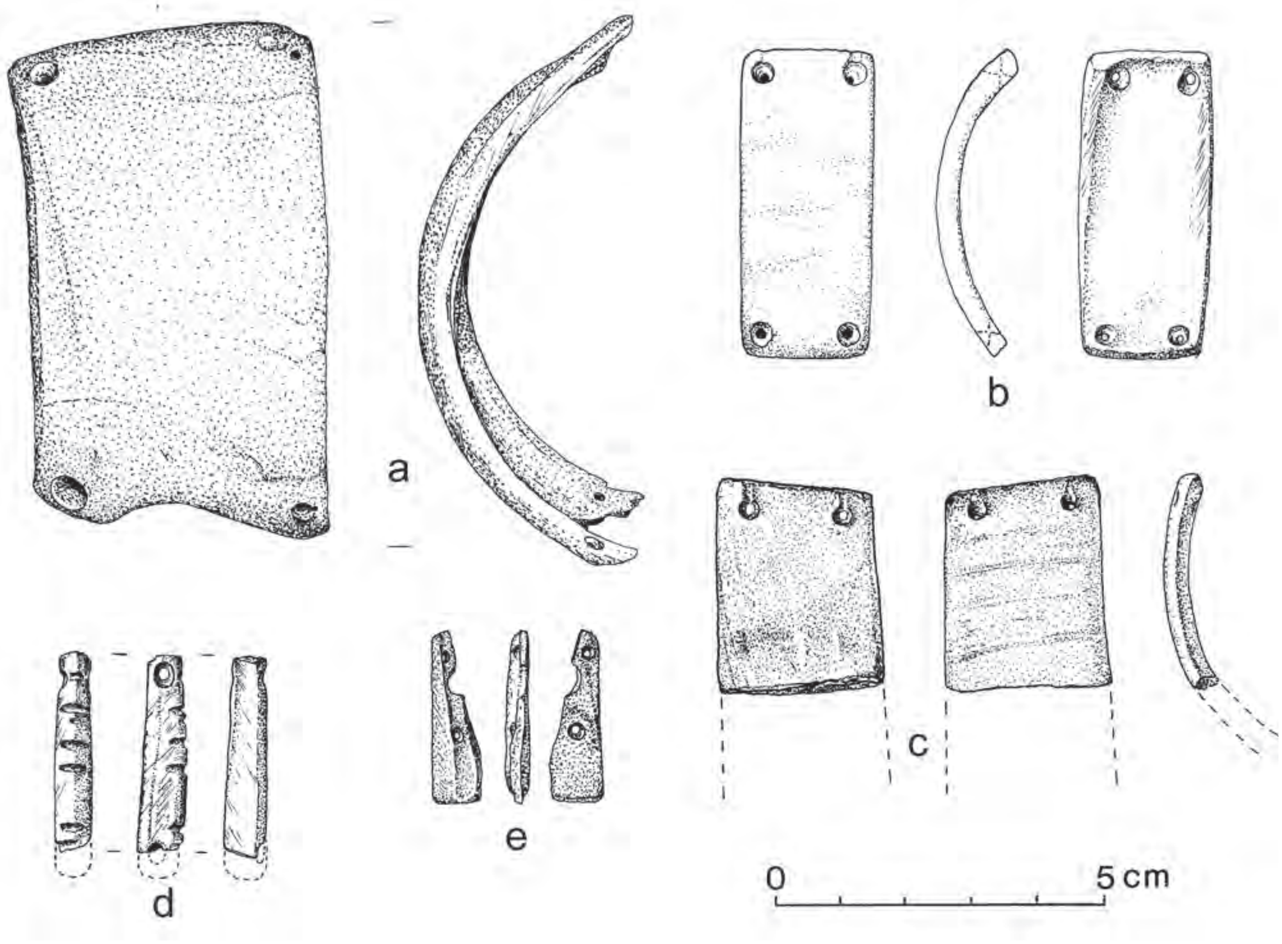

Figure 13.33. Shell exchange valuables: *a*, Class B rectangular unit, ECA-47-5-3; *b*, Class B rectangular unit, ECA-68-5-1; *c*, Class B rectangular unit, ECA-38-8-47; *d*, Class A long unit, ECA-40-8-8; *e*, Class A long unit, ECA-51-6-1. (Drawings by Margaret Davidson.)

35 mm). This has but a single drilled perforation, 4.5 mm in diameter, set in the middle of the extant end near the margin.

The other three examples of Class B objects are somewhat smaller in size, although similar in morphology to those discussed above. These smaller *Conus*-shell bands are identical to ethnographically documented exchange valuables from the Gulf Province of Papua New Guinea that were lashed with fiber string in sets of three, forming two or three parallel rows (see Cat. No. E1987.2-3, National Museum of PNG, from Avihara Village). The best example in our collection comes from the Area B Extension excavations, and is illustrated in Figures 13.33, b, 13.34, a, and 13.35, a. It was manufactured from a shell with an original diameter of about 70 mm, and measures 47 mm long and 21 mm wide. Each corner has a bi-drilled perforation (averaging about 3.5 mm in diameter). Curiously, the two perforations on one end have shallow grooves linking these with the shell margin, possibly the result of wear from a coarse fiber cord. A second complete specimen (Figure 13.34, c; Figure 13.35, d) from excavation Unit W200N160 is from a shell with an original diameter of about 70 mm, and measures 44 mm long by 15.5 mm wide. This differs from the previously described piece in having one drilled perforation centered at one end, and three perforations closely spaced at the other end. Close examination of this specimen suggests that it may have gone through two phases in its use-life, since the end or margin with the single perforation shows a rough, fractured edge which has only been partially reground. Possibly, the original piece had four drilled perforations, one in each corner; after breaking, a single new perforation was drilled near the freshly broken edge, and another single (larger) perforation centered on the other end. If this interpretation is correct, it might imply that these objects had a great deal of inherent value, sufficient to justify their reworking and reincorporation into composite exchange valuables, even after breakage. Finally, we have a broken specimen from Area B (Figures 13.33, c; 13.34, b; 13.35, b). This was from a shell with a diameter of perhaps 75 mm, and is 25 mm wide. Biconically drilled perforations are present in each of the extant corners, and on both interior and exterior surfaces there are shallow grooves connecting the holes with the outer margin or edge. Again, these grooves might be the result of wear from a rough fiber cord or lashing. This artifact is extremely well polished on all surfaces, including the end and margins, lending it an ivory-like feel in the hand. Indeed, all of these smaller *Conus*-shell bands have been very extensively ground and polished on their exterior surfaces, so that they exhibit no traces of the original shell surface or its coloration, but rather have an alabaster-like texture.

Three additional objects (ECA-51-1-2, ECA-54-6-10, and ECA-61-4-2) from Area B and vicinity might represent unfinished, or broken, examples of smaller Class B rectangular units, as these are in the size range of the smaller objects just discussed. All of them lack perforations.

Class C: Shell Rings

Three classes of what have variously been called "rings," "circular units," "bracelets," or "armrings" in the literature on Lapita artifacts are recognized here, depending upon the material from which they were manufactured. Most abundant in the Mussau assemblages are items of Class C1, made from the spire portion of several species of *Conus* shell. Although these objects have sometimes been functionally labeled as "bracelets" (e.g., Poulsen's "narrow bracelet" category, 1987:192–196), many are of diameters too small to pass over a human hand and wrist (except, perhaps, for those of a small child). Ethnographically, such rings are

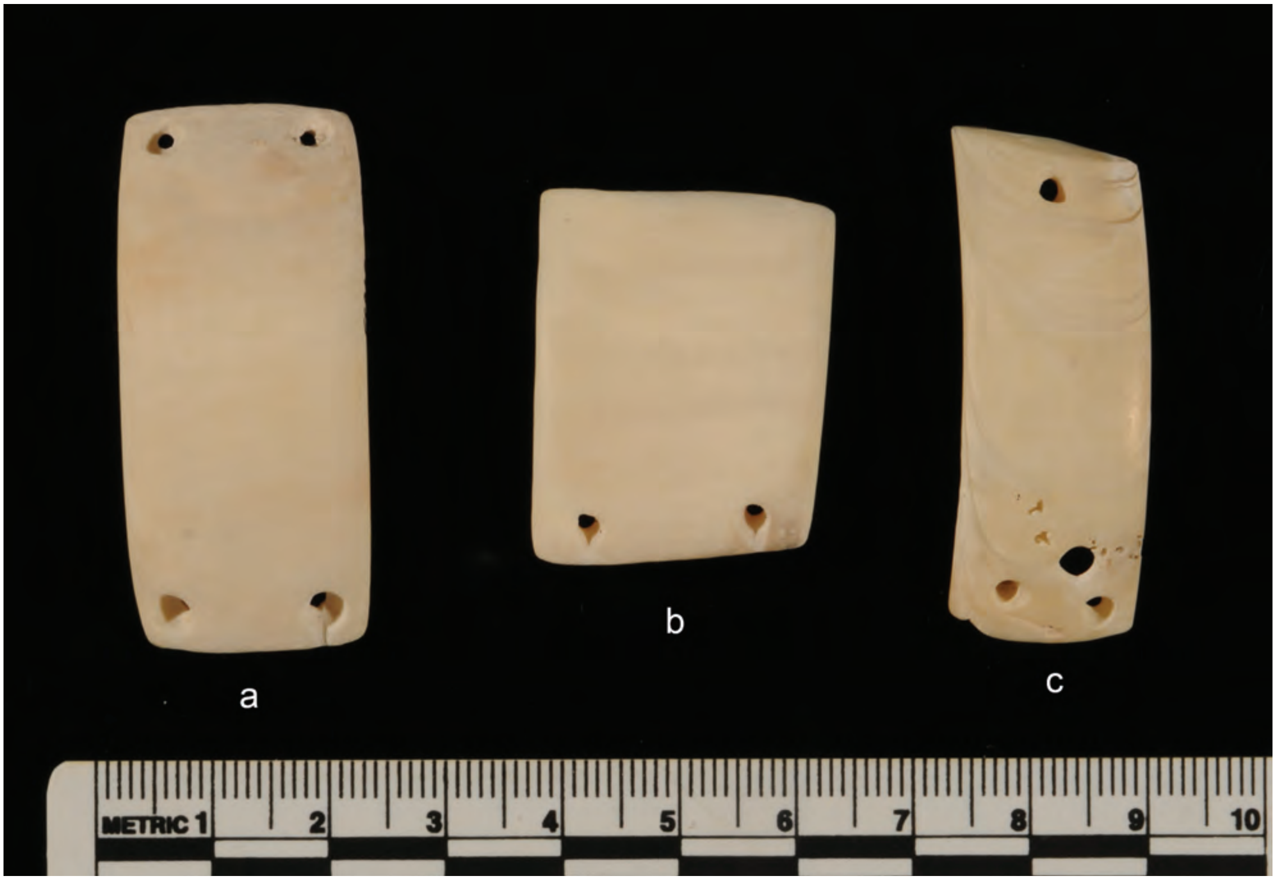

Figure 13.34. Class B rectangular units of *Conus* shell, front view: *a*, ECA-68-5-1; *b*, ECA-38-8-47; *c*, ECA-57-8-1.

known to have been lashed along with other shell objects onto wooden staffs or as part of compound exchange valuables, and this may well have been their function in Lapita times as well. This, of course, does not preclude some of the larger examples from having been worn. Class C2, made from *Tridacna* shell, generally have larger diameters, and may indeed have functioned as armrings or bracelets. Given that these *Tridacna* rings required the greatest investment of energy and time in manufacture (see below), it would be surprising if they were not also highly valued in Lapita communities. Whereas both Classes C1 and C2 are found in the Lapita-period assemblages, Class C3 "armrings" made from the large basal whorls of *Trochus niloticus* are confined in their temporal distribution to post-Lapita sites in Mussau. While these *Trochus*-shell rings are known from ethnographic accounts to have been worn on the upper arm, they are also valued items of exchange, particularly at the household level (such as marriage exchanges).

Class C1. *Conus*-Shell Rings

One of the most common shell artifact classes at Talepakemalai, and represented at several other sites as well, is a ring made from the spire of several species of *Conus* shell. Three whole rings were found at ECA, as well as 144 fragments of finished rings, and another 39 fragments from unfinished rings, presumably broken during the manufacturing process. This process, well exemplified by unfinished specimens from ECA and other sites, is described below. The ring diameters were controlled by the maximum diameter of the natural shell itself, at the top of the body whorl at its junction with the spire. This was the part of the shell extracted and sequentially chipped, ground, and polished to produce the finished ring. Three complete *Conus*-shell rings from Area B at ECA are illustrated in Figure 13.36, a–b, along with several typical broken fragments; the complete rings are shown in Figure 13.37.

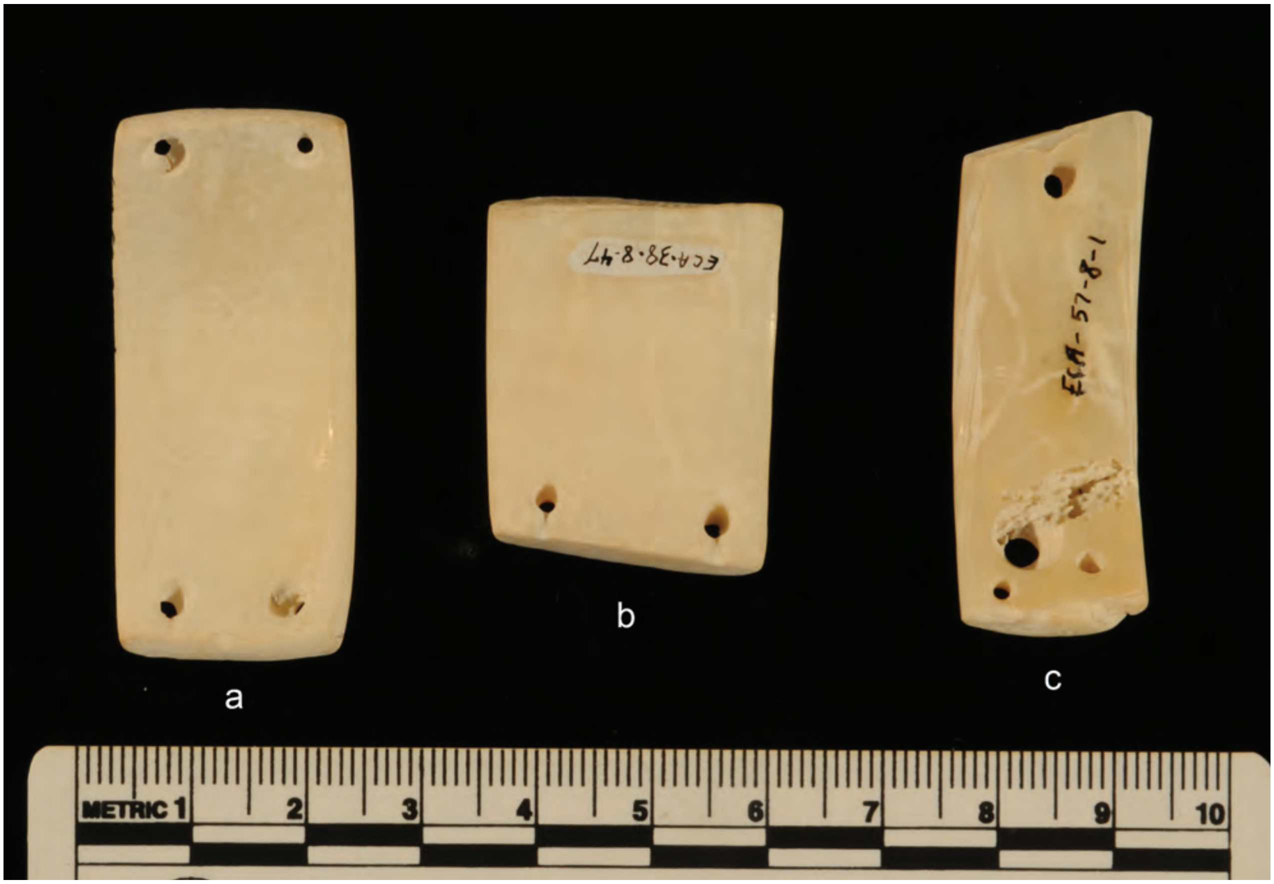

Figure 13.35. Class B rectangular units of *Conus* shell, back view: *a*, ECA-68-5-1; *b*, ECA-38-8-47; *c*, ECA-57-8-1.

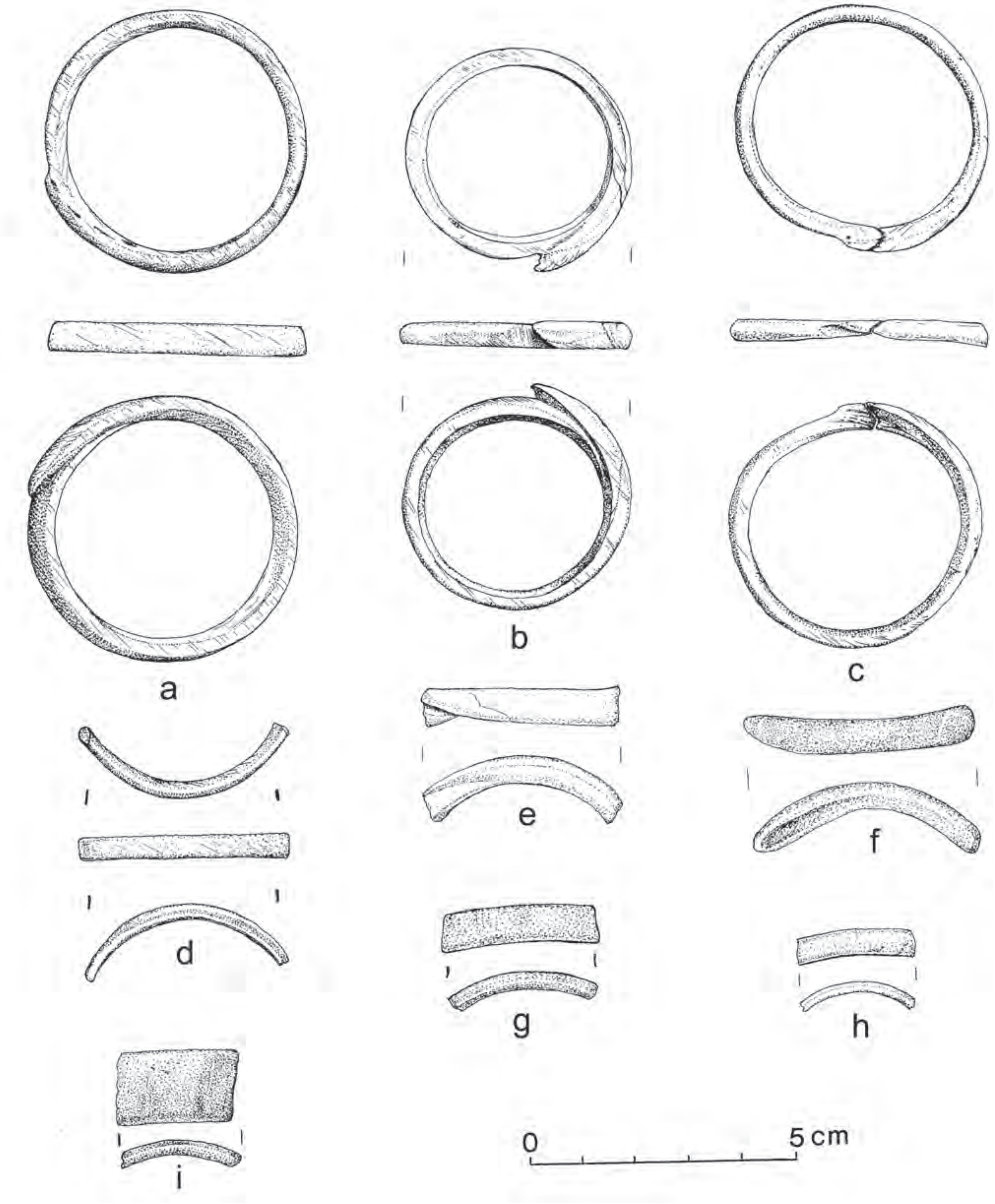

Figure 13.36. *Conus*-shell rings: *a*, ECA-37-9-53; *b*, ECA-36-12-31; *c*, ECA-36-12-30; *d*, ECA, catalog data missing; *e*, EKQ-1-14-5; *f*, EKQ-1-12-4; *g*, EKQ-1-9-6; *h*, EKQ-2-15-3; *i*, EKQ-1-15-5. (Drawings by Margaret Davidson.)

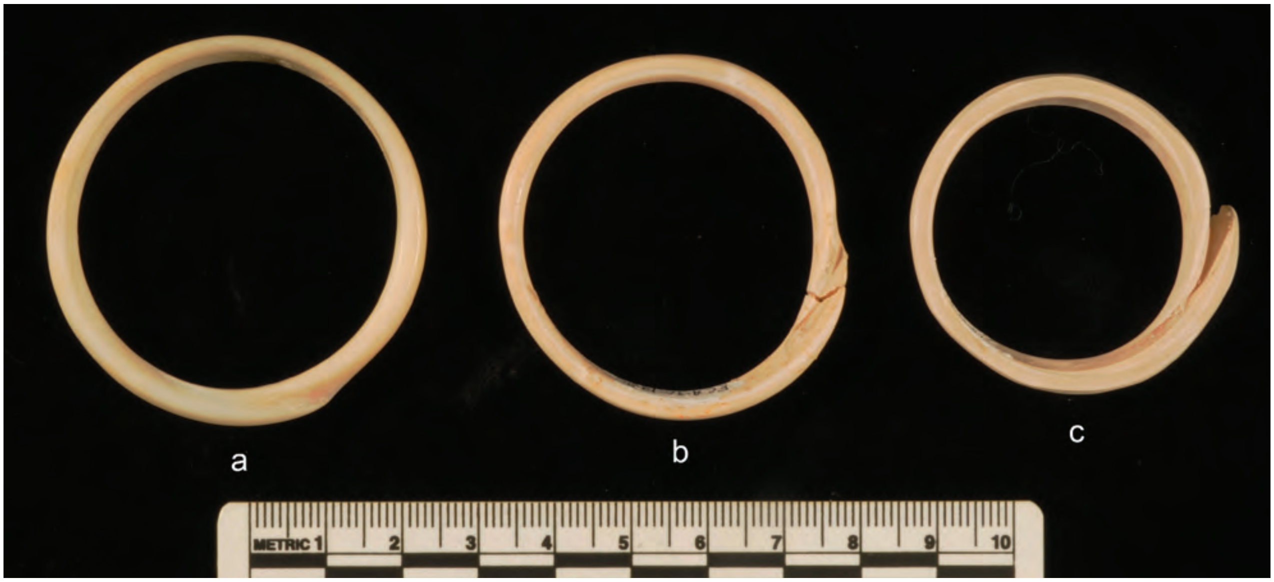

Figure 13.37. Complete *Conus*-shell rings: *a*, ECA-37-9-53; *b*, ECA-36-12-30; *c*, ECA-36-12-31.

A histogram plot of *Conus*-shell ring diameters for a sample of 68 measurable specimens from Area B (ECA) is shown in Figure 13.38. There is a strong mode at 40–45 mm diameter, a second mode at 60 mm, and outliers extending up to 80 mm. These largest rings were manufactured from one of two large species, *C. leopardus* and *C. litteratus*. For most rings, the species used cannot be determined because all traces of distinctive coloration patterns were removed by extensive grinding and polishing. The mean diameter is 50.84 ± 10.81 mm, with the range from 37–80 mm. Given that the majority of rings are less than 50 mm in (external) diameter, and that the average human wrist is typically greater than 60 mm, it is evident that few—if indeed any—of these objects were meant to be worn as "bracelets."

Width of the rings (their dimension when viewed from the side) also varies considerably, with a mean of 6.27 ± 2.33, and a range from 2.8–15.2 mm. There is a strongly unimodal distribution, with the mode at about 6 mm. Ring thickness varies only slightly, with a mean of 4.05 ± 0.89 (range 2.3–7 mm), which is not surprising given that this dimension is controlled primarily by the natural thickness of the cone shell.

Finished rings were typically thoroughly ground and often highly polished, giving them an "alabaster" appearance. Their cross sections also vary, and it seems that some effort was made to work them into particular shapes. Rounded, oval, rectangular, and square cross sections are all evidenced in the sample from Area B at ECA.

A single specimen, from excavation Unit W240N140 of site ECA, differs from all others in our sample in having a small, rectangular "lug" projecting from the outer surface of the ring, sticking out about 1.5 mm. The ring itself was finely made, with a square cross section 3.2 by 3.2 mm.

Manufacture of *Conus*-Shell Rings

The manufacturing process for *Conus*-shell rings is well represented by 40 unfinished rings and discarded detritus from Talepakemalai, three partly finished rings from site ECB, and a single large unfinished ring from site EKE (Figures 13.39, a–c). From these objects we can reconstruct the following steps in *Conus*-shell ring manufacture. (1) The first stage was to remove the spire (the portion of the shell from which the ring itself was produced) from the columella and body whorl. This seems to have been done in some cases by simple chipping, probably with a hammerstone, but in other cases a wide groove was abraded a few centimeters below the spire. Such abraded grooves are evidenced on 18 examples of rejected whorls or whorl fragments, as illustrated in Figures 13.39, d, and 13.40. The tool used to abrade these grooves could have been an *Acropora*-coral abrader (see above). However, since so few

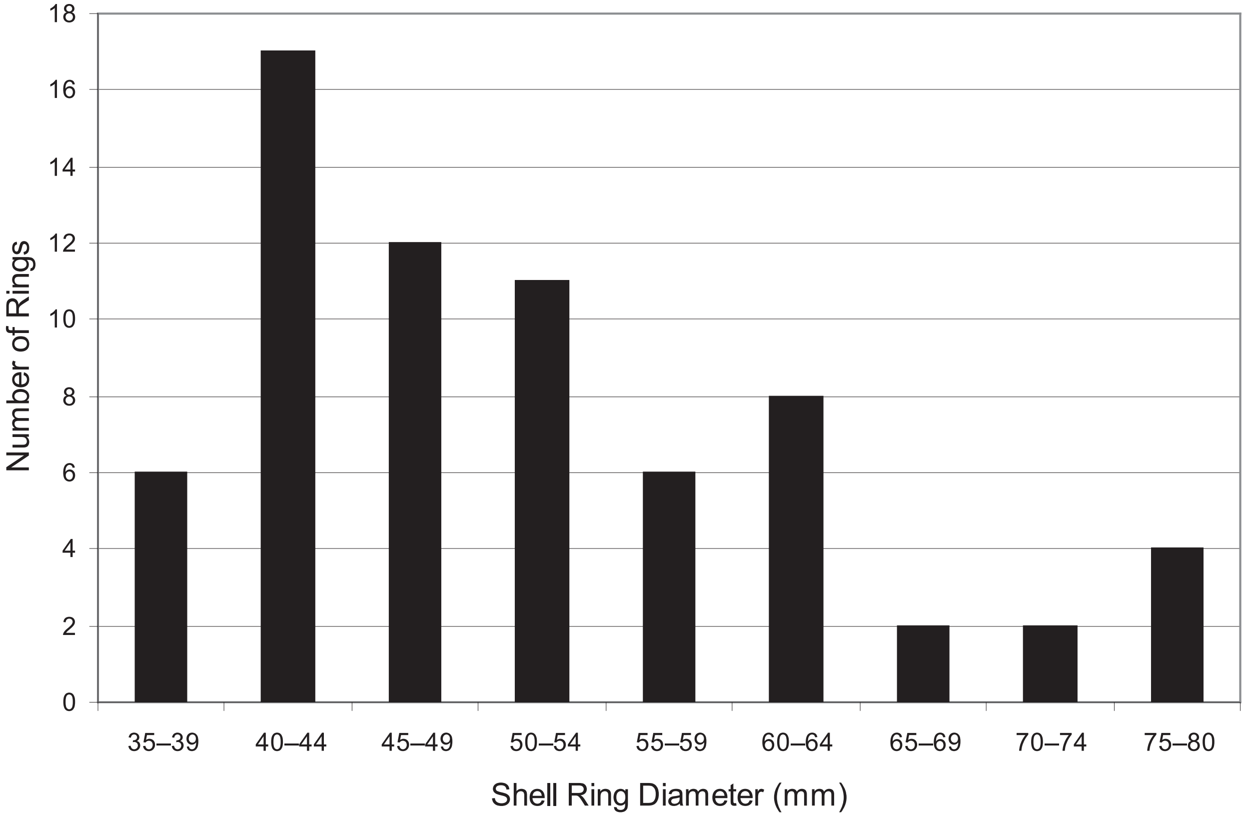

Figure 13.38. Histogram plot of *Conus*-shell ring diameters.

coral abraders were recovered from the site, we suspect that other tool types were involved. One possibility would have been an abrasive material such as ray or shark's skin stretched around a wooden shaft. (2) Once the spire had been removed, the ragged anterior edge was trimmed by chipping. (3) Grinding the spire then commenced, presumably by rubbing the spire against a stationary grindstone. There are examples in which only the anterior, or only the superior, surfaces have been ground, suggesting that there was no preferred sequence. Most specimens exhibit grinding on both superior and anterior surfaces. (4) The objective of grinding seems to have been to reduce the spire to a thin disc, at which point the remaining columella could be removed, leaving a nearly complete ring. (5) The final stage of manufacture was grinding to a uniform thickness and finishing of the interior edge, probably using a hand-held abrader of some sort. The outer edge was often left unground, so that traces of the shell's natural coloring (the periostricum) remained visible, but in some cases this too was ground and polished.

The spatial distribution of unfinished *Conus*-shell rings and detritus is noteworthy, since with the exception of the single large specimen from site EKE, these all come from Talepakemalai. Moreover, of 40 such specimens from ECA, fully 60% were recovered from the Area B excavation (including the Area B Extension). Six specimens were recovered from the Area A excavation on the elevated beach ridge. Another six specimens were recovered from the W250 transect, mostly concentrated between N100 and N150. These data suggest that the manufacture of *Conus*-shell rings was spatially focused within the site, confined essentially to the beach terrace (Area A) and to the stilt houses immediately offshore from the original shoreline. These deposits collectively date to the earlier portion of the Lapita occupation sequence at Talepakemalai (see Chapters 3 and 5), indicating that *Conus*-shell ring manufacture was characteristic of the earlier phase of occupation at the site. The absence of such manufacture debris in Area C, or in the later Lapita EKQ site, is indicative of a decline in the production of *Conus*-shell rings in the late Lapita period.

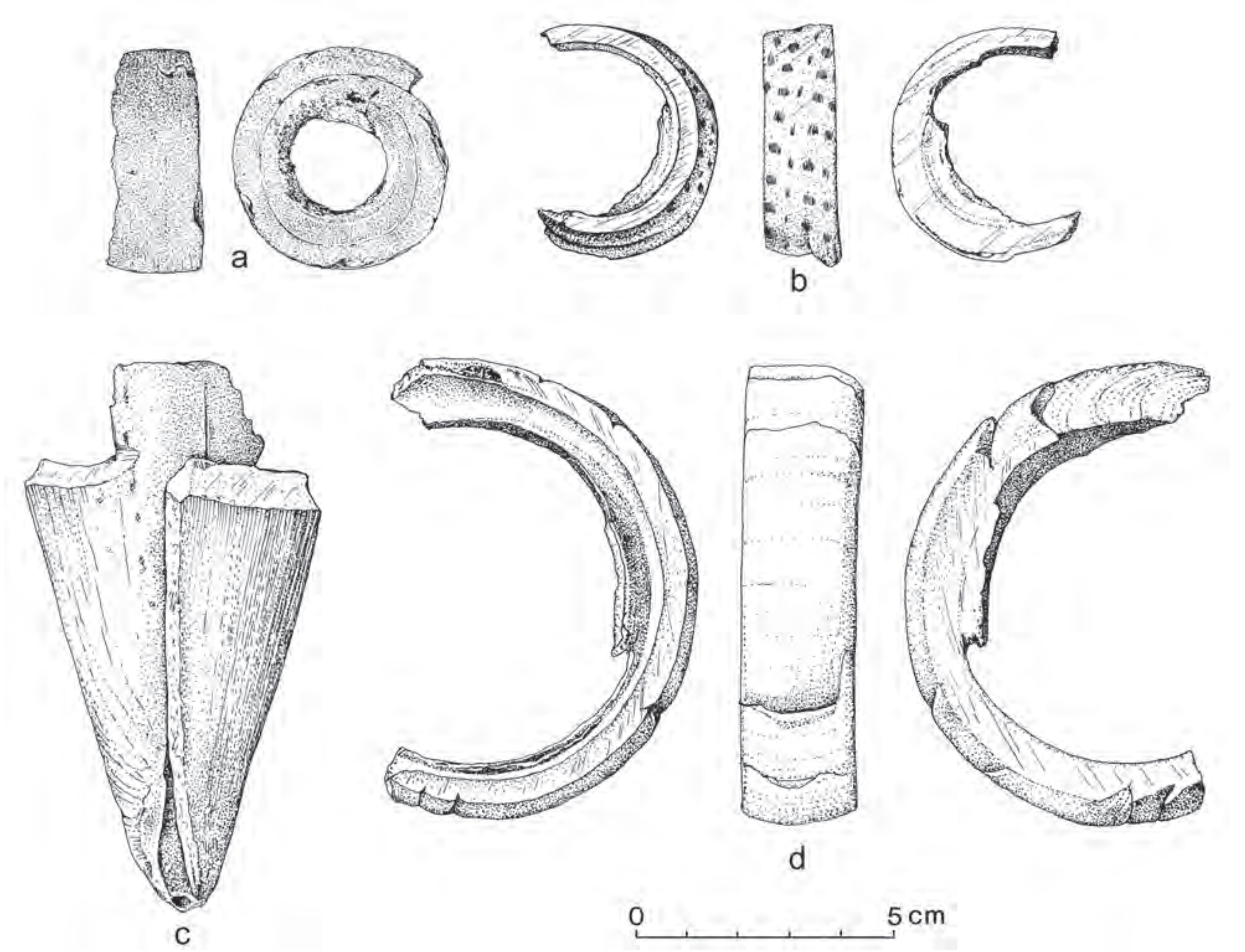

Figure 13.39. Stages in the manufacture of *Conus*-shell rings: *a*, partially ground *Conus*-shell spire, ECB-9-1-4; *b*, partially ground *Conus*-shell spire, ECA-39-9-18; *c*, partially ground *Conus*-shell spire, EKE-6-5-1; *d*, discarded *Conus*-shell whorl showing abraded facet, ECA-37-3-15. (Drawings by Margaret Davidson.)

During the interval between the 1986 and 1988 field seasons I had become increasingly aware that the manufacture of shell valuables of various kinds could have been a significant aspect of craft specialization at Talepakemalai (Kirch 1988c). During the 1988 fieldwork I decided to carefully examine all large *Conus*-shell (i.e., shells of either *C. litteratus* or *C. leopardus*) debris which showed any signs of breakage or modification, in an effort to quantify the scale of cone-shell working at the site. In previous seasons such shell debris (if it did not show signs of obvious grinding, or shaping by means of regular chipping or flaking) had been weighed together with other mollusk "midden" material, as was the practice on most Lapita site excavations.

In 1988, all *Conus* material from either *C. litteratus* or *C. leopardus* recovered from the Area B Extension excavation units and from the W250 transect units was separated out in the field lab into three sorting categories: (1) spires or apices, that portion of the shell that was worked into cone-shell rings, or more rarely, discs; (2) the columellar shaft, which typically had much of the whorl spiral still attached to it; and (3) smaller fragments that were not part of the spire and did not include any portion of the columella. (These three classes were exclusive of any *Conus* specimens showing obvious signs of cutting, grinding, or polishing, which were cataloged as artifacts, and have already been enumerated and discussed above.) Prior to being manually broken apart—whether for meat extraction or to separate

Figure 13.40. Discarded *Conus*-shell whorls showing abraded facets resulting from removal of the spires for ring manufacture: *a*, ECA-61-3-5; *b*, ECA-75-9-7; *c*, ECA-37-3-15; *d*, ECA-79-7-7.

the spire from the columellar shaft for purposes of artifact manufacture, or both—each *Conus* shell consists of a single spire capping a single columellar shaft. Elementary logic tells us that if the mollusks were being broken open simply for meat extraction, and the shell debris discarded on the site, we should find approximately equal numbers of spires and columellar shafts distributed throughout the archaeological deposits. If, however, either part of the broken shell was preferentially utilized for artifact manufacture, then we would expect to see an unequal ratio of these parts. Such a ratio might provide some index, even if only on an order-of-magnitude scale, of the degree of cone-shell working at Talepakemalai.

Table 13.7 summarizes the results of this sorting procedure for broken and fractured large *Conus* shell, along with counts of worked *Conus* shell sufficiently advanced in the manufacture process to be regarded as artifacts. These latter include partly ground spires, columellar shafts or whorl fragments with cut grooves, and unfinished (partially ground and polished) rings. These data reveal that there are significantly more columellar shaft and whorl sections than there are corresponding spires, in both areas (a ratio of 2.87:1 in Area B, and 3.4:1 in the W250 sample). If we take into account spires that have been partly or wholly modified through the process of manufacturing *Conus*-shell rings, these ratios drop to 2.5:1 for Area B and 2.03:1 for the W250 transect sample. Nonetheless, the disparity in numbers of spires (including artificially modified spires) to numbers of columellar shafts and whorls—which should in theory be 1:1—is notable. Evidently a significant portion of the large *Conus*-shell spires that should have been present at the site if all manufacturing debris were deposited in situ is in fact missing. The most plausible explanation is that substantial quantities of finished *Conus*-shell rings that were manufactured at Talepakemalai—represented by the "missing" spires—were moved off-site to other localities. We infer that these rings were exported out of Talepakemalai, and probably out of the Mussau group altogether, as a major item of external exchange.

How many exported shell rings are represented by this sample? The data in Table 13.7 provide a basis for making at least an order-of-magnitude estimate. The area of ECA sampled by the Area B extension and the W250 transect covers at least 4,000 m^2 (the zone immediately west and north of the former shoreline, and occupied by the early phase of stilt houses). Over this zone, the average density of columellar shafts + whorls is 21.1/m^2, giving a total estimated number of worked *Conus litteratus* and *C. leopardus* in this zone of 84,560 shells. Given that roughly 45% of the spires that should be associated with these shells are not represented in the site, the number of "missing" spires, each presumably representing a finished, exported shell ring, would be 38,052. This part of Talepakemalai might have been occupied for possibly as long as 400 years, and

Table 13.7. Worked *Conus* shell and manufacture detritus from the Area B Extension and the W250 Transect, Site ECA (1988)

Material Category	Area B Extension (4 m^2)	W250 Transect Units (16 m^2)
Shell spires	39	17
Columellar shafts and whorls	112	58
Whorl fragments	1	64
Columellar shafts and whorls with cut/filed grooves	1	3
Partly ground, unfinished rings	3	7
Finished ring fragments*	3	6
Total columellar parts	113	61+
Total spires + rings	45	30
Columella-to-spire ratio	2.5:1	2.03:1

* Count only includes those rings with diameters large enough to have been manufactured from *C. litteratus* or *C. leopardus*.

probably for not less than about 200 years (see Chapter 5). This would suggest that somewhere between 100 and 200 large *Conus*-shell rings could have been manufactured and exported out of the site each year. Note that this figure does not include rings made from several smaller species of *Conus*, which we did not attempt to quantify.

These estimates should not be taken as more than a rough index to the scale of *Conus*-shell ring manufacture at Talepakemalai. Nonetheless, the quantification of a significant proportion of "missing" *Conus*-shell spires from this portion of the site leaves no doubt that rings were being manufactured, in significant quantities, for distribution beyond the local community, and not simply for internal use. I believe these data strongly support the hypothesis that at least some of the shell objects found in Lapita sites functioned as important articles of external exchange (Kirch 1988c).

Class C2. *Tridacna*-Shell Rings

This class consists of rings carved out of either *Tridacna gigas* or *T. crocea*, representing a great deal of labor investment (see discussion of manufacture, below). Since nothing remains of the original shell morphology, it is impossible to determine which species was used, although one example of an early rough-out stage in the manufacture process is of *T. gigas*. Except for one eroded fragment from site ECB, all of these come from Talepakemalai, both from Area B and from the W250 transect. All are broken, and each specimen differs somewhat from the others in details of morphology. The most delicate (ECA-76-7-1), from the W250 transect, has a triangular cross section (with the apex pointed outward), and a reconstructed external diameter of 80 mm. The ring itself is 5.5 mm thick and 7 mm wide. As with other examples of this class, it has been finely worked and polished. The second specimen, illustrated in Figure 13.41, a, is wider and has a deep, V-shaped groove encircling the exterior. The reconstructed diameter is 90 mm, thickness is 6.5 mm, and width is 12.5 mm. This specimen is extremely well polished, having an alabaster-like appearance. A third specimen (ECA-62-6-9), also with a single external groove, measures 10 mm wide and 4.5 mm thick, and has a reconstructed diameter of 70 mm. Shown in Figure 13.41, b, is a finely worked ring from Area B, with four parallel, shallow grooves that define five ridges; it also has an alabaster-like sheen. This ring has an external diameter of 55 mm, width of 13 mm, and thickness of 4.5 mm. Lastly, there is a somewhat weathered specimen (ECA-40-11-53) from Area B, similar to that just described but with only two parallel grooves and three ridges. It has a reconstructed diameter of 70 mm, width of 12.5 mm, and thickness of 4.5 mm.

Manufacture of *Tridacna*-Shell Rings

The manufacture of *Tridacna*-shell rings was a far more arduous and time-consuming process than for *Conus*-shell rings, because the former had to be "hewn" out of a massive blocks of dense shell, whereas the basic form of the *Conus*-shell ring was inherent in the shell's natural morphology. It is not surprising, then, that there are far fewer *Tridacna*-shell rings in the Mussau assemblages; one presumes that these objects were more highly valued.

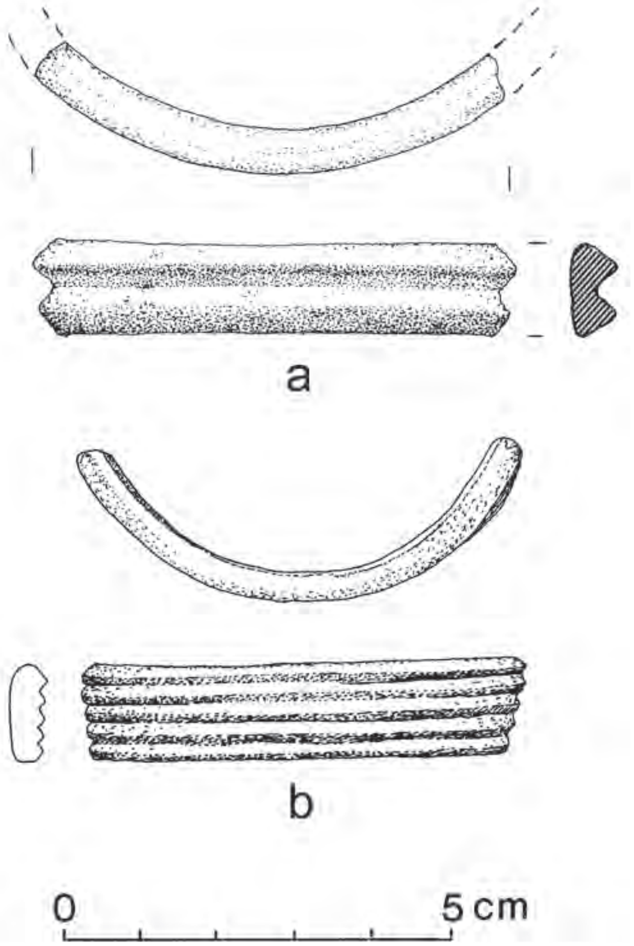

Figure 13.41. *Tridacna*-shell rings: *a*, ECA-18-8-6; *b*, ECA-48-5-25. (Drawings by Margaret Davidson.)

Although there are only five examples of broken, finished *Tridacna*-shell rings (see above), we excavated 25 specimens in various stages of manufacture, 19 of these from ECA and six from ECB. As nearly as can be determined, all are from the larger *Tridacna gigas*, which has a much thicker shell from other species of this genus. The first stage in manufacture was to begin the reduction of a *T. gigas* valve by flaking or chipping around the margins. Continued chipping and pecking reduced the valve to a circular disc, examples of which are illustrated in Figures 13.42 to 13.46. The complete discs have diameters ranging from 65 to 109 mm, with a mean of 95 mm. The next stage was to gradually reduce this disc in thickness, and to produce a cuplike depression in the center, all accomplished by pecking rather than grinding. Eventually, continued pecking in the central part of the disc opened a perforation in the center, creating the outline of a ring, which was gradually widened. Grinding does not appear to have been used until the last stages of manufacture, as illustrated in a complete but still unfinished ring shown in Figure 13.46 (this specimen has a diameter ranging from 129 to 117 mm).

The manufacture of *Tridacna*-shell rings was carried out at both sites ECA and ECB, and at the former was concentrated around Areas A and B, and in the comparable zone along the W250 transect. Thus, as with *Conus*-shell rings, *Tridacna*-ring manufacture debris is associated with the earlier stages in the occupation of Talepakemalai. There is no evidence for such production in the later Area C deposits, or at the late Lapita site of EKQ.

Class C3. *Trochus*-Shell Rings (Armrings)

Large armrings made from the basal whorl of *Trochus niloticus* shell are known ethnographically from various

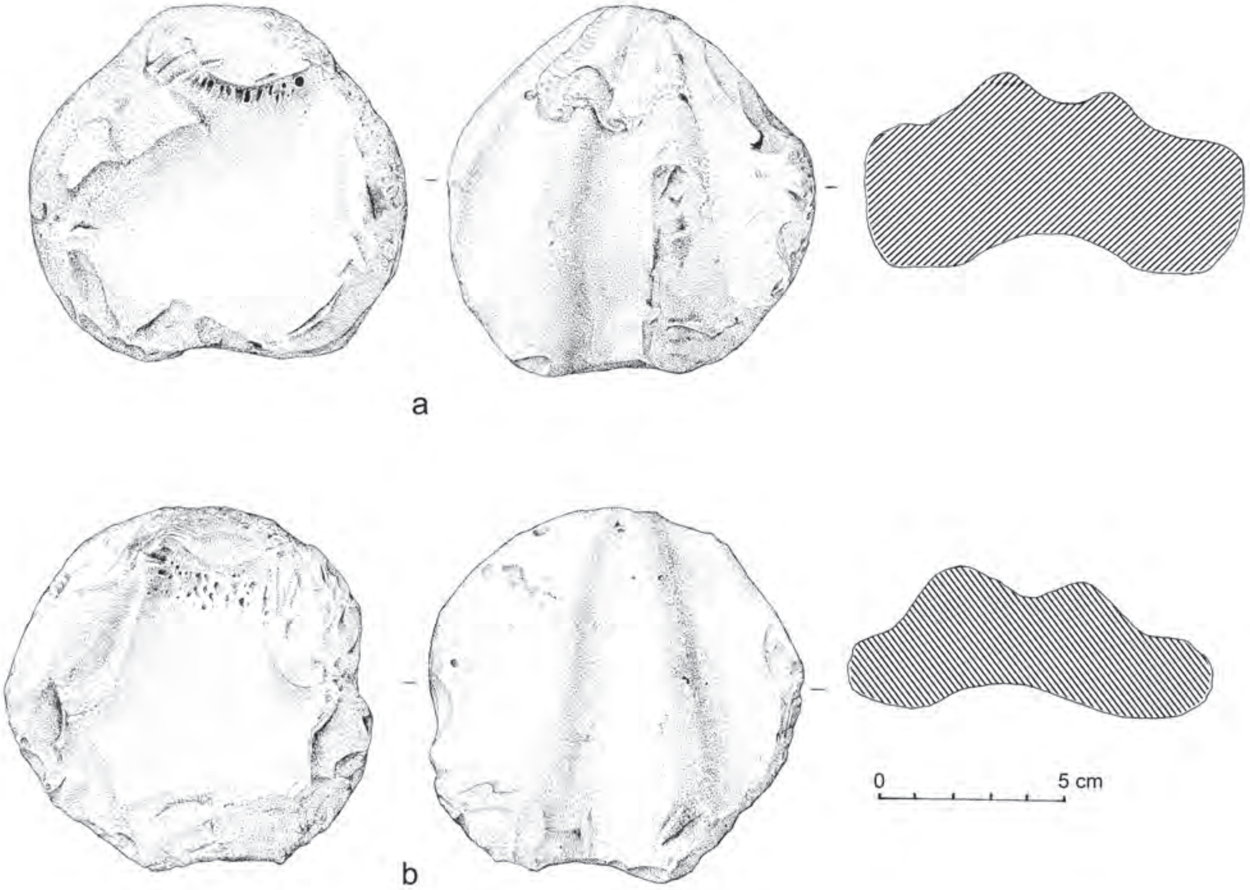

Figure 13.42. *Tridacna*-shell ring preforms from site ECA: *a*, ECA-42-5-15; *b*, ECA-49-7-1. (Drawings by Margaret Davidson.)

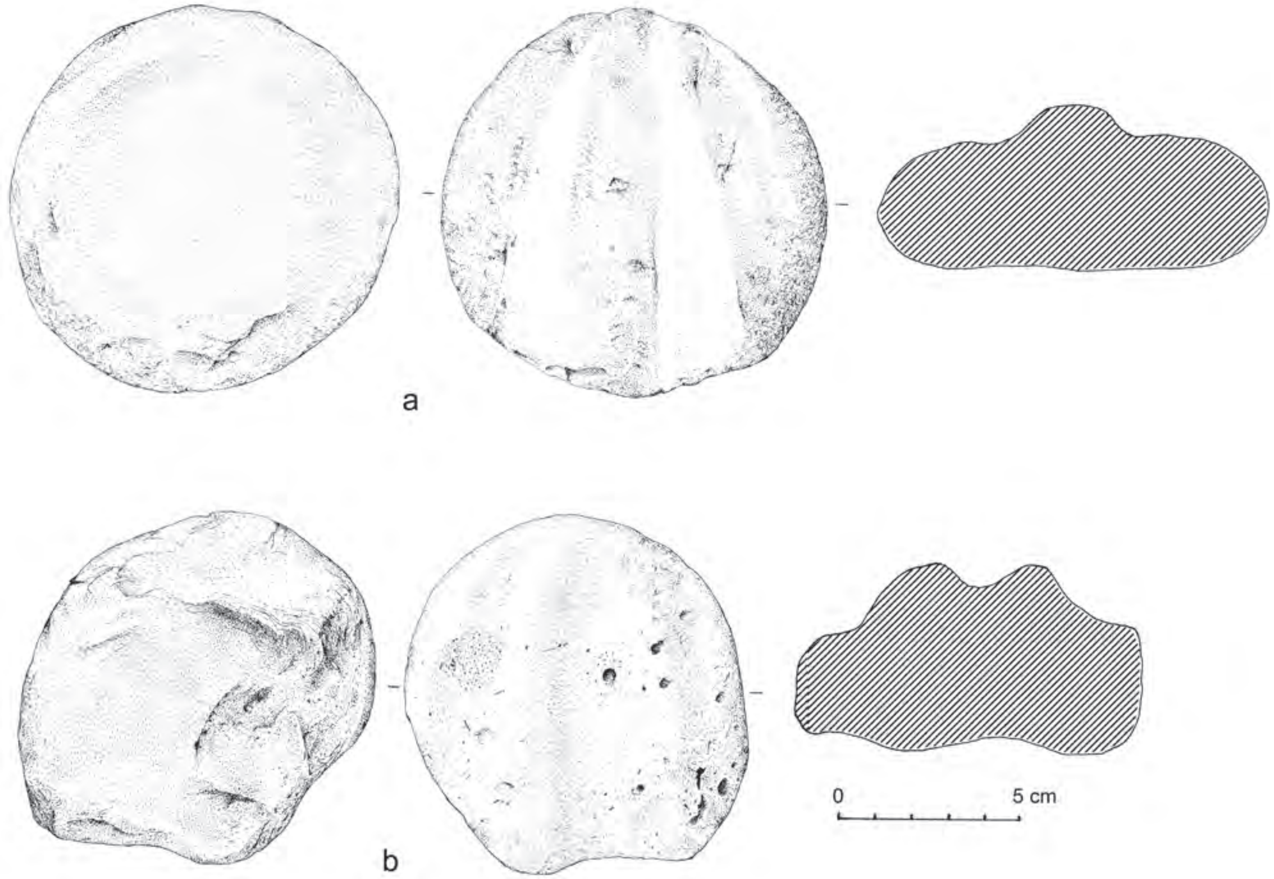

Figure 13.43. *Tridacna*-shell ring preforms from site ECB: *a*, ECB-4-3-6; *b*, ECB-19-1-3. (Drawings by Margaret Davidson.)

parts of Melanesia, and were in use in Mussau at the time of the Südsee Expedition. Nevermann (1933:76–77) reports that these armrings were usually worn by men, above the elbow on both arms. He also comments that seven to ten of these constituted a "set" but does not further explain the cultural meaning of a "set."

Archaeologically, *Trochus*-shell armrings occur almost exclusively in post-Lapita deposits, especially at sites EKE, EHM, EHN, EKO, EKQ, and EKS. A single fragment of a finished *Trochus*-shell armring came from the uppermost level of excavation Unit W180N140 at ECA, which is a deposit of disturbed garden soil; this specimen most likely postdates the Lapita occupation at Talepakemalai. There are also two chipped fragments of *Trochus niloticus* whorl, but these are not sufficient to establish the presence of actual armrings in the Lapita period. Indeed, the evidence strongly suggests that this artifact class postdates the Lapita period. Fragments of both finished, ground and polished armrings and unfinished, chipped armring preforms were excavated at the post-Lapita sites. At site EKS, Weisler recovered two complete specimens, shown in Figure 13.47. A complete preform from site EKS is shown in Figure 13.48, and examples of finished and unfinished *Trochus*-shell armrings are illustrated in Figures 13.49 and 13.50.

Class D1. *Conus*-Shell Disks

This class is morphologically intermediate between *Conus*-shell beads (which have a small perforation) and *Conus*-shell rings, and is represented by just three specimens, two from ECA and one from ECB. One of the two discs from ECA is illustrated in Figure 13.51; this has a diameter of 37 mm and thickness of 6.5 mm, and has been well ground on both sides.

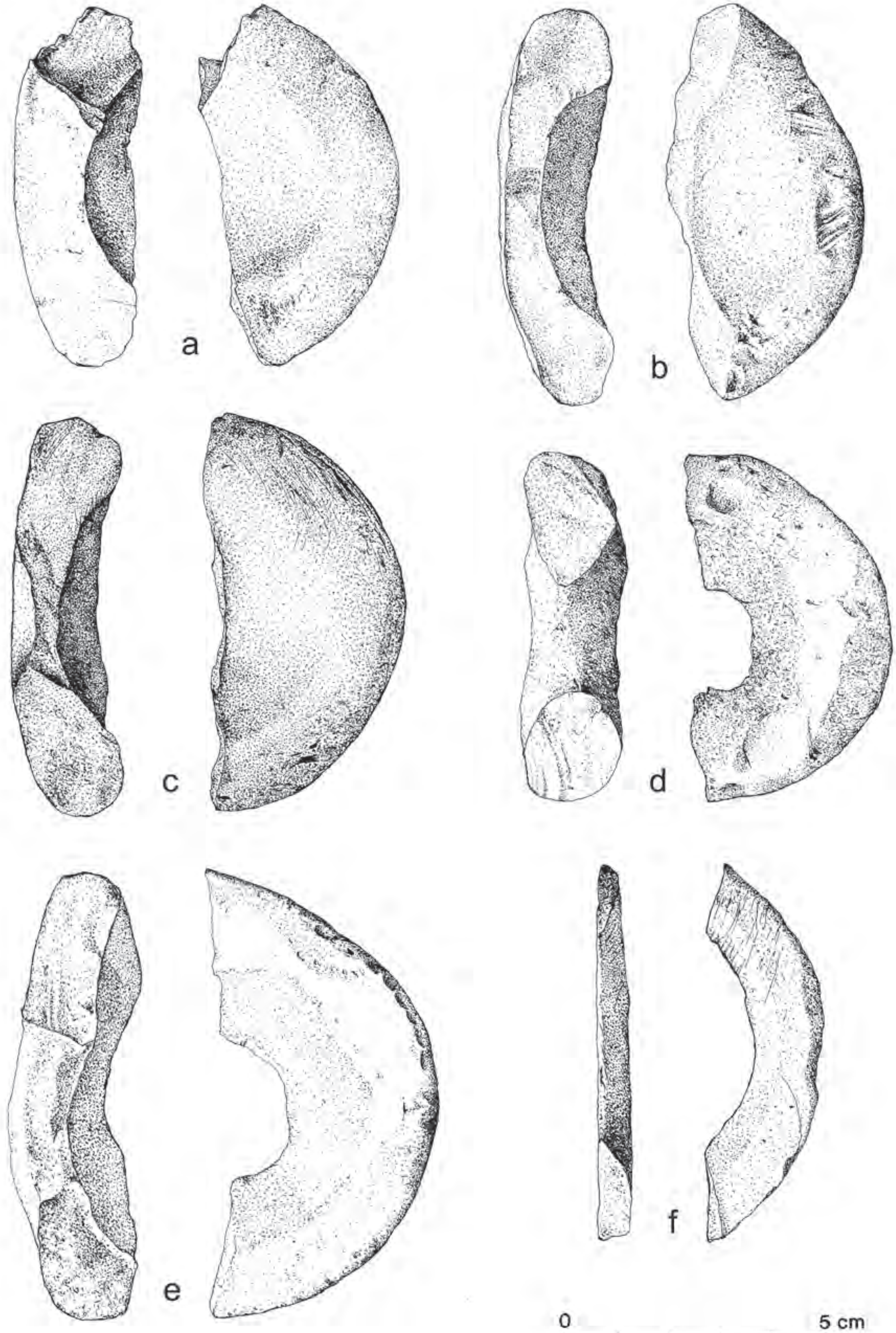

Figure 13.44. Unfinished *Tridacna*-shell rings: *a*, ECB-10-7-2; *b*, ECA-55-9-3; *c*, ECB-4-1-26; *d*, ECA-62-6-3; *e*, ECA-55-3-1; f, ECB-18-1-2. (Drawings by Margaret Davidson.)

Figure 13.45. *Tridacna*-shell preforms and unfinished rings: *a*, unfinished ring, ECB-4-1-26; *b*, unfinished ring, ECB-0-0-25; *c*, preform, ECB-4-3-6; *d*, preform, ECB surface find.

Figure 13.46. Large unfinished *Tridacna*-shell ring, ECA-94-2-1.

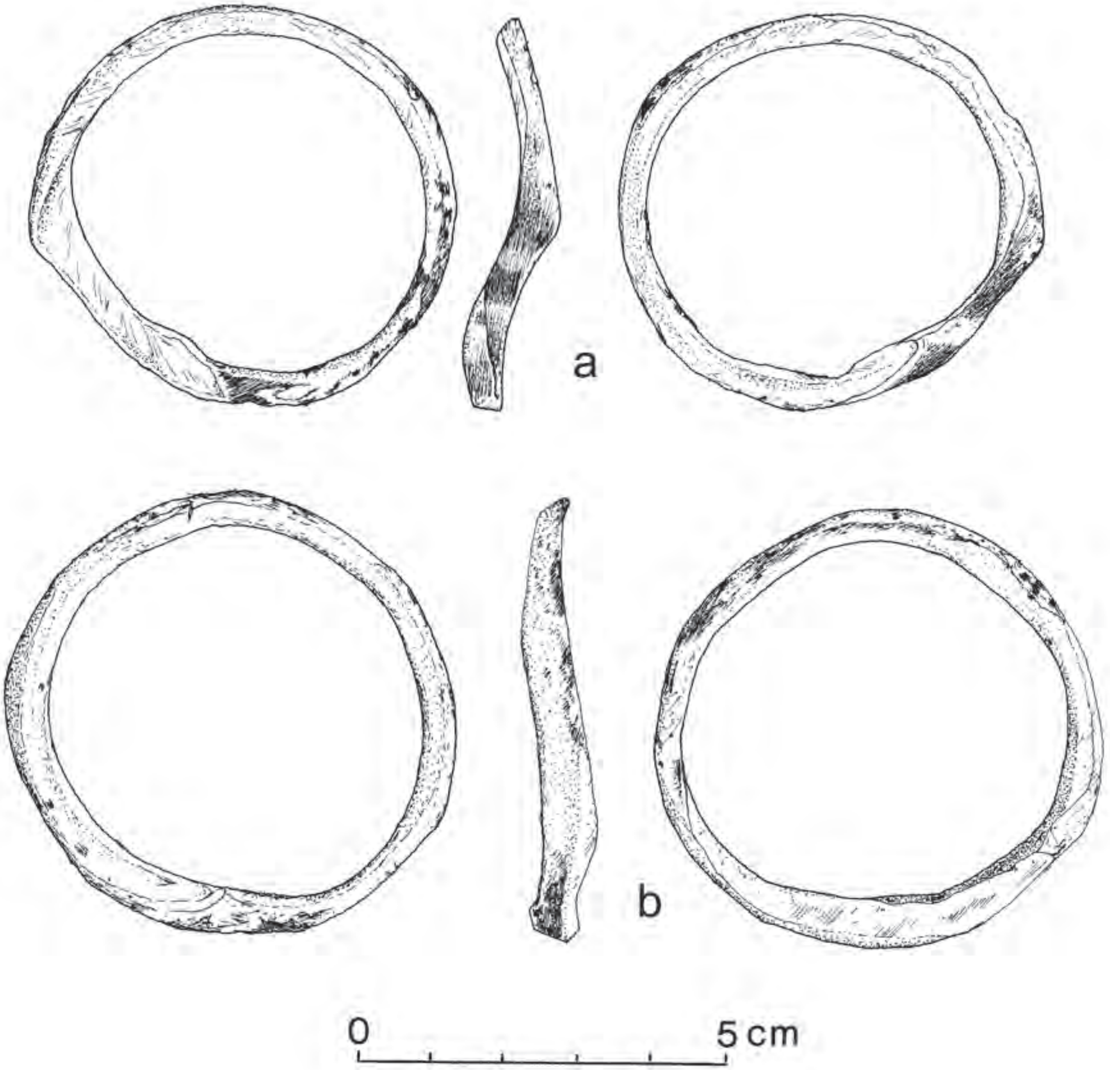

Figure 13.47. Finished *Trochus*-shell armbands from site EKS: *a*, EKS-0-0-55; *b*, EKS-0-0-54. (Drawings by Margaret Davidson.)

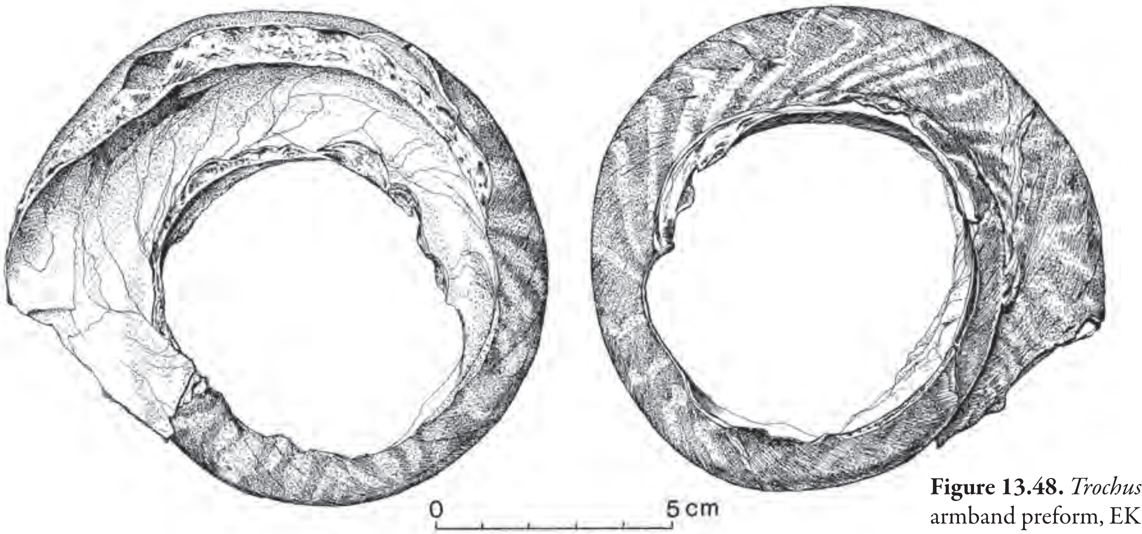

Figure 13.48. *Trochus*-shell armband preform, EKS-0-0-14. (Drawings by Margaret Davidson.)

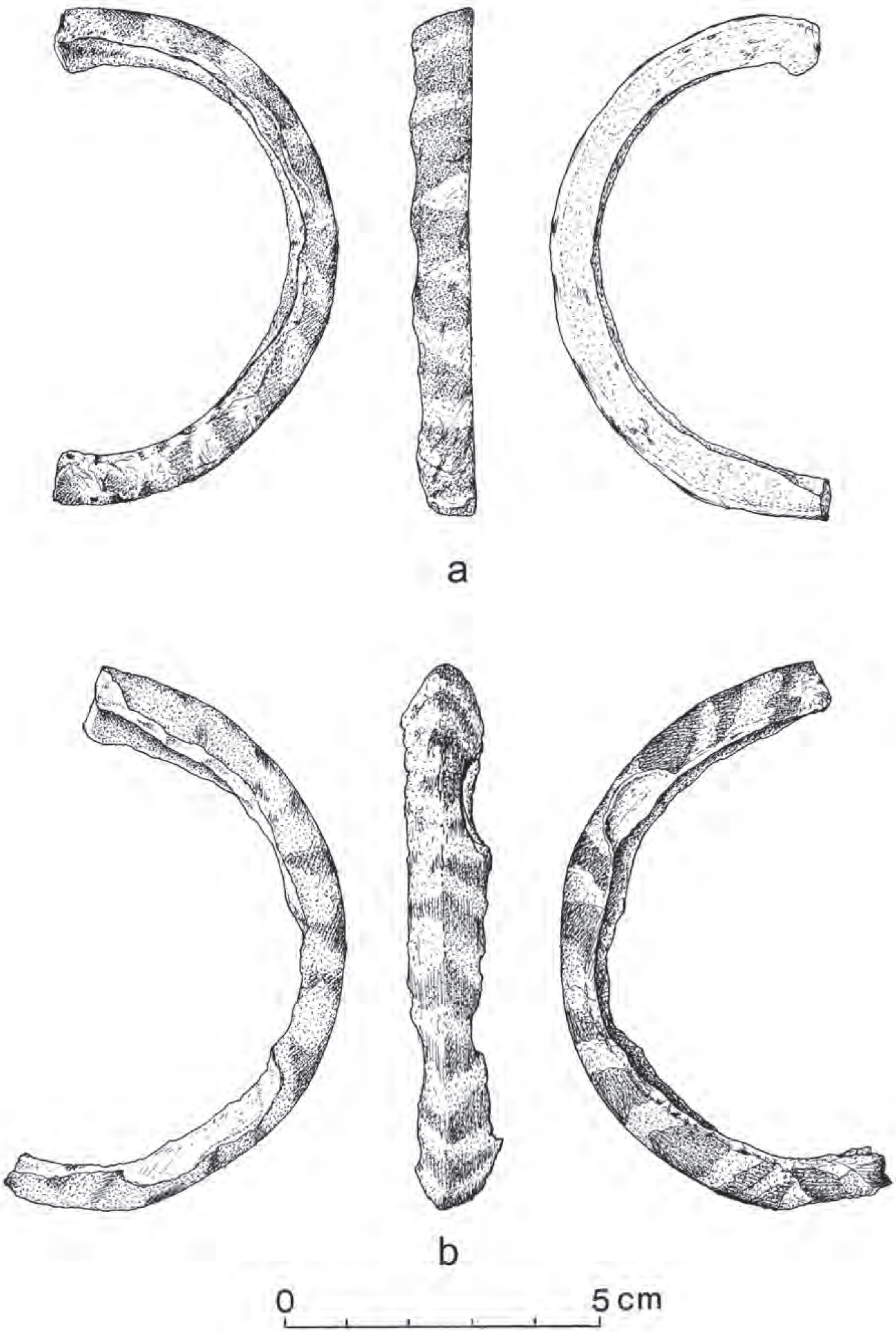

Figure 13.49. Unfinished *Trochus*-shell armrings: *a*, EKS-1-4-2; *b*, EKS-2-6-5. (Drawings by Margaret Davidson.)

Figure 13.50. Unfinished *Trochus*-shell armrings: *a*, EKS-0-0-14; *b*, EKS-2-6-6; *d*, EKS-0-0-21; *e*, EKS-2-6-5; *f*, EKS-0-0-46; *g*, EKS-1-4-2.

Figure 13.51. *Conus*-shell disc, ECA-16-7-1.

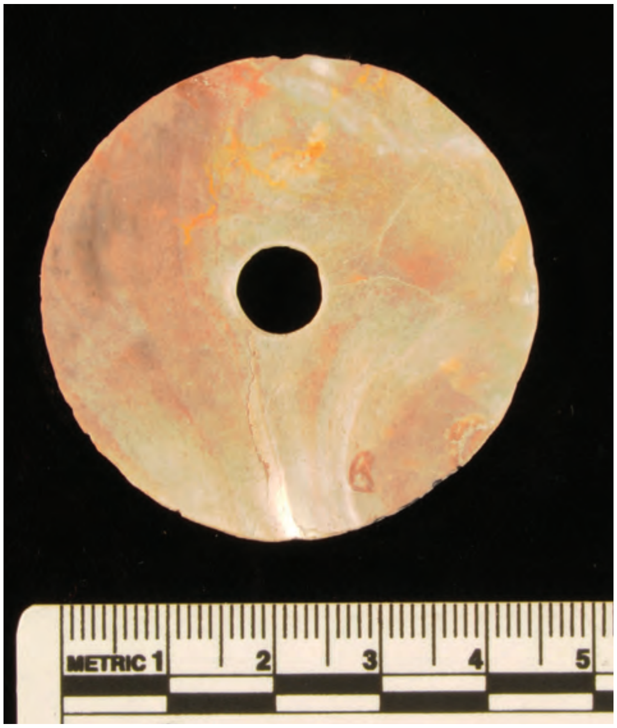

Figure 13.52. Pearl-shell disc, ECA-73-3-2.

Class D2. *Spondylus*-Shell Disk

There is but a single example of this subclass, a broken disk of *Spondylus* shell with an original diameter of about 23.5 mm, from Talepakemalai. A mere 1.75 mm thick, it was carefully ground flat and polished on both sides, and has a central perforation (biconically drilled) 2 mm in diameter. I have classified this as a disk rather than a bead (see E2) as it seems that it was intended to be lashed onto a surface, rather than strung as with a necklace component.

Class D3. Pearl-Shell Disk

A single representative of this class came from excavation Unit W250N150 at site ECA (Figure 13.52). Made from a piece of *Pinctada* sp. pearl shell that retains the original interior shell surface but has had the exterior surface ground down to expose the nacrous interior (mean thickness 2 mm), this disk is nearly circular (45–46 mm in diameter), with a central perforation 8 mm in diameter. It may have been lashed onto some other object, such as a headdress or breast plate.

Class E1. *Conus*-Shell Beads

Conus-shell beads are fairly common at Talepakemalai, with 38 specimens; one example was also excavated from the ECB site (Figure 13.53). These beads were manufactured from the spires of one or more smaller species of *Conus* shell, grinding the spire flat on both sides to expose the natural perforation in the spire tip. A few partly finished examples suggest that the top and bottom grinding was completed first, and then the sides were polished.

A sample of 36 measurable *Conus*-shell beads from ECA have a mean diameter of 9.73 ± 3.38 mm (range 5.4–20.9 mm), and a mean thickness of 2.55 ± 1.15 mm (range 1.1–7.5 mm). As seen in a histogram plot of bead diameter (Figure 13.54), however, all but two specimens range between 5 and 15 mm, with a strongly unimodal distribution. (The two outliers at about 20 mm diameter might, in fact, be better classified as smallish disks, rather than beads.)

Class E2. Spondylus-Shell Beads

This subclass includes a set of ten, morphologically rather varied small objects, all exquisitely worked from the distinctive, salmon-colored shell of *Spondylus* spp. bivalves, and all

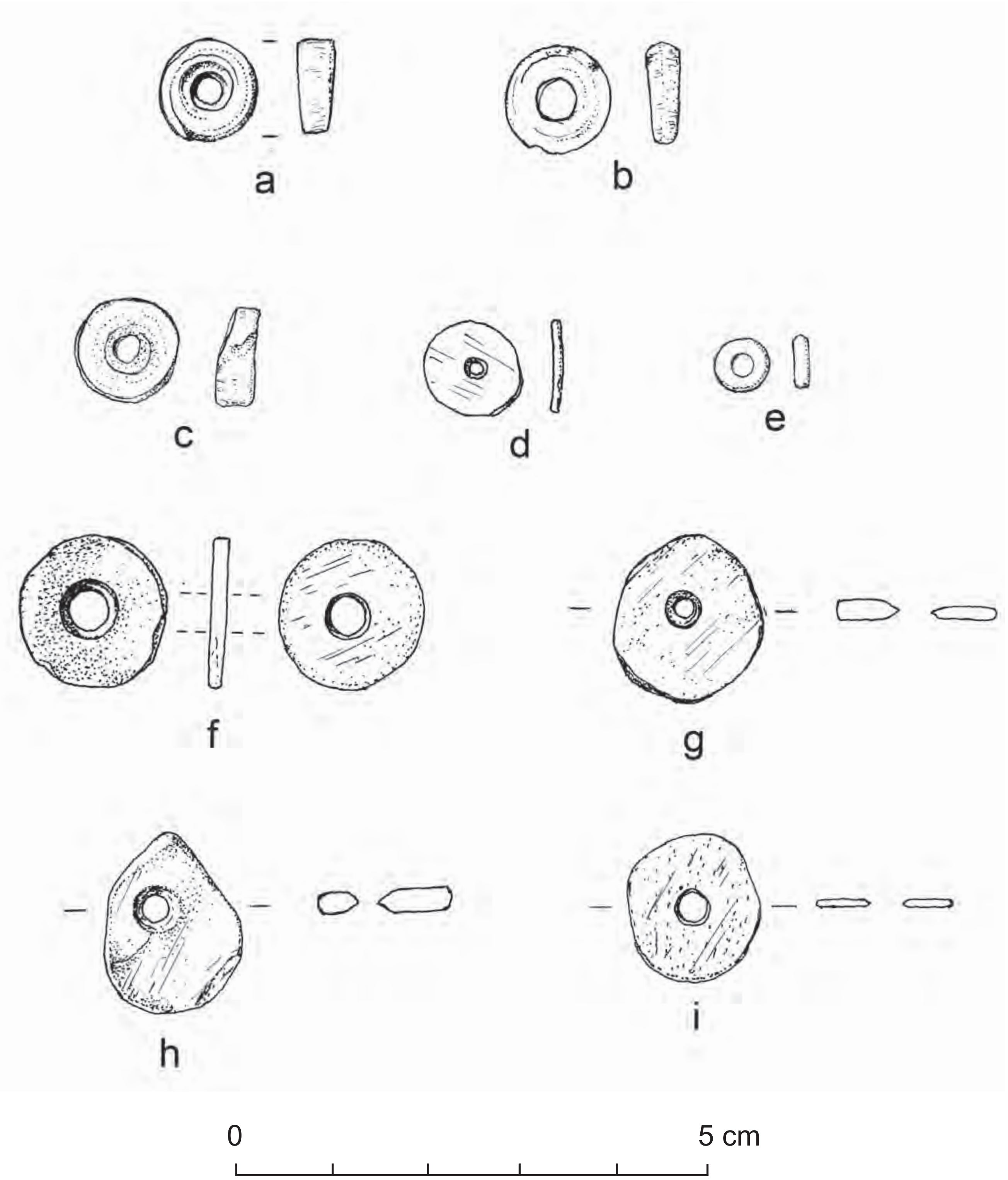

Figure 13.53. *Conus*-shell and pearl-shell beads: *a*, *Conus*-shell bead, ECA, catalog data missing; *b*, *Conus*-shell bead, ECA-34-9-39; *c*, *Conus*-shell bead, ECA-34-9-38; *d*, pearl-shell bead, ECA-35-7-48; *e*, Conus-shell bead, ECA-36-13-21; *f*, pearl-shell bead, ECA-76-6-2; *g*, pearl-shell bead, ECA-17-7-X; *h*, pearl-shell bead, ECA-54-5-2; *i*, pearl-shell bead, ECA-17-7-X. (Drawings by Margaret Davidson.)

having a single drilled perforation for line attachment or suspension. Most of these came from Area B at site ECA, but one specimen is from the deep Lapita levels in the EKQ rockshelter. All but one of these beads are illustrated in Figure 13.55. The largest of these (Figure 13.55, i) is particularly noteworthy, an elongated, tubelike bead 53.5 mm long and 8.5–13 mm wide. This bead has a perforation running through its central axis, an amazing technological feat for a craftsperson lacking metal drill points. How this perforation was achieved is not evident, but I suspect it may have been through repeated, painstaking application of a small lighted stick, or perhaps a coconut mid-rib, gradually reducing the calcium carbonate into ash. Certainly the manufacture of this unique bead must have required many hours of labor. The specimen shown in Figure 13.55, a, is also quite striking, a roughly rectangular bead with little lugs or nubbins projecting from each corner. One specimen from ECA (ECA-18-8-15) might perhaps be better classified as a "ring," but given its small size (diameter 21.5 mm), I have included it here with beads. It has a width of 2 mm and thickness of 3.5 mm. All of the *Spondylus*-shell beads are beautifully polished, always invoking admiring comments from anyone who has examined them.

Class E3. Pearl-Shell (*Pinctada margaritifera*) Beads

There are five small beads of *Pinctada margaritifera* shell, all from site ECA (Figure 13.53, d, f–i). Three of these are nearly circular in shape, with diameters ranging from 14.9 to 15.9 mm, and thicknesses between 6.5 and 7.1 mm. They have drilled central perforations about 3 mm in diameter. The fourth specimen (Figure 13.53, h) is irregular, with a diameter varying between 14.5 and 18.5 mm, and is 7.4 mm thick. I have classified these as beads, but alternatively they might have functioned in the same manner as the *Nautilus*-shell disks, described below. Two of these pearl-shell beads were found together in the same level of excavation Unit W200N130, and are virtually a matched pair, perhaps adding strength to the argument that these could be inlay pieces, as argued for the *Nautilus* disks.

Class F: Shell Pendants

Four separate classes of shell pendant are evidenced in the Mussau collection, defining a "pendant" as an ornamental object that is elongated and has a single perforation at one end, for stringing on a line. It is impossible to determine, of course, whether these objects were used as single pendants or as components in multi-unit necklaces or other arrangements (such as secondary ornamentation lashed to a rectangular unit, for example). Ethnographically documented *mwali* or "armrings" from the Massim area, for example, are embellished or ornamented by tying various other kinds of small beads (both indigenous shell beads and, in recent times, glass trade beads) onto them.

Class F1. *Tridacna*-Shell Pendant

There is only one example of this subclass, an exquisitely worked specimen from the W250 transect at Talepakemalai (Figure 13.56). The alabaster-like *Tridacna* shell was carefully worked into the shape of a tooth or tusk, flattened at the proximal end and pointed at the distal end, curved when viewed from the side. The pendant has a length of 42 mm, maximum width of 11 mm, and average thickness of 7 mm. There is a deep V-shaped groove running down one side. The presence of the groove suggests that the pendant was made from a broken (recycled) section of a *Tridacna*-shell ring (Class C2) with a peripheral groove. The perforation was drilled biconically from both faces.

Class F2. *Spondylus*-Shell Pendants

There are two pendants of *Spondylus* shell, one from excavation Unit W200N140 and one from the W250 transect at Talepakemalai. The larger of these (Figure 13.57, b) is a rectangular block of shell 35 mm long, 9 mm wide, and 5.5 mm thick, but with a large chip missing from one corner of its proximal end. It is well polished overall, with the suspension hole drilled from the thin edge or side. The smaller specimen (which could be called an elongated bead, or a pendant) measures 19 mm long, 4.5 mm wide, and 3.5 mm thick, and has been "scalloped" by carving three evenly-spaced grooves into one face (Figure 13.57, a). The suspension hole was drilled from one side only, and now has a small segment missing at the tip.

Class F3. *Conus*-Shell Pendants

This class is represented by five examples, all from Area B of site ECA; two of these are illustrated in Figure 13.57 (c, d). They may well have been necklace components, possibly interspersed between groups of *Conus*-shell beads. Given that all come from the same stratigraphic context,

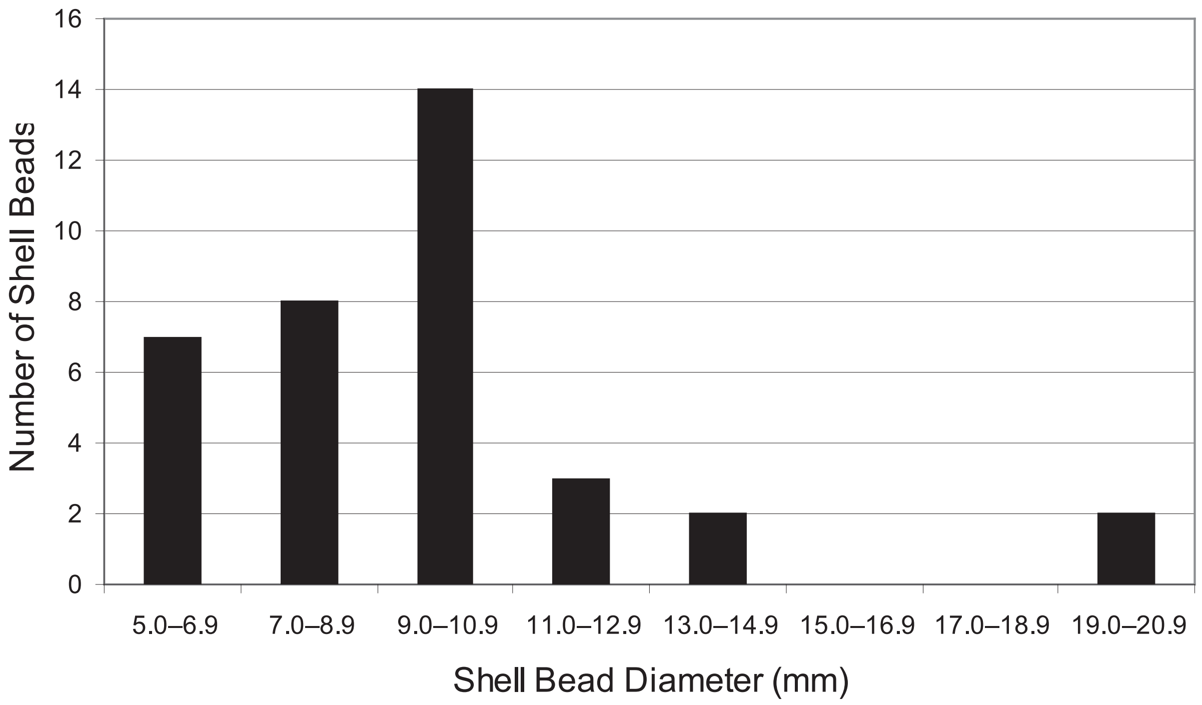

Figure 13.54. Histogram plot of *Conus*-shell bead diameters.

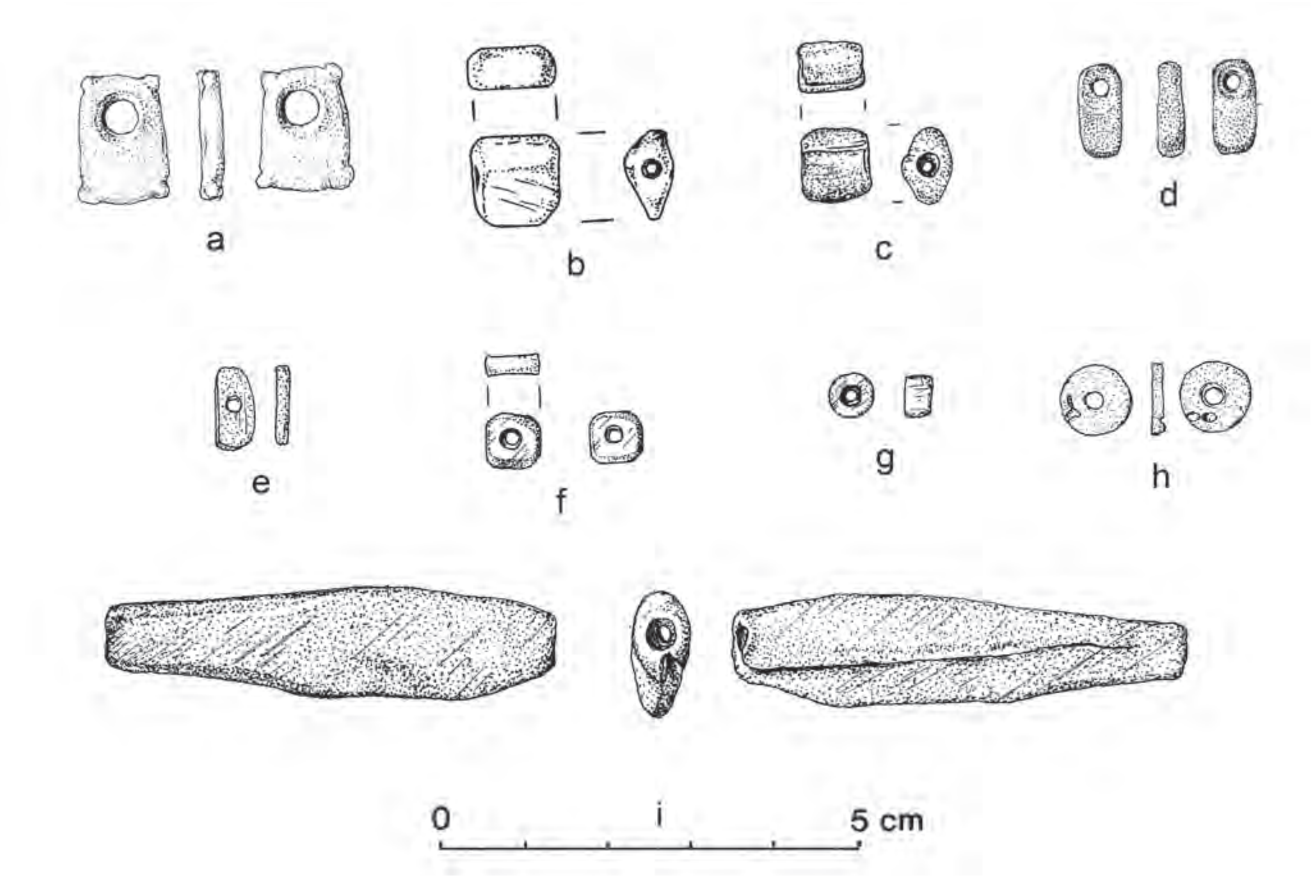

Figure 13.55. *Spondylus*-shell beads: *a*, ECA-0-0-16; *b*, ECA-31-10-26; *c*, ECA-48-6-2; *d*, EKQ-1-22-2; *e*, ECA-35-7-47; *f*, ECA-38-8-47; *g*, ECA-18-8-8; *h*, ECA-62-6-1; *i*, ECA-32-9-62. (Drawings by Margaret Davidson.)

it is conceivable that they were all part of a single compound object, such as a necklace. All are quite similar in shape and size, and appear to be "dentiform" or toothlike, possibly imitations of a real tooth or tusk. In side view they are curved, following the natural curvature of the *Conus*-shell body whorl, while viewed straight on (with the perforation hidden from view) they are pointed or tapered at both ends. The suspension holes were biconically drilled, except in one case which has no perforation and is thought to be unfinished. In length these pendants range from 32–38 mm (mean = 34.5 ± 2.5); in maximum width they range from 5–6.5 mm (mean = 5.75 ± 0.61 mm).

Class F4. Pearl-Shell Fish Pendant

A truly remarkable object is the "ichthymorphic" or fish-shaped pendant of pearl shell (*Pinctada margaritifera*) found at Area B of Talepakemalai (Figure 13.57, e; Figure 13.58). There is little doubt that this exquisitely carved piece is a stylized representation of a fish, and the biconically drilled perforation is slightly offset from center to correctly represent the position of a fish eye. Overall, the pendant measures 47 mm long, with a maximum width of 11.5 mm and maximum thickness of 2.5 mm.

Figure 13.56. *Tridacna*-shell pendant, ECA-86-5-1.

Polinices-Shell Ornaments

Polinices tumidus is a creamy-white gastropod ranging from about 30–50 mm in length. Three of these shells, all from site ECA, were modified for use as ornaments, probably pendants (Figure 13.59, c–e). In two of the shells, a perforation was chipped through the shell wall at the narrow end of the body whorl, near the aperture. In the third specimen (Figure 13.59, c), modification was more extensive, with a ground facet on the outer margin of the body whorl, and a carefully drilled hole (3 mm diameter) through this facet.

Identical *Polinices*-shell pendants are known both ethnographically and archaeologically from Tikopia in the Eastern Solomons (Firth 1936:508, Plate XXIIIB; Kirch and Yen 1982:251, Figure 100, a–d). In Tikopia, these shell ornaments are specifically used as dance ornaments by unmarried women, suspended from the pierced nasal septum by means of a turtle-shell ring.

Other Shell Ornaments

There are a few other examples of shells (in each case a single taxon is represented by one specimen each) that have been modified, presumably for use as ornaments. Because these appear to be ad hoc modifications, I have not classified these objects as exchange valuables, although they could have functioned in this manner. A *Pecten* sp. valve from excavation Unit W250N90 at site ECA has had a perforation made by grinding away the outer shell surface just below the umbo, presumably for suspension. In Area B at ECA we found a small patellid shell which had most of the apex completely ground down (Figure 13.59, a). And, from a Lapita context at the Boliu Island site (EKE), we recovered a small gastropod of unidentified taxon with a hole 6.5 mm in diameter made by grinding away part of the main body whorl (Figure 13.59, b).

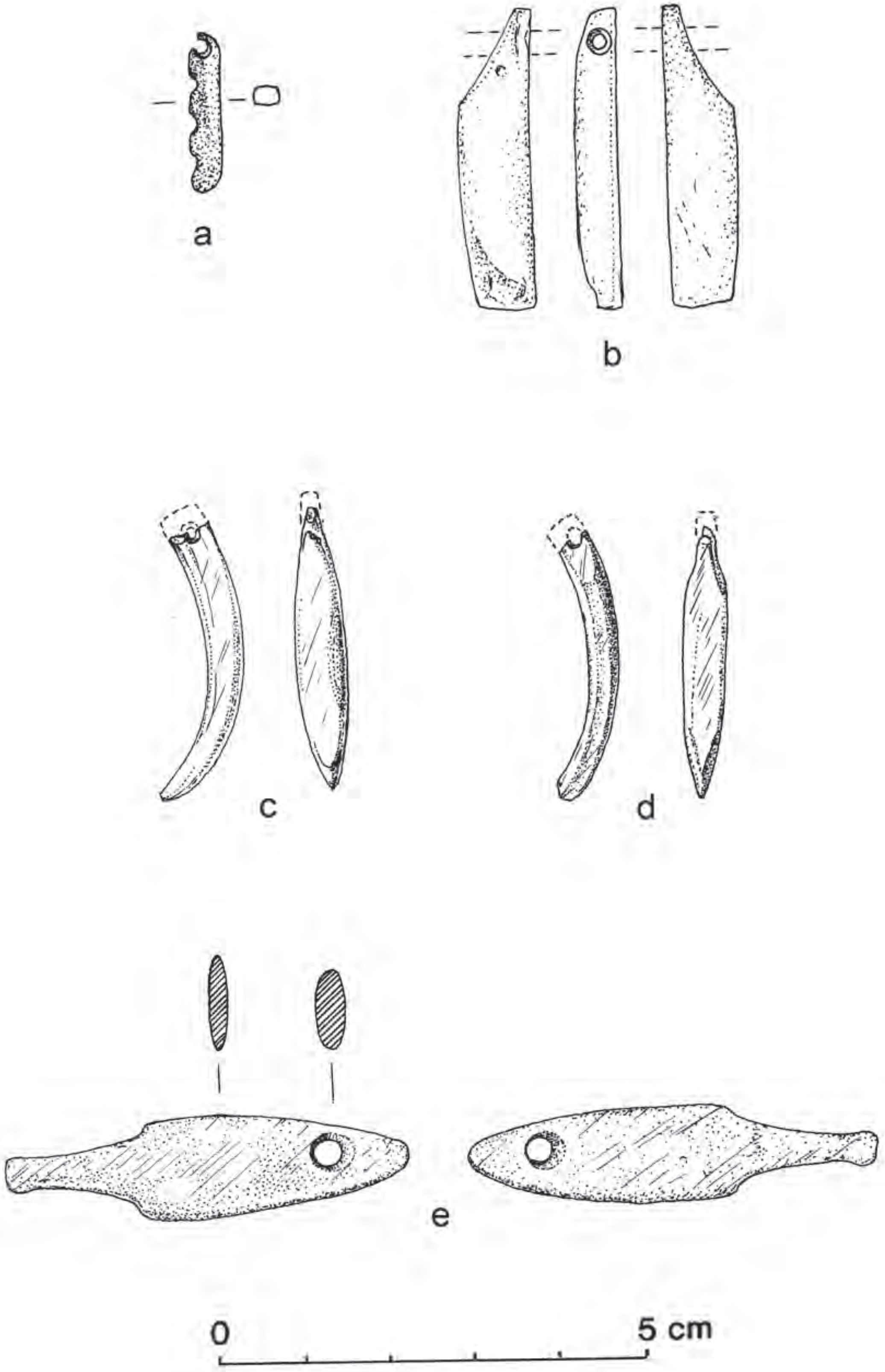

Figure 13.57. Shell pendants: *a*, *Spondylus*-shell pendant, ECA-16-8-3; *b*, *Spondylus*-shell pendant, ECA-78-4-2; *c*, *Conus*-shell pendant, ECA-41-7-12; *d*, *Conus*-shell pendant, ECA-38-6-55; *e*, pearl-shell fish-shaped pendant, ECA-39-8-35. (Drawings by Margaret Davidson.)

Tooth and Tusk Pendants

Eleven different objects (nine from ECA and two from EKE) appear to be pendants or necklace units, all with suspension holes, made from various kinds of animal teeth or tusks; a selection of these is illustrated in Figures 13.60, 13.61, and 13.62. Four pig (*Sus scrofa*) tusks from Talepakemalai each have a single drilled hole (1–2 mm diameter) in their proximal ends (Figure 13.60, a; Figure 13.61). There are two teeth from a small species of odontocete (probably a porpoise, such as a *Grampus* sp.), each with a drilled perforation (1.5 mm diameter) through the root (Figure 13.60, b). The use of dolphin teeth as necklace units is ethnographically described and illustrated by Nevermann (1933:60). From the same level of Unit W200N120 at ECA came two modified shark teeth that appear to be a matched pair (Figure 13.60, c). These shark teeth have the basal flanges cut off leaving only a slender shaft of the central part of the root, which was finely ground down, and then drilled through for line suspension. A single tooth of a balistid fish (possibly *Pseudobalistes* sp.) from Area B at ECA has a 2 mm diameter hole drilled through the root for suspension (Figure 13.60, d). Finally, from the upper levels of excavation Unit E200N150 at the EKE site on Boliu Island, in what is probably a post-Lapita context, we found two dog (*Canis familiaris*) canine teeth, each with a drilled perforation in the root (Figure 13.60, e, f; Figure 13.62). One of these also has three notches or grooves on one side of the root.

Bone Ring

A unique ring of bone (probably turtle plastron) comes from Unit W220N140 at Talepakemalai. The ring is broken, but its external diameter can be measured as 37 mm, and the opening has a diameter of 17 mm (ring width = 10 mm); the ring averages 3 mm thick. It has been finely ground and polished over all surfaces.

Anthropomorphic Image and Possible Image Inlays

Perhaps the most remarkable object recovered during our three seasons of excavation in Mussau is the small bone anthropomorphic figurine shown in Figures 13.63 and 13.64. Found in Zone C1 of Area B at Talepakemalai, this image can only be described as a stunning work of mobiliary art, executed with a minimalist yet sophisticated sense of style. The image was carved from a heavy piece of bone, almost certainly of a cetacean (probably porpoise), although precise identification is not possible because no traces of the original bone surface or morphology remain. It is 72.5

Figure 13.58. Fish-shaped pendant of pearl shell, ECA-39-8-35.

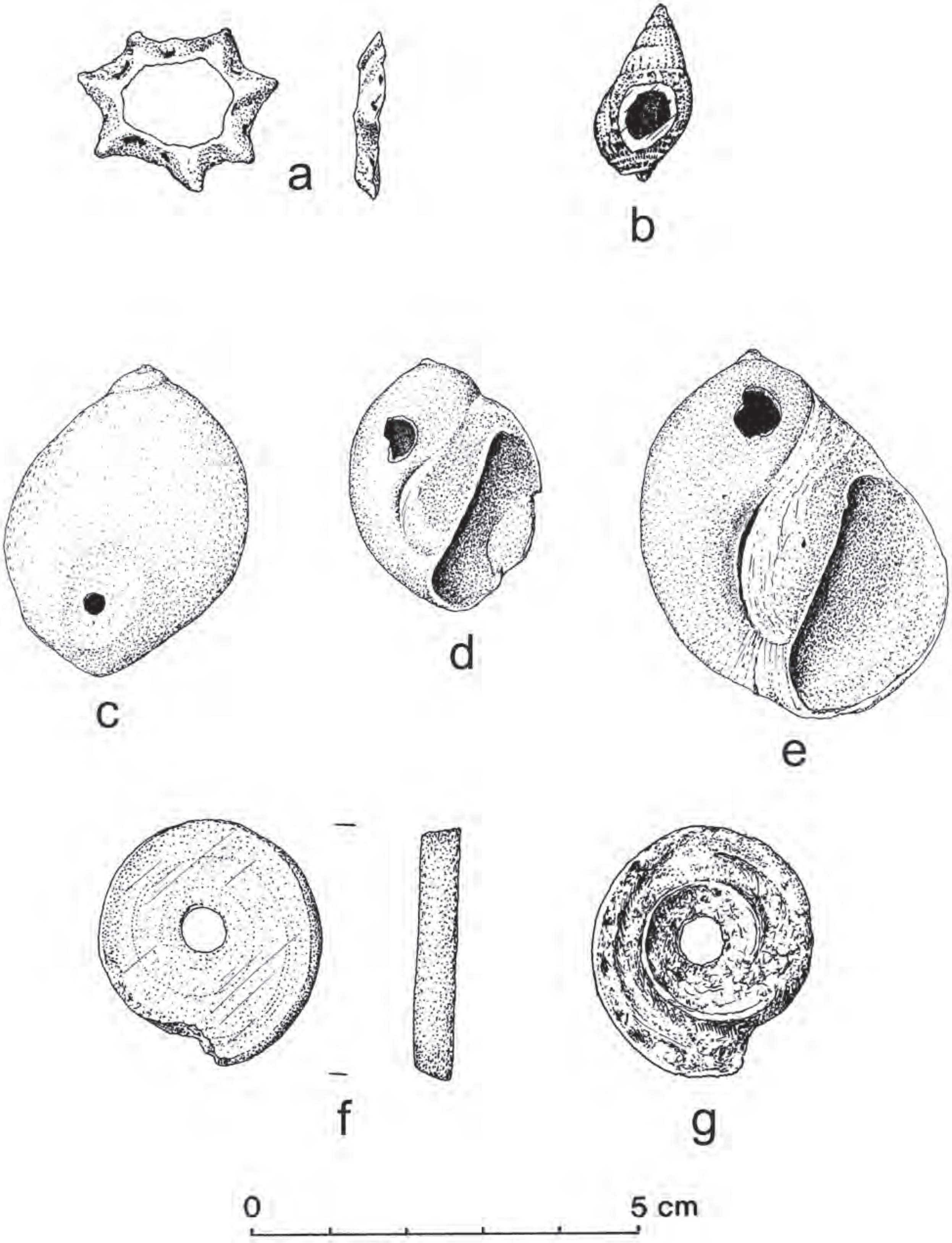

Figure 13.59. Shell ornaments: *a*, ground patellid shell, ECA-31-7-50; *b*, perforated gastropod shell, EKE-6-9-4; *c*, perforated *Polinices* shell, ECA-19-1-14; *d*, perforated *Polinices* shell, ECA-36-17-12; *e*, perforated *Polinices* shell, ECA-54-3-7; *f*, *Conus*-shell disc, ECA-16-7-1; *g*, *Conus*-shell disc, ECA-42-4-14. (Drawings by Margaret Davidson.)

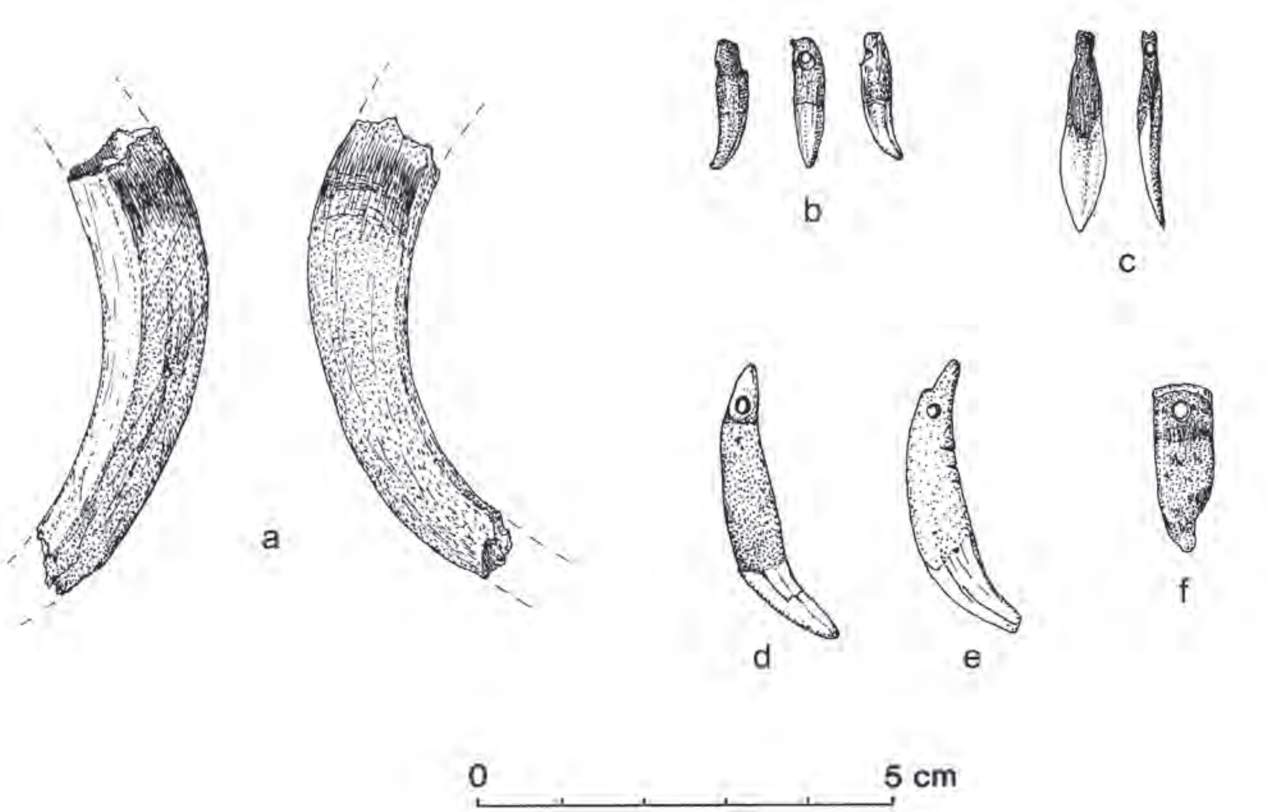

Figure 13.60. Tusk and tooth ornaments: *a*, pig tusk, ECA-39-9-17; *b*, odontocete tooth, ECA-33-8-120; *c*, modified shark tooth, ECA-18-8-11; *d*, dog tooth, ECA-45-6-4; *e*, dog tooth, EKE-5-3-1; *f*, balistid fish tooth, EKE-5-1-4. (Drawings by Margaret Davidson.)

Figure 13.61. Pig tusk pendants: *a*, drilled tusk, ECA-46-4-1; *b*, drilled tusk, ECA-84-5-1; *c*, tusk fragment, ECA-39-9-7.

mm long, has a maximum width of 27 mm, a maximum thickness of 14.5 mm, and weighs 22 g. The piece has been worked on both sides, but details are expressed only on the front, with traces of the interior cancellous bone remaining on the obverse. In cross section, the image has a distinctly lanceolate head, rounded with a slight peak or crest when viewed frontally.

The dominant feature, to which one's gaze is inevitably attracted, is the slightly protruding, elongated nose (11 mm long), flanked by eyes minimally executed as shallow grooves with slightly overhanging brows. This nasal emphasis resonates with the various anthropomorphic two-dimensional images found on the decorated pottery (see Chapter 11), and there is every reason to believe that both this image and the ceramic representations are based on the same artistic concepts. Below the nose there are semi-oval grooves or depressions, suggestive of the outline of a face for the upper, and possibly a minimalist expression of arms for the lower. This lower semi-oval terminates in the uppermost of two parallel, horizontal grooves that appear to define a waist. Below this "waist" the image diverges into two short "legs" or lugs, which also have shallow grooves cutting across them. These legs are defined by a space about 5 mm wide and 8 mm deep that separates them.

It is conceivable that the "legs" were inset into a staff or wand, possibly of wood, on which the image could have been mounted. In this case, the low horizontal grooves may have facilitated lashing of the image onto its mount. Of course we have no conclusive evidence that the object was so mounted.

No similar carvings in bone have, to my knowledge, been found at other Lapita sites. As noted above, however, this object certainly fits well with the anthropomorphic style exhibited on numerous ceramic design fields from Mussau, as well as from other Lapita sites (see Green 1979b; Spriggs 1990b, 1993a). It thus constitutes additional evidence that Lapita art was of the *pervasive*, as opposed to *partitive*, type (Green 1979b), in which the same artistic style and conventions were applied to a range of media. Furthermore, it raises the question of whether three-dimensional anthropomorphic carvings might not have been more common, but typically executed in wood (or even woven from fiber?), and thus have not survived in the archaeological record. Indeed, a number of carefully worked *Nautilus*-shell discs, described below, may well have been inlay pieces from such images.

Figure 13.62. Drilled dog tooth pendants: *a*, EKE-5-7-4; *b*, EKE-5-3-1.

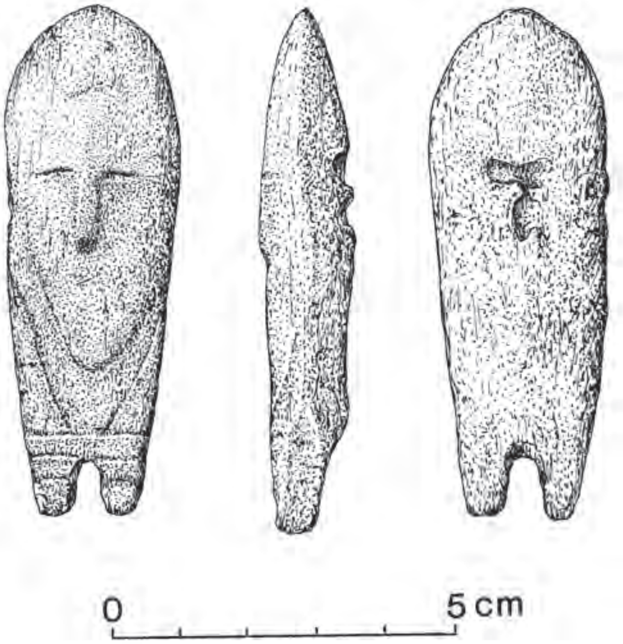

Figure 13.63. Anthropomorphic image made of cetacean bone, ECA-37-6-74. (Drawings by Margaret Davidson.)

Figure 13.64. Anthropomorphic image made of cetacean bone, ECA-37-6-74.

Another piece of heavy cetacean bone (ECA-42-9-62), also from Area B at ECA, is of roughly similar dimensions to the image just described (in this case measuring 80 mm long, 28 mm wide, and 13.5 mm thick), and might possibly represent a rough-out or preform for another image. The bone has been roughly shaped but not finely finished or polished, suggesting it was abandoned before completion. There is a rough, wide groove about 25 mm from one end.

Nautilus-Shell Inlay Discs

There are several reasons for inferring that a group of nine small discs, all finely worked from the lustrous interior shell of the chambered nautilus (*Nautilus pompilius*), may have been inlay pieces (Figure 13.65). First, they are extremely thin (mean = 0.88 ± 0.21 mm) and delicate, unlikely to have been able to withstand use as separate beads or ornaments. Indeed, four of the nine have no perforations and thus no way to attach or suspend them unless they were inlaid or glued to a firmer foundation or support. Ethnographically, *Nautilus* shell is known to have been used as inlay material on wood carvings, as in the famous carving tradition of Santa Anna and nearby islands in the southeastern Solomons. These delicate, circular objects would have been ideal as representations of eyes on anthropomorphic wooden carvings, or possibly on images made from other kinds of perishable material, such as fiber, wicker, or even barkcloth. Since we know from both the representations on pottery and the bone image described above that Lapita art emphasized anthropomorphic representations, there is no reason to think that they might not also have made such representations in other media.

The *Nautilus*-shell discs are almost all from Area B at Talepakemalai, with one from a test unit about 20 m west of Area B but still in the same vicinity, and a single other example from a Lapita-period context at the Boliu Island site (EKE). The discs have a mean diameter of 22.6 ± 4.7 mm (range 15–31 mm), and as noted earlier average a mere 0.88 mm thick. Four discs lack any perforation, while three have artificially chipped or drilled central holes, presumably for line attachment (possibly lashing the disc to a fiber foundation, as in ethnographic examples from Oceania). Two others have natural perforations made by the siphuncle that connects the numerous chambers of the *Nautilus* shell. Two of the unperforated discs (Figure 13.65, a, b; Figure 13.66) may be a matched pair, as they have identical diameters of precisely 20 mm, and both come from Area B; such matched pairs would be expected if these discs did function as eye inlays.

The working of *Nautilus* shell at site ECA is also indicated by a single specimen of *Nautilus* that has been extensively chipped, with much material removed (Figure 13.67). This was excavated from Unit W250N130.

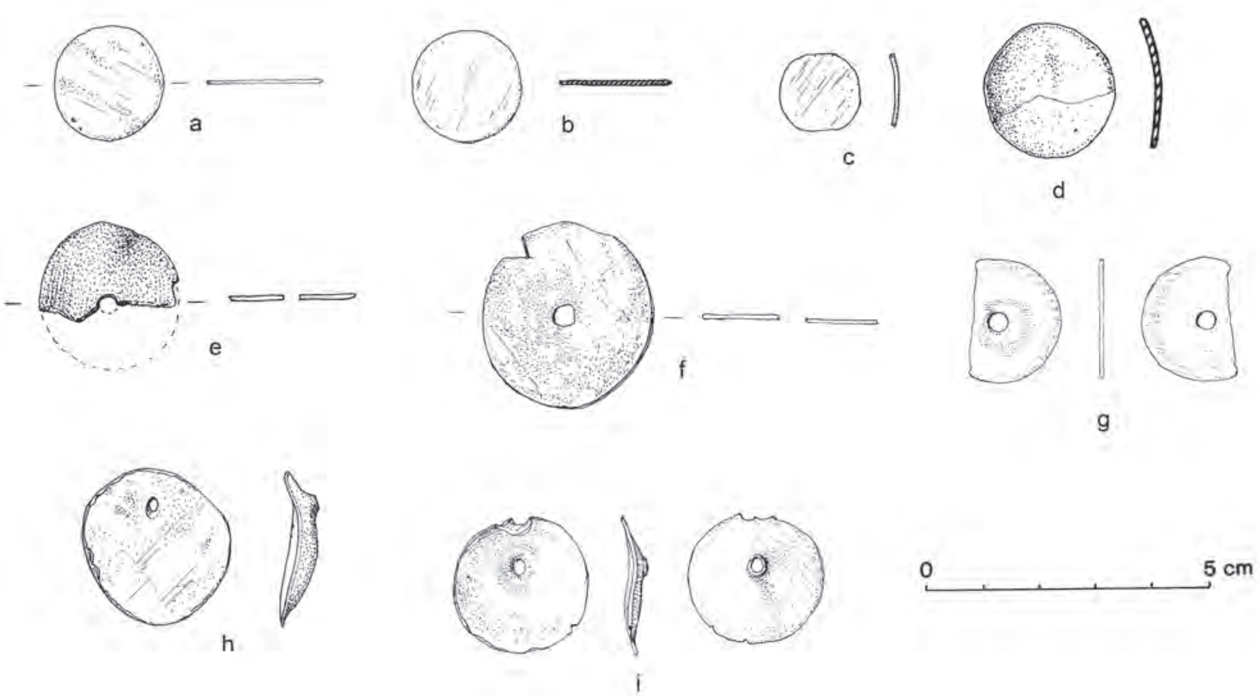

Figure 13.65. *Nautilus*-shell discs: *a*, ECA-48-5-9; *b*, ECA-0-0-15; c, ECA-40-11-55; *d*, EKE-10-2-2; *e*, ECA-46-4-4; *f*, ECA-50-4-3; *g*, ECA-62-7-1; *h*, ECA-37-8-31; *i*, ECA-50-2-4. (Drawings by Margaret Davidson.)

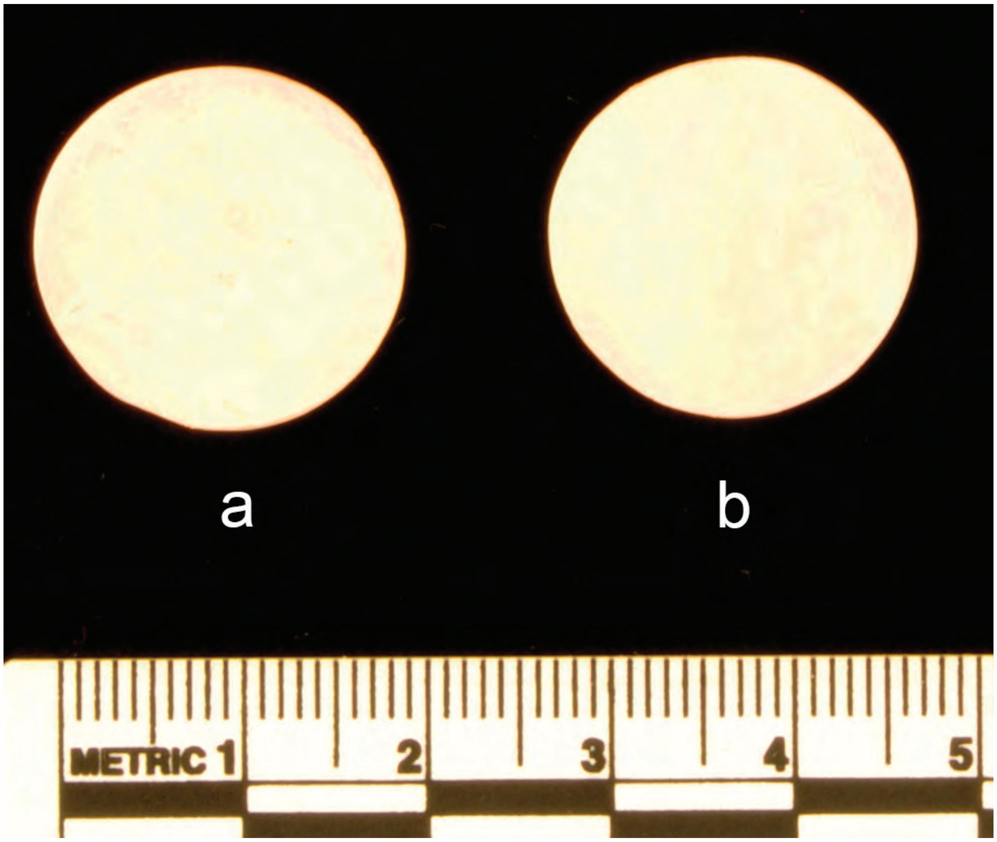

Figure 13.66. Matched pair of *Nautilus*-shell discs: *a*, ECA-48-5-9; *b*, ECA-0-0-15.

Figure 13.67. Worked *Nautilus* shell, ECA-77-10-4.

Miscellaneous Objects of Bone

Three miscellaneous objects of bone are illustrated in Figure 13.68. The first of these is a spatula, presumably made from a human long bone that has been extensively ground, with a rounded tip, and a total length of 145 mm (Figure 13.68, a). This spatula, which was excavated from a post-Lapita context at site EKE, closely resembles a bone spatula illustrated by Nevermann (see Figure 2.19, d). Such spatulae were used ethnographically to remove slaked lime from a container during the process of preparing betel nut chews. The second bone object, from site ECA (Figure 13.68, b), is an incomplete ring of flat bone, possibly turtle bone. Finally, from site EKE and again in a post-Lapita context, we recovered a bone point of unknown function, shown in Figure 13.68, c.

Flaked Stone

Obsidian

Obsidian was the most abundant of all types of flaked stone in the Mussau sites, although its distribution is rather uneven (Table 13.8). Obsidian does not occur locally in the Mussau Islands, and was imported from several others in the Bismarck Archipelago. A total of 8,744 flakes and cores of obsidian were recovered, the majority from Talepakemalai (67.5%), with flakes far outnumbering cores. However, the density of obsidian in the excavated sites varies greatly, as indicated in Table 13.8. The highest density, calculated by either count or weight, occurs in site EKQ, probably reflecting the concentration of material within a confined rockshelter setting. Fairly high densities of obsidian are also present at the main Lapita sites (ECA, ECB, and EHB). Of the post-Lapita sites, only EKU had a reasonably high density of obsidian, and obsidian was entirely absent at sites EHN, EKS, EHK, and EKL. More detailed analyses of obsidian sources and of the technology of obsidian flaking at site ECA are presented in Chapters 14 and 15.

Table 13.8. Obsidian cores and flakes from Mussau archaeological sites

Site	Cores		Flakes		Total		Density N/m^2	Density g/m^2
	N	Weight (g)	N	Weight (g)	N	Weight (g)		
ECA	48	747	5,853	9,859	5,901	10,606	70.2	126.3
ECB	11	89	1,222	1,367	1,233	1,456	64.9	76.6
EHB	17	174	388	508	405	682	45	75.7
EHM			2	3	2	3	0.6	1
EKE			408	434	408	434	21.5	22.8
EKO			6	20	6	20	2.4	8
EKP			5	3	5	3	1	0.6
EKQ	1	3	696	556	697	559	348.5	279.5
EKU	1	384	86	128	87	512	17.4	102.4
Totals	78	1,397	8,666	12,878	8,744	14,275		

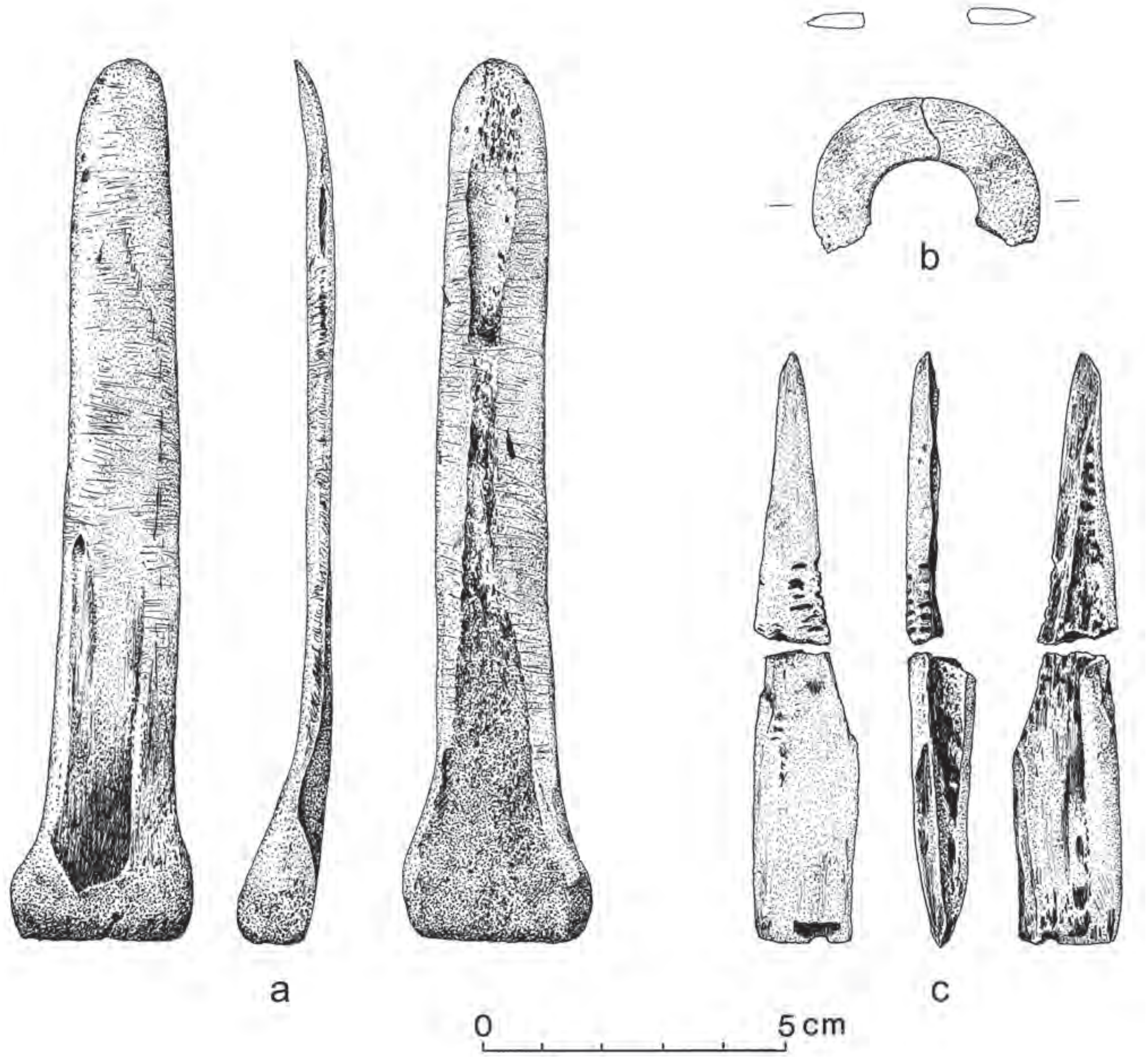

Figure 13.68. Miscellaneous objects of bone: *a*, bone spatula, EKE-11-4-1; *b*, bone ring, ECA-62-4-2; *c*, bone point, EKE-7-3-12, 13. (Drawings by Margaret Davidson.)

Other Flaked Stone

Small quantities of flaked chert were present, with 13 flakes and 3 cores from ECA, 1 flake each from ECB and EKE, and 2 flakes from EKQ. The sources of this chert are not known, but might be from local upraised limestone of Quaternary age on Eloaua or the main island of Mussau, although farther-flung sources are also possible.

Four flakes of a greenish, metavolcanic stone were found at site ECA and one at ECB. This kind of greenish stone was favored for the manufacture of adzes during the Lapita period (Green 1979a). The ECA site also yielded four flakes of basalt. Additional flakes of unspecified volcanic or metavolcanic stone include 15 from ECA, 12 flakes (and 2 cores) from ECB, 2 flakes from EHB, and 1 flake from EKQ.

Manuports

Manuports—unmodified ("natural") stones transported to a site by human action—could readily be identified at the offshore islets such as Eloaua and Boliu, because their igneous or metamorphic character reveals them to be outside of their natural geologic context. During excavation we collected 120 such manuports, primarily from ECA (N = 69), ECB (N = 24), EHB (N = 8), and EKE (N = 15). A petrographic study of 60 of these manuports was conducted by William R. Dickinson (see Chapter 17), with the results indicating that a substantial number of these stones were imported from localities outside of the Mussau Islands.

Summary and Conclusions

The rich assemblage of non-ceramic portable artifacts from Talepakemalai, along with the small assemblages from the ECB, EHB, and EKQ sites, provide the largest collection of Lapita material culture yet excavated in the Bismarck Archipelago. Although limited to nonperishable items (despite the presence of worked wood, no finished wooden objects were encountered in the waterlogged deposits), the collection spans a range of functional categories, from tools to fishing gear, food preparation equipment, and ornaments and exchange valuables.

The early Lapita tool kit included adzes of both stone and *Tridacna* shell, with the shell adzes made from the heavy hinge portion of the giant clam. Small chisels of *Tridacna* shell were also used, perhaps for fine carving work. Other tools included abraders of both branch coral and stone, whetstones or small grindstones, and hammerstones.

The range of reef, benthic, and pelagic fish indicated by the faunal remains at the Mussau sites (see Chapter 7) were no doubt obtained with a variety of fishing methods, some of which are indicated by the fishing gear. One-piece angling hooks (primarily made from *Trochus niloticus* shell) are well represented, with a range of sizes that would suggest pole-and-line fishing on the reef (small hooks) as well as bottom fishing from canoes (larger hooks). The trolling hooks of *Trochus* shell are of particular interest, as these appear to be prototypes for later two-piece (compound) trolling (or "spinner") hooks found across island Melanesia and into Western Polynesia. The use of nets is also indicated by net weights and a probable net mesh gauge.

In the realm of food preparation, the numerous *Cypraea*-shell scrapers and pearl-shell peeling knives attest to the presence of crops whose fruit or tubers needed to be scraped or peeled prior to cooking. The *Cypraea*-shell scrapers were most likely used to scrape the skins of breadfruit (*Artocarpus altilis*), while the peeling knives were probably used to remove the skins of taro and/or yam tubers. Because soft, fleshy tissue did not preserve in the anaerobic deposits at ECA, we lack direct macrobotanical evidence for breadfruit, taro, or yams, hence the significance of the indirect evidence of the scrapers and peeling knives. Of course, all three crops are well attested linguistically by reconstructions of their names in Proto-Oceanic (Kirch 1997, Table 7.2).

Talepakemalai is especially notable for the diversity of shell objects that were used either for personal adornment or as objects of exchange. Made from *Conus*, *Tridacna*, *Spondylus*, and other shell, these objects arguably functioned as "exchange valuables" in a manner analogous to later, ethnographically documented artifacts. The large number of unfinished objects, as well as the quantification of manufacture debris, indicates that Talepakemalai was a locus of shell-valuable production, and that significant numbers of shell objects (especially *Conus* shell rings) were exported out of Mussau to other nodes within the Lapita exchange network. While these shell objects were being produced in Mussau and exchanged outward, other materials were being imported into Mussau, most notably ceramics (or the clay and temper components to make pottery) and obsidian.

Unfortunately, the long hiatus in the extant archaeological record for Mussau (a period extending from roughly 2700 to 1200 BP, see Chapter 5) does not allow us to trace a continuous evolution of material culture in the islands. Assemblages from post-Lapita sites such as EHK, EKS, and EKU, however, do provide some evidence for artifact types present in late prehistory. Notably, there are some significant differences from the earlier Lapita assemblages. This is particularly evident with the adzes, which in the late sites are made exclusively from the ventral margins of *Tridacna crocea*; these are quite common in and on the surface of these later sites. Also frequently found at these sites are adzes of *Terebra* shell, an adze type lacking in the Lapita assemblages. Another major difference is the absence, in the later sites, of angling or trolling fishhooks. And in the realm of ornaments or exchange valuables, the range of types present in the Lapita sites is absent in the later assemblages, where these are replaced by an emphasis on *Trochus*-shell armrings. The general absence of obsidian in later sites is yet a final difference between the Lapita and later prehistoric assemblages.

CHAPTER 14

Mid- to Late Holocene Obsidian Importation in the Mussau Islands

Melinda S. Allen

Preamble

In the late 1980s, a sourcing analysis of 3,975 obsidian artifacts from 18 sites in the Mussau Islands, spanning nearly four millennia, was undertaken. Two methods of source attribution were used: one based on the specific gravities of specimens and the other using automated PIXE-PIGME (proton-induced X-ray emission and proton-induced gamma-ray emission) technologies. This chapter was drafted soon thereafter, and then substantially revised in 1998. In the years since, major technological advances have revolutionized stone tool sourcing studies in the Pacific. From a technical perspective, the density sourcing method described herein is now mostly of historical interest, while the PIXE-PIGME method has been largely replaced by other less costly, high-resolution technologies. Indeed, a major finding of this study was that the specific gravity of western Pacific obsidians overlapped to a greater degree than previously indicated, and even the two major source regions, the Admiralty Islands and West New Britain, are not unambiguously differentiated with this method. Nonetheless, the findings reported here continue to have relevance for interpreting density-sourced assemblages, including both the Mussau assemblages and other similarly processed assemblages that have yet to benefit from high-resolution, fast-throughput technologies such as portable X-ray fluorescence (pXRF). Usefully, the latter has more recently been applied to a large sample of obsidian specimens from the ECA site (see Chapter 15).

In addition to technological advances, understandings of the prehistory of the Bismarck Archipelago in particular, and the Lapita cultural complex more generally, have been enriched by new field studies and laboratory research. Rather than attempt to integrate this more recent work with the Mussau sourcing results reported here, the chapter has been left largely as it was written in 1998, with some modest revisions for the sake of accuracy and clarity (including integration of the dating analyses reported in Chapter 5). As such it gives insights into the context in which the initial Mussau sourcing work was undertaken and the understanding of Lapita exchange systems at the time. This also seemed appropriate given that an unpublished version of this chapter has been circulating for more than thirty years, and has been occasionally referenced in the literature. Scholars new to the area may find the review of sources and subsources useful as well, as variability in raw material form, quality, and accessibility is considered in some detail. In a few places 2019 notes have been added in square brackets, mostly in reference to Ross-Sheppard's recent analyses (Chapter 15).

Despite technical and substantive progress in West Pacific obsidian studies and Lapita archaeology in general, the Mussau obsidian analysis remains the largest sourcing study from this archipelago and it demonstrates a particularly close association between the Admiralty sources and sites of the Mussau Islands, from the early Lapita period and continuing into late prehistory. The assemblages here also uniquely inform on the earliest intersection of two long-standing obsidian exchange networks that extend back into the late Pleistocene, those of the Admiralty Islands and West New Britain, which had been discrete interaction spheres, at least with respect to obsidian, until the arrival of Lapita colonists.

Introduction

Long-distance transport of exotic goods, particularly obsidian, has been a hallmark of the Lapita cultural complex (e.g., Ambrose and Green 1972; Kirch 1988b). Increasingly, however, the evidence shows that such long-distance movement of goods (including plants and animals) by the bearers of Lapita pottery may be an outgrowth of, or at least parallel, more ancient patterns (e.g., Gosden 1993; White 1996). Recent work [from a 1998 perspective] on Pleistocene sites in Near Oceania now allows us to place obsidian use in deeper historical context. In the terminal Pleistocene, obsidian was carried between islands and over distances of more than 350 km (Summerhayes and Allen 1993), a process that was to intensify in the early Holocene. Given these long-standing patterns, questions are now focusing on the extent to which late Pleistocene to mid-Holocene obsidian procurement and consumption may have changed with the appearance of Lapita pottery.

The limited geographic distribution of obsidian in the Pacific makes it a particularly valuable tool for tracking human movement and interaction. Five discrete source regions have been identified in Near Oceania. Most have been known for some time, but the Mopir and Manus Island obsidians were poorly known when the Mussau field work was initiated in 1985 (Allen and Bell 1988). Within the last decade, considerable research has been aimed at identifying chemically discrete subsources within these five regions and, on New Britain, characterizing the abundance, nature, and quality of obsidian exposures (e.g., Bird et al. 1997; Fredericksen 1997a; Kennedy 1997; Torrence et al. 1992; Summerhayes et al. 1993, 1998).

Among the more intriguing questions is how and why obsidian was moved over long distances, particularly in localities where local stone resources were available. Coincident with Lapita expansion into Remote Oceania, Near Oceania obsidians were carried over distances of up to 3,700 km (e.g., Best 1987; Green 1987; Kirch and Yen 1982). They also appear in at least one site that lies west of Papua New Guinea but was penecontemporaneous with Lapita occupations to the east (Bellwood and Koon 1989:617, 620). Various models have been proposed to explain both the mechanics and the underlying drivers of obsidian transport (e.g., Green 1987; Green and Kirch 1997; Kirch 1990a; Summerhayes et al. 1998). Green (1987) suggested three distance-related exchange systems for the Reef/Santa Cruz Islands, including direct access, "one stop" reciprocity, and down-the-line exchange. More recently Green and Kirch (1997) stressed the varied and dynamic nature of Lapita exchange systems, while White (1996:204) argues that no "system" per se can be archaeologically demonstrated and various exchange mechanisms could account for the available archaeological evidence.

The function of Lapita exchange is similarly debated. One explanation is that exchange acted as a form of insurance or risk management, serving to maintain critical links between colonists advancing into new territories and their original homeland communities (e.g., Green 1987:246; Hunt 1989:218–221; Kirch 1988c:113, 1990a:128, 1991a). Obsidian also may have been a prestige good that was exchanged for other high-status products such as "shell valuables" (Kirch 1988c; see also Green 1987; Sheppard 1993). In many respects, however, the degree, regularity, and kind of interaction represented by obsidian and other exotic goods remain poorly understood. As a contribution to resolving these issues, this chapter reports on the combined results of PIXE-PIGME and relative density analyses of obsidian artifacts from 18 Mussau sites spanning nearly four millennia of occupation. This work draws on intensive research in analytical instrumentation and source characterization by W. Ambrose, R. Bird, R. Fullagar, R. Torrence, G. Summerhayes, P. White, and others, and refines preliminary interpretations of the Mussau obsidian record as reported by Kirch and others (1991).

Regional Obsidian Sources

Obsidian occurs in four discrete geographic areas within Island Melanesia: the Admiralty Islands, West New Britain Province, Fergusson Island in the D'Entrecasteaux Group, and the Vanuatu Archipelago. These regions correspond to particular volcanic complexes with chemically distinct obsidians, which are also distinctive, to varying degrees, in terms of their specific gravities (see below). Within each of these geographic regions multiple "subsources" (following Allen and Bell 1988:84), or "subgroups" (after Summerhayes et al. 1998) can be further chemically differentiated. Subsources, defined on the basis of distinctive chemistry, are typically comprised of several flows from one or more related volcanoes but also may correspond to differently-aged flows from the same volcano (see Ambrose and Duerden 1982; Ambrose et al. 1981). Defined on geochemical grounds, subsources do not necessarily consist of exposures that are geographically adjacent to one another within a source region. Two obsidian regions are relevant to the present discussion: West New Britain and the Admiralty Islands. The following discussion highlights features of these major source areas, and their subsources, which relate to accessibility, raw material form, and the quality of the obsidian—all dimensions of variability that could potentially affect obsidian procurement, use, and discard by the prehistoric inhabitants of the Mussau Islands.

Admiralty Islands

In the Admiralty Islands, obsidian exposures have been identified on Manus Island, at various localities on Lou Island, and on the smaller islands of Pam Lin, Pam Mandian, and Tuluman. Materials from all, except possibly the latter, have been identified from archaeological contexts (e.g., Ambrose et al. 1981). The 12 km long island of Lou is composed of 12 coalesced volcanoes (Johnson and Smith 1974:334), with obsidian available at several localities. Materials typically occur as boulders and cobble blocks in pumice, ash, and ignimbrite formations, and occasionally as pebbles in dry stream beds (Ambrose and Duerden 1982:85).

Umleang Ridge, on the northern end of Lou Island, is the best studied Admiralty extraction area (Fullagar and Torrence 1991). As many as 25 quarry shafts, some up to 17 m deep, have been recorded here (Ambrose et al. 1981:7; Fullagar and Torrence 1991). These shafts were excavated to access obsidian flows that were deeply buried by thick ash layers. Quarry shafts also have been reported at Solon, 5 km to the southwest (Ambrose et al. 1981:7). These shafts reflect relatively late quarrying activities of the last 200 years (Ambrose and Duerden 1982:88).

In the nearby village of Rei, archaeological excavations indicate that access to the island's obsidian sources has occasionally been interrupted (Ambrose et al. 1981:3). Here flaked stone tools from a geochemically distinct but physically as yet unidentified Lou subsource were found blanketed under 3 m of ash and pumice deposited about 1,600 years ago, suggesting some previously used surface exposures are now buried. A second major eruption at around 2800 BP also may have disrupted access to certain exposures (Ambrose and Duerden 1982:87).

Based on geochemical analyses of artifacts and surface collections, Ambrose and Duerden (1982) identified nine geochemically distinct Admiralty subsources. Subsequently, Bird (personal communication, 1992) and colleagues have collected materials from five of the 12 Lou Island volcanic centers: Lakou, Umrei, Wekwok, Solang, and Baun. According to Bird (personal communication 1992), the Wekwok subsource is geochemically distinct from the others but was represented by a single sample. Subsequently, Fredericksen (1994, 1997a, 1997b) used energy-dispersive X-ray spectroscopy (EDS) to separate Wekwok/Baun obsidians from other subsources on the Lou mainland. Extensive workshop areas and shallow excavation pits up to 1 m deep have been observed at Wekwok (Ambrose and Duerden 1982:85; Ambrose et al. 1981). Umrei, Solang, and Baun cluster together geochemically but overlap with Lakou. The Lakou material is reportedly of poor quality and unsuitable for artifact production (Bird, personal communication, 1992). Bird notes that "Lapita artefacts attributed to Lou (Umrei) show a greater spread than do the currently available Umrei source samples," again raising the possibility of buried exposures.

Pam Lin, another Admiralty subsource, is a small islet about 6 km southeast of Lou Island. The approximately 500 m diameter islet has a centrally located obsidian flow, which is about 2 m above the high-water mark (Ambrose et al. 1981:7). The slightly larger islet of Pam Mandian is located immediately southwest of Pam Lin. On Pam Mandian, obsidian occurs both as rhyolite-obsidian flows and as boulders. Ambrose and colleagues note that the Pam Mandian material is of poor quality, but workable. PIXE-PIGME analyses of Pam Mandian materials are not available but Fredericksen's (1997b) analysis using EDS indicates that they are geochemically distinct from other Admiralty subsources.

Tuluman Island, immediately south of the Lou mainland, has large pitchstone-obsidian cliffs (Ambrose et al. 1981:3). The island is, however, quite youthful, having emerged in the mid-1950s (Reynolds and Best 1976). Obsidian exposures also have been identified on Manus Island at Malai and Southwest Bays (Ambrose and Duerden 1982:87; Fredericksen 1994; Kennedy 1997; Kennedy et al. 1991). The Manus materials are reported to be geochemically distinct from other Admiralty subsources (Bird et al. 1988; Fredericksen 1994).

West New Britain Province

The northern side of New Britain Island is dominated by a series of volcanic complexes which are part of the Bismarck volcanic arc (Johnson et al. 1973). Within this volcanic series, two primary regions with multiple obsidian exposures have been identified, Willaumez Peninsula and the Mopir area of Cape Hoskins.

Willaumez Peninsula. The Willaumez Peninsula is a geologically complex formation comprised of 11 Quaternary-age volcanoes (Lowder and Carmichael 1970). Six of these have contributed obsidian flows, including the mainland volcanoes of Mount Gulu (the source of materials sometimes referred to as Voganaki and Pilu), Mount Humugari, Mount Kutau (also known as Mount Schleuther and including the location known specifically as Talasea), Mount Bao, and the Garua Island volcanoes of Mount Hamilton and Mount Baki. Specht (1981) initially distinguished a northern group of exposures where obsidian occurs as thick banded flows, including Voganaki, Bamba, and on Garala Island (Schaumann Is.). He contrasted these with a southern group where obsidian is more commonly found as boulders and cobbles in inland gullies and under volcanic ashfall, including exposures at Talasea, Bitokara, Volupai-Liapo, Waru-Dire, Kumeraki, and Kumuvavo.

Initial assessments of Talasea obsidian by Kamminga (1982) showed that relative to flakable stone from Australia and Papua New Guinea, Talasea materials were resistant to static loading, but not particularly tough. In terms of elasticity and resistance to compressive and tensile strength properties they were intermediate. Subsequently, Torrence and others (1992) attempted to evaluate the general flaking quality and accessibility of a larger number of Willaumez Peninsula exposures. Of the 60 localities tested, most produced obsidian with good conchoidal fracturing properties. Two exceptions were materials from Mount Hamilton and Mount Gulu. Mount Hamilton has extensive obsidian flows with large blocks, but the material "invariably contains a very high density of small, white phenocrysts" and has poor conchoidal fracturing properties (Torrence et al. 1992:88). This subsource is, however, occasionally represented in archaeological contexts (Summerhayes et al. 1998). Mount Gulu obsidians also are described as physically accessible but the raw material itself "often marred by a high density of large phenocrysts which impede flaking" (Torrence et al. 1992). Nevertheless, Torrence et al. (1992:96) identify two high-quality and three medium-quality exposures in the Mount Gulu region that were used in the relatively recent past. They also note that physical properties, such as color and translucency, are far too varied to allow assignment of artifacts to particular collection localities based on appearance alone. The 1992 study of Torrence and colleagues demonstrates that the potential range of sources for prehistoric consumers on the Willaumez Peninsula was considerable. This corresponds with the earlier observations of Specht and others (1988: 5), who reported "the density of obsidian sources is so high that nowhere in the Talasea region is [obsidian] more than a few minutes' walk."

Summerhayes and others (1993; see also Bird et al. 1997) introduced technical improvements to the characterization process in the 1990s and analyzed the same 60 discrete Willaumez Peninsula obsidian exposures detailed in Torrence and others (1992). Building on the work of Fullagar and others (1989), their PIXE-PIGME results identified four distinct geochemical groups, two on the New Britain mainland and two on offshore Islands: 1) Mount Kutau/Mount Bao; 2) Mount Gulu; 3) Mount Hamilton, Garala Island; and 4) Mount Baki with flows on both the northeastern side of Garua Island and the smaller island of Garala.

Summerhayes and colleagues (Summerhayes et al. 1993, 1998) found that over much of the prehistoric past, the Kutau/Bao subsource predominated, as indicated by source assignments of 1,002 samples from 26 New Ireland and New Britain sites (many of which are stratified). This large sample covers a broad time period, from the Pleistocene into late prehistory. Seventy-six percent of the obsidian samples were from Kutau/Bao, 4% from Baki, 2% from Gulu, and less than 1% from Hamilton. In practical terms, these findings are not surprising, as Torrence and others (1996:219) report that the Kutau/Bao exposures are on the whole more extensive and contain greater quantities of large obsidian nodules that are easier to quarry compared to those of the other three subsources. At Kutau/Bao, discrete bands of obsidian commonly occur in rhyolitic flows, and vary in thickness from less than 1 cm to several meters. Moreover, the quality of the rock is described as good to medium (Torrence et al. 1992). Good-quality obsidian also is found as cobbles and boulders in secondary or detrital contexts.

Mopir, Cape Hoskins. Mopir is another important source, located on Cape Hoskins, roughly 50 km east of the Willaumez Peninsula and 30 km inland from Kimbe Bay. Early geological reports noted obsidian in the vicinity of Mount Witori and Mount Buru (Blake and Ewart 1974:323). More recently, archaeologists identified Mopir as an important obsidian source for prehistoric populations of the region (Bird et al. 1988; Fullagar et al. 1991; Specht and Hollis 1982). Studies by Fullagar and others (1991) and Torrence and others (1996) indicate that both the quality and quantity of Mopir obsidian are comparable, if not superior, to that found on the Willaumez Peninsula. In particular, Mopir material tends to have fewer inclusions relative to that from the Willaumez Peninsula.

In the Mopir source area, over 21 exposures have been observed and materials are spread over an area of about 40 km^2 (Fullagar et al. 1991). These exposures tend to be well spaced and occur principally in water courses. They vary from massive, 2 to 3 m thick flows with extensive evidence of quarrying, to loose clastics in ashy deposits (Fullagar et al. 1991:111). Secondary deposits of obsidian boulders are also common. The Mopir obsidians are geochemically distinct from those of the Willaumez region and fairly homogenous (Bird et al. 1988:109; Summerhayes et al. 1998). Moreover, they have a limited specific gravity range (Torrence and Victor 1995).

Methods and Materials

The Mussau Obsidian Assemblages

The obsidian assemblages analyzed for this study (N = 3,975) come from 18 sites that date from sometime between 3750–3450 BP and late prehistory. The sites are located on the main island of Mussau and small nearby islands, and include open settlements, rockshelters, and middens. Details of the site contexts and stratigraphy (presented in Chapters 3 and 4) and chronological associations (reviewed in Chapter 5; see also Kirch 2001a) are briefly reviewed here as background to the obsidian sourcing study. Excavations at three extensive open Lapita-age settlements, Etapakengaroasa (EHB), Etakosarai (ECB), and Talepakemalai (ECA Areas A, B, and C), provided relatively large obsidian assemblages. The localities of EHB (N = 404), ECB (N = 444), and ECA Area A (N = 476) are considered single occupations; EHB dates from around 3750–3450 BP, ECB from 3200–3050 BP, and ECA Area A from around 3600–3000 BP. ECA Area C showed internal variation in the density of obsidian specimens (N = 176), ceramics, and other artifacts but there were no clear stratigraphic distinctions and thus this assemblage is treated here as a single analytical unit. At ECA Area B, six stratigraphic zones were recognized, Zone A being the most recent (late prehistoric) and disturbed by recent gardening and Zone C3 the earliest at around 3200–2950 BP. Obsidian from all zones of excavation Units W195N150, W197N150, W199N150, and W200N150 (N = 274) were processed; for an additional 18 excavation units at Area B, specimens only from Zones C1, C2, and C3 (N = 674) were analyzed. Lapita-age deposits from two rockshelters also provided obsidian. The EKO site and its obsidian (N = 37) is dated by a single ^{14}C determination to sometime between 3601–3009 BP. At the EKQ rockshelter seven strata were observed and four main occupation zones defined, with the initial occupation dating from about 3200–2950 BP and extending to about 2700 BP. Obsidian from the lower levels (levels 5–20) and strata (II–VII) of EKQ (N = 715) inform on usage patterns in the late Lapita period.

Three sites are definitively post-Lapita in age based on the associated ^{14}C dates and, to some extent, the artifact inventories. These include the four upper levels (levels 1–4, Stratum I) of the EKQ rockshelter (N = 19), which dates from around 1200 BP. Other late sites include the open site of EKU (N = 154) and EKS (N = 9), a midden that dates to immediately prior to European contact. Surface collections from two other possible late prehistoric sites on offshore islets were analyzed: EKG (N = 13) and EKV (N = 33). Excavations at the open site of EKE on Boliu Island provided obsidian (N = 383) from both Lapita and post-Lapita contexts. As stratigraphic details were not available in 1987, this site is not further discussed; however, for the record, more than 90% of the EKE assemblage was allocated to the Admiralty source on the basis of specific gravity. Finally, obsidian from a handful of sites of uncertain chronological associations were analyzed, including EKP (N = 8), EHM (N = 2), and surface collections from four open sites: EHO (N = 7), EKC (N = 134), EKN (N = 7), and EKX (N = 6).

The nature of the Mussau obsidian specimens is treated at length elsewhere (see Chapter 16). For the most part they include small flakes with little purposeful retouch but occasional use-wear. A small number of cores were observed but cortex was uncommon. The quality of the raw materials varied considerably, from glassy, translucent, highly flakable to grainy, spherulitic, and/or vesicular.

Previous Chemical Characterization Studies

Archaeological efforts to distinguish among Pacific obsidian source areas were initiated by Roger Green in New Zealand using emission spectrography. Subsequently, proton-induced X-ray emission (PIXE) and proton-induced gamma-ray emission (PIGME) techniques were introduced and became a primary means of distinguishing the obsidians and volcanic glasses of Near and Remote Oceania (Ambrose and Duerden 1982; Bird and Russell 1976; Bird, Ambrose, et al. 1981; Bird, Duerden, et al. 1981; Duerden et al. 1979). PIXE-PIGME provides information on the relative concentrations of 26 elements; recent technical advances, coupled with more intensive sampling, have greatly added to the precision and accuracy of source and subsource allocations (e.g., Bird, personal communication, 1992; Bird et al. 1988; Summerhayes et al. 1998). In 1990, in particular, technical adjustments were made to allow finer discriminations within the main geographic regions (see Summerhayes et al. 1998). Importantly in this regard, the initial PIXE-PIGME analyses of the Mussau materials were made in 1988. White and Harris (1997) subsequently reanalyzed seven Mussau specimens in conjunction with their Duke of York Islands study, in an effort to take advantage of these improvements and facilitate comparisons with their own assemblages (see Discussion below).

While the precision and reliability of these prompt nuclear techniques are high, they are costly and thus only can be applied to small samples of archaeological collections. In an effort to circumvent these limitations, Green (1987), building on the earlier work of Ambrose and Green (1972; see Ambrose 1976; Best 1975 in Green 1997), developed a technique that involved sorting large numbers of samples on the basis of specific gravity differences. The idea was that these specific gravity groups could subsequently be subsampled for PIXE-PIGME analyses—the approach applied to the Mussau assemblages in the late 1980s.

Relative Density Separation

Ambrose and Green (1972; see also Ambrose n.d.; Ambrose 1976) first demonstrated that obsidian from the various Melanesian source regions had variable specific gravity ranges. Samples from Talasea (Willaumez Peninsula), for example, varied in density from 2.3300 to 2.3870 gms/cm^3, while materials from Lou Island (Admiralties) varied from 2.3700 to 2.41 gms/cm^3. Although there was some overlap between the two major sources, Green (1987) suggested that most archaeological specimens were drawn from a more restricted portion of the specific gravity range of any given source. Notably, at the time of Green's study, Mopir was not recognized as a distinct and important prehistoric obsidian source.

Following the Mussau analysis, Torrence and Victor (1995) attempted to use the density method to separate Willaumez

Peninsula and Mopir materials, and the Willaumez subsources. Based on an analysis of 334 specimens from Willaumez Peninsula and Mopir, they found that the two main sources could not be distinguished on the basis of relative density, and neither could the four chemically distinct Willaumez Peninsula subsources be differentiated. Importantly, however, Mopir, as well as the Willaumez subsources of Baki and Hamilton, had relative density ranges that were distinct from those reported for the Admiralty Islands by Ambrose (1976). The Mount Gulu and Kutau/Bao subsources, on the other hand, have quite wide specific gravity ranges, particularly so in the case of Mount Gulu (1.9855 to 2.3609). Subsequently, White and Harris (1997), using direct density measurement of specimens coupled with PIXE-PIGME determinations, demonstrated that the maximum density for Kutau/Bao obsidian is 2.378, overlapping with Admiralty obsidians (other than the Pam Island materials) to only a minor degree.

The Torrence and Victor (1995) study also provided some relevant methodological insights. Most notably, they showed that the presence of cortex did not influence specific gravity. Inclusions, in contrast, did have some effect on the accuracy of density assignments when they were present in abundances of greater than 15%. The authors observed that few localities in West New Britain produced materials with more than 5% inclusions and for this reason they suggested that inclusions are not likely to significantly bias relative density results.

For the Mussau study, the density work was carried out with a powdered heavy liquid, sodium metatungstate ($3Na_2WO_4.9WO_3$) and distilled water. Green (1987) and Ambrose (1976) had previously suggested the critical cutting points for separating materials from the main source regions (Willaumez and Admiralty Islands) and two solutions were prepared. Two kinds of standards were used to establish and maintain the density of the solutions: flakes provided by Roger Green whose density had been directly measured (precise to 0.0005) and a single commercial specific gravity indicator bead (precise to 0.01). Flakes provided by Green included:

ANU 375/3	Willaumez Peninsula	density = 2.3564
ANU 508	Willaumez Peninsula	density = 2.3596
ANU 512	Admiralty Islands	density = 2.3869

As both calcium carbonates and clays are reported to react with sodium metatungstate to form precipitates, they had to be removed prior to heavy liquid separation. Specimens with calcium carbonate encrustations were washed in 10% acetic acid, while those with adhering clays were cleaned in distilled water. Bird and others (1988) also report that sodium metatungstate can affect PIXE-PIGME analyses; therefore, following immersion in the heavy liquid, all flakes were rinsed thoroughly in distilled water.

Difficulties were encountered in keeping the standards suspended midway in the solution column, confounding efforts to monitor and maintain a constant solution density. Therefore, two standards were used in each solution as a check on one another. The density of the solution was taken to be an average of the two standards. The density of Solution A, for example, was 2.36 gm/cm^3, as measured by flakes ANU 375/3 with a density of 2.3564 and ANU 508 with a density of 2.3596. The density of Solution B was 2.38, as measured by the 2.38 commercial specific gravity indicator bead and flake ANU 512 with a density of 2.3869. The two density solutions allowed the Mussau specimens to be divided into three density classes:

Density Class 1 (less than 2.36)
Density Class 2 (greater than 2.36 but less than 2.38)
Density Class 3 (greater than 2.38)

Specimens that floated in Solution A were assigned to Density Class 1, which was assumed to represent Willaumez Peninsula materials. Specimens that sank in Solution A, but floated in Solution B, were assigned to Density Class 2 and thought to represent both Willaumez and Admiralty materials based on published source density ranges. Specimens that sank in Solution B were assigned to Density Class 3 and assumed to represent either the Admiralty Islands or a Vanuatu source, with the latter considered an unlikely possibility.

To test the accuracy of the technique, a subsample of 50 specimens was reprocessed using fresh sodium metatungstate solutions. The technique was found to be 100% reliable, with all 50 specimens being attributed to the same density class as in the first run. During the analysis it became evident that very small flakes (under 5 mm) might be problematic. Specifically, several such small specimens that could be refitted to larger ones sorted differently from their "parent flakes" in the heavy liquid solutions.

PIXE-PIGME Analyses

The PIXE-PIGME analyses were intended to test the efficacy of the relative density method in separating Admiralty Islands materials from those of West New Britain origin, and to provide information on subsources. As described above, the working hypothesis was that specimens in Density Class 1 represented the Willaumez source, Density Class 2 both the Willaumez and Admiralty sources, and Density Class 3 the Admiralty source alone.

One hundred and one specimens were sent to Dr. Roger Bird of the Atomic Energy Research Establishment at Lucas Heights, Australia in 1992 as part of the Lapita Homeland Project (see Bird et al. 1997). Materials from four excavated sites were represented in this sample, including EHB (N = 21), ECB (N = 20), ECA Area B (N = 39), and EKQ (N = 21) (Table 14.1). The 101 specimens were a non-random grab sample aimed at representing the petrographic variability observed in the three density classes and across the four sites. For example, samples from Density Class 1 included both classic Talasea materials (translucent, brownish, with no inclusions) and matte, gray-black flakes with white spherulites. Density Class 2 was sampled the most heavily, as this was where we expected the greatest source overlap. The aim was to identify correspondences between physical attributes and chemically distinct obsidian groups; Torrence and others (1992:88) have more recently demonstrated that even within a given chemical group, physical attributes can be quite varied. Very small (see above) specimens were excluded from the PIXE-PIGME sample, a wise decision in light of findings by Summerhayes and others (1998), who found that such samples can be problematic in elemental analysis.

Table 14.1. Number of PIXE-PIGME obsidian samples by density class

Site	Class 1	Class 2	Class 3	Totals
EHB	4	10	7	21
ECB	5	10	5	20
ECA Area B	7	20	12	39
EKQ	5	10	6	21
Totals	21	50	30	101

Results

General Comments

The PIXE-PIGME findings did not fully support our initial expectations about the relationships between sample densities and particular source regions. Thus, these findings must first be reviewed in broad outline before discussing the relative density results. Importantly, the PIXE-PIGME analyses indicated that Mopir, D'Entrecasteaux, and Vanuatu sources were not represented in the 101 samples submitted, suggesting that these sources were unlikely to be important in (or were possibly altogether missing from) the Mussau assemblages at large.

The most significant finding, however, was that the density ranges of the Willaumez and Admiralty sources overlap to a greater degree than previously reported. While the earlier work of Ambrose (1976) and Green (1987) (and subsequently, Torrence and Victor 1995; White and Harris 1997) illustrated this problem, the overlap was believed to be minor (e.g., certain overlapping subsources were not widely used; archaeological specimens are derived from a limited portion of a source's range, etc.). Contrary to these expectations, the Mussau PIXE-PIGME analysis demonstrated that of the 21 Density Class 1 specimens, 48% (N = 10) derive from the Admiralty Islands. The remaining 80 specimens (Density Classes 2 and 3) can be assigned to the Admiralties. The problematic Admiralty subsource was tentatively identified as Pam Lin, with a density range of 2.337 to 2.4055 as reported by White and Harris (1997) for the Duke of York Islands specimens and their direct density measurements of a select sample of Mussau materials. Further extrapolating from the Mussau PIXE-PIGME results, Density Class 3 (N = 30) is largely (if not entirely) from the Umrei subsource, while 64% (N = 32) of the Density Class 2 specimens are likely to be from Pam Lin and 26% (N = 13) from Umrei. Note that some material could not be allocated.

These results indicate that density class results are not easily interpretable. Also problematic is the issue of how representative the PIXE-PIGME samples are of the Mussau assemblages as a whole. If physical variation is not linked to chemical variability (Torrence et al. 1992), which was one criterion on which Mussau samples were selected for PIXE-PIGME analysis (see above), then certain subsources might not be represented, particularly the rarer ones. Larger, randomly selected samples from each site would improve confidence in the representativeness of the Mussau PIXE-PIGME analyses. [The pXRF analyses undertaken by Ross-Sheppard, as reported in Chapter 15, are informative in this respect.]

Relative Density Analyses

With these caveats in mind, the combined PIXE-PIGME and relative density data (Figures 14.1 through 14.4) allow for an assessment of broad trends in obsidian use in the Mussau Islands over the last 3,700 years. The PIXE-PIGME results form the basis for extrapolating the percentage of Willaumez Peninsula specimens present in the larger Mussau assemblages (i.e., the proportion of Density Class 1). Density Class 2 is considered most likely to represent the Admiralty source, although the possibility that Mount Gulu is represented in Classes 2 and 3, and Kutau/Bao in Class 2, cannot be entirely discounted, despite their absence from the smaller PIXE-PIGME sample (see Chapter 15).

In Figure 14.1 the Lapita sites of Mussau are placed in approximate chronological order based on their associated radiocarbon dates and artifact assemblages. The combined density analyses and PIXE-PIGME results indicate that both the Willaumez and Admiralty sources are represented in the Lapita occupations of EHB, ECB, EKO, and ECA Area A, as well as the somewhat later Lapita occupations of ECA Area B, EKQ, and ECA Area C. The overall counts (and weights) suggest a greater reliance on the more proximate Admiralty source (Density Classes 2 and 3). Density Class 1 specimens are best represented in Zone C1 of ECA Area B, where they comprise 57% of the assemblage by count (N = 47; Figure 14.2). Extrapolating from the PIXE-PIGME results, approximately half of this might derive from the Willaumez region and the other half from Pam Lin. At the earlier sites of EHB and ECB, Density Class 1 comprises 27% and 38% of the specimens by count (N = 109, N = 167 respectively; Figure 14.1),

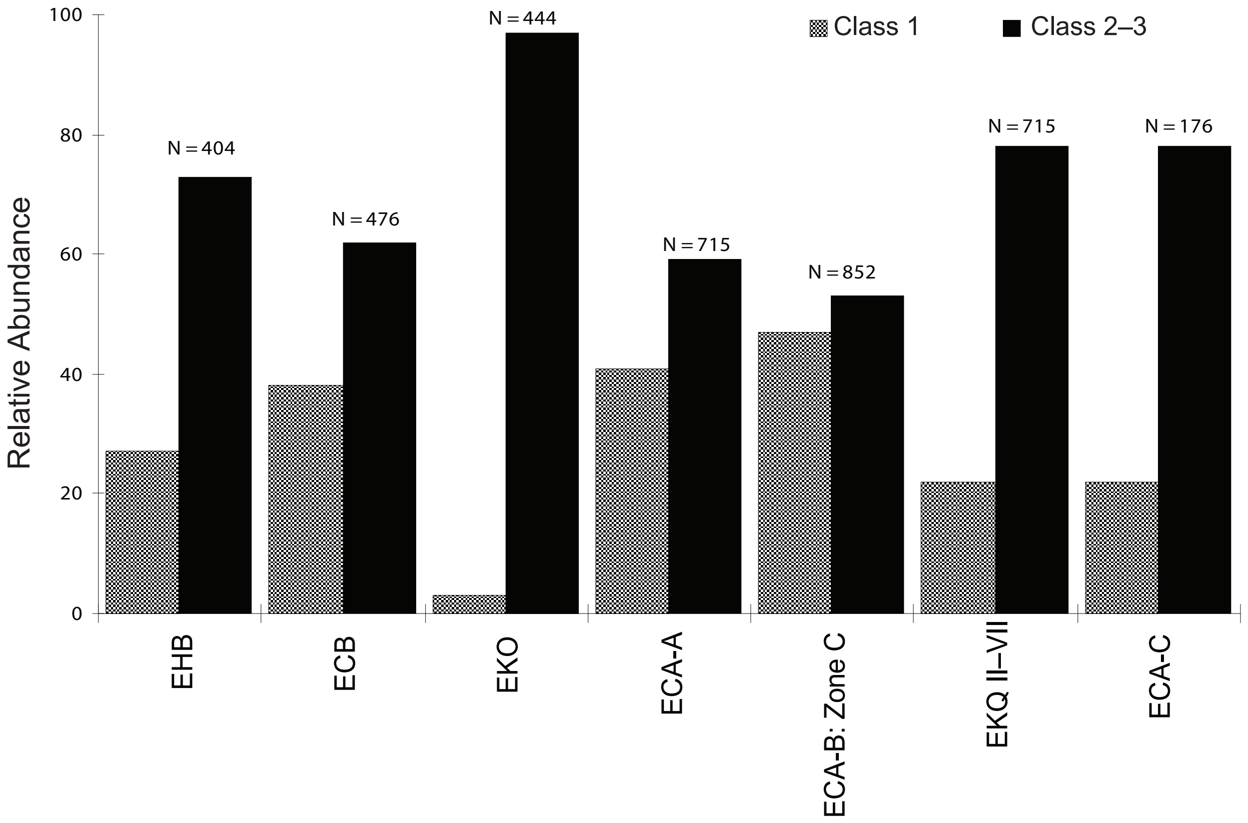

Figure 14.1. Relative abundance (counts) of specific gravity density classes in the main Lapita sites, with sites ordered chronologically from earliest (left) to most recent (right); values at top of bars are stratigraphic zone totals.

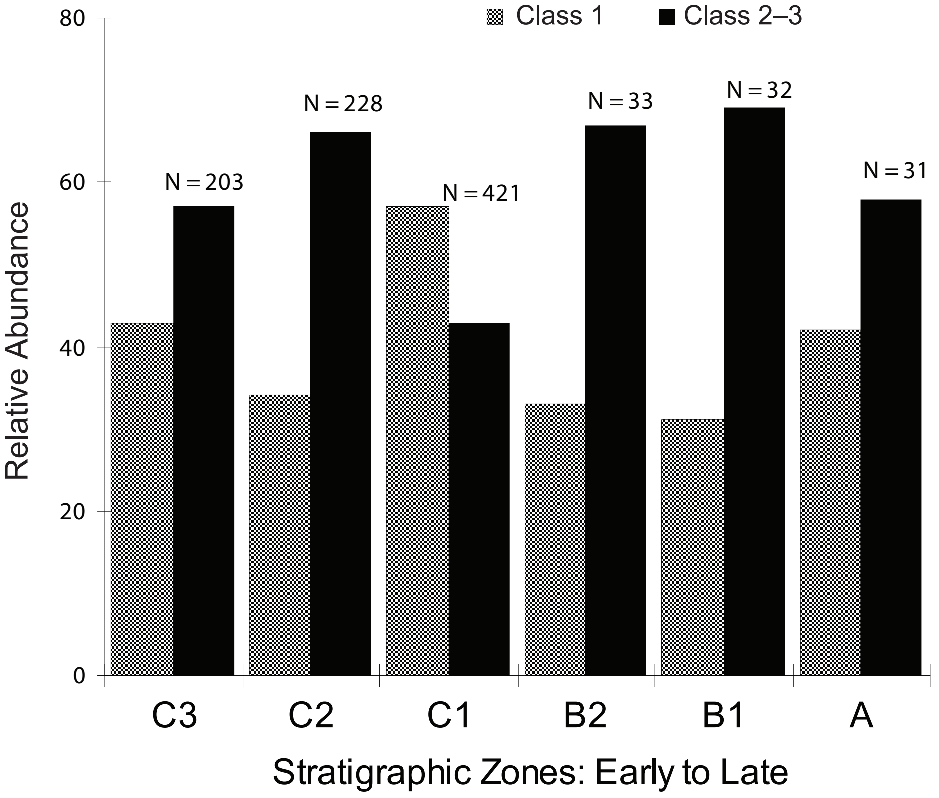

Figure 14.2. Relative abundance (counts) of specific gravity density classes by stratigraphic zone at site ECA, Area B, from earliest (C3) to more recent (A); values at top of bars are stratigraphic zone totals.

while the small (and possibly unrepresentative) sample from EKO contains very little Density Class 1 material.

The ECA Area B stratigraphic sequence provides useful information on changing patterns of source use through time (Figure 14.2). Density Class 1 peaks in Zone C1, declining thereafter but with a modest increase in the late Zone A Seven Density Class 1 specimens were submitted for PIXE-PIGME analysis and five were assigned to Kutao/Bao. In the EKQ rockshelter, where initial site use dates to roughly the same time interval as Zone C1 of ECA Area B (see Chapter 5), Density Class 1 is well represented (Strata IV–VII), but declines thereafter (Figure 14.3). Here only two of the five Density Class 1 specimens from the early strata were provenanced to Kutao/Bao by the PIXE-PIGME analyses. In the late prehistoric Stratum I of the EKQ site, Density Classes 2 and 3 dominate, and extrapolating from the overall PIXE-PIGME findings, even the small amount of Class 1 material found here could be from the Admiralty Islands.

The trends at sites ECA and EKQ are corroborated by other single-occupation sites (Figure 14.4). The excavated EKU assemblage, for example, provides a good indication of the post-Lapita part of the Mussau sequence, with a marked dominance of Density Classes 2 and 3. By late prehistory, as seen in both excavated sites and surface collections, the Admiralty source dominates almost to the exclusion of Density Class 1 specimens. Only small quantities of Density Class 1 are found at the late sites of EKU and EKS, and among the surface collected materials from the likely late sites of EKV and EKG, and even these specimens may be low-density Admiralty obsidian (e.g., from Pam Lin Is.).

The EKQ rockshelter sequence demonstrates other important trends. Radiocarbon dates indicate that Strata IV through II date to the later period of Lapita occupation on Mussau. During this time, a decline in Density Class 1 materials is accompanied by an overall increase in obsidian exploitation (Figure 14.3). In Stratum II (levels 5–10) obsidian use peaks, as reflected in both counts and weights. In addition, the size of the pieces increases (see Chapter 16). These changes suggest a shift in the character of obsidian procurement, use, and, by extension, the nature

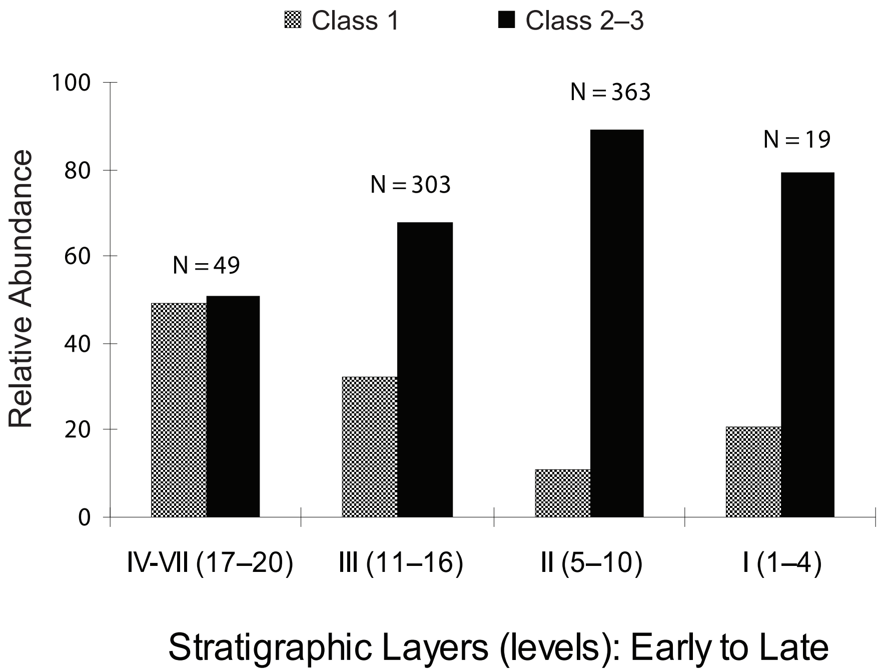

Figure 14.3. Relative abundance (counts) of specific gravity density classes by stratigraphic layers (and levels) at the EKQ rockshelter, from early (Strata IV–VII) to late (Strata I); values at top of bars are stratigraphic layer totals.

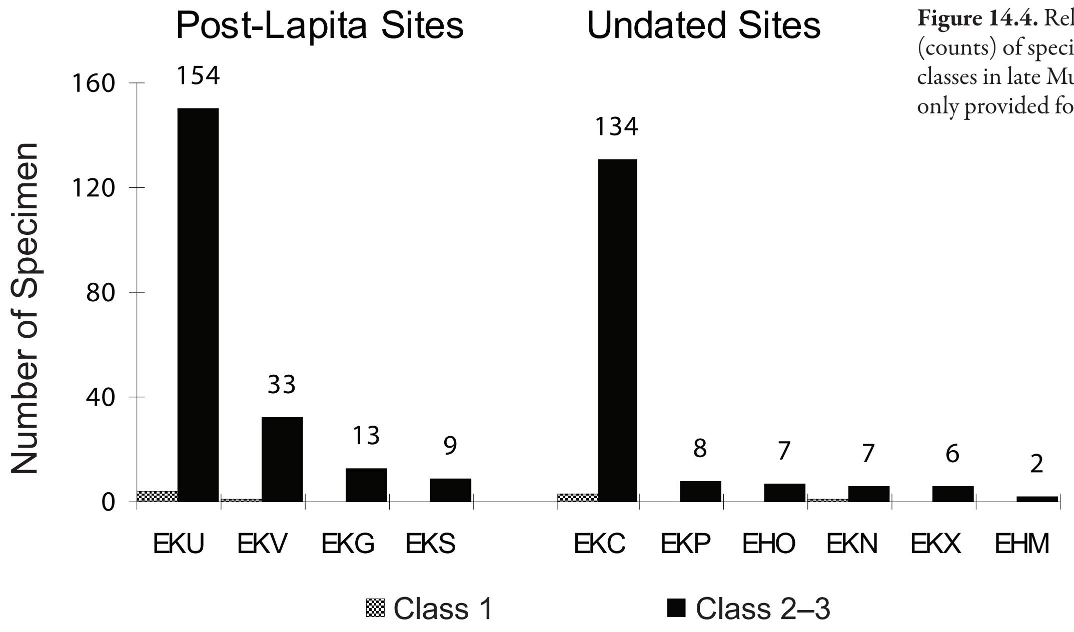

Figure 14.4. Relative abundance (counts) of specific gravity density classes in late Mussau sites (counts only provided for Class 2–3 results).

of the activities taking place in the rockshelter. Similarly at the four ECA Area B excavation units where all zones were analyzed, obsidian deposition peaks in Zone C1 and thereafter is more than halved in Zones B2 through A.

In the late prehistoric phase of the EKQ rockshelter (Stratum I, ca. post-1200 BP), there is little obsidian, a pattern that is echoed in other late sites. The one exception is the late open site of EKU, where a relatively large amount of obsidian was recovered in excavation. Nevermann (1933:116), in his ethnography of the Saint Matthias Group, raises the possibility that at least some of the obsidian found in late prehistoric and early historic contexts may be recycled from earlier occupations. He reports obsidian being used in 1908 as razors and for skinning small animals, but importantly this obsidian was collected in the bush, where presumably the locals were mining the archaeological sites.

PIXE-PIGME Analyses

As discussed above, the PIXE-PIGME analyses identified two major regional sources in the Mussau obsidian assemblages from four sites (Table 14.2). Two samples could not be allocated to a particular source. One of these, Specimen 3620 from ECA Area B, gave off strong W X-rays, which interfere with the measurement of other elements and confuse statistical analyses (Bird, personal communication, 1988). The specimen is grayish-colored, layered, and non-glassy; Bird suggests it may have absorbed sodium metatungstate during the density analysis. Geochemically, it bears similarities to both Talasea and the Malai Bay (Manus Is.) sources. A second unallocated sample, Specimen 3674 from the EKQ rockshelter, most closely matches the Admiralty source.

An attempt also was made to identify the representation of various subsources within major source regions (Table 14.2). In initial assignment of the Mussau specimens, Bird (personal communication, 1992) cautioned that most subsources were poorly sampled and their variability was not well known. He also noted that artifacts from the Lapita Homeland Project (which includes the Mussau specimens) were measured with lower precision techniques than are available today [note: as per 1998]. Thus, the Mussau subsource allocations discussed below should be viewed as tentative. At the time these allocations were made, the New Britain subgroups showed better distinctions than those in the Admiralty Islands. Particularly tentative is the single attribution to the Wekwok subsource. If the Wekwok assignment is valid—and Bird (personal communication, 1992) considered it questionable—then this source may be of greater antiquity than previously suggested by the work of Ambrose and Duerden (1982:87; see also Fredericksen 1997b:71; see Ross-Sheppard, Chapter 15, on evidence for Wekwok). Two attributions to Tuluman seem unreasonable given the youth of that island. Bird, Ambrose, and others (1981:22) note that the Tuluman subsource is geochemically similar to older Admiralties flows, and suggest that derivation from the Umrei subsource is more likely.

As suggested above, overall the Umrei subsource of Lou Island is the best represented in the Mussau assemblages. Yet the small offshore islet of Pam Lin was an important subsource as well. The various Admiralty subsources are not equally represented across the four sites. At ECA Area B and EKQ, Umrei materials predominate, contributing 46% and 48% of the site assemblages respectively

Table 14.2. PIXE-PIGME source and subsource assignments by site[1]

Site	New Britain	Admiralty Islands			Unallocated		Totals
	Kutau/Bao[2]	Pam Lin	Umrei	Wekwok	Subsource	Source	
EHB	2	11	6	0	2	0	21
ECB	2	11	5	1	1	0	20
ECA Area B	5	11	18	0	4	1	39
EKQ	2	8	10	0	0	1	21
Totals	11	41	39	1	7	2	101

[1] Tentative subsource assignments as reported by J. R. Bird and W. Ambrose (1992), personal communication.

[2] These specimens were assigned to Gulu in 1992; in 1995 several were run by J. R. Bird, G. Bailey, and J. P. White under improved conditions and all reassigned to Kutau/Bao based on these and other regional analyses.

(Table 14.2). In contrast, at older sites Umrei is less well represented, contributing only 29% at EHB and 25% at ECB. The greater percentage of Umrei obsidian at ECA Area B, where imports in general are well represented, may be significant. [Ross-Sheppard's recent pXRF results are broadly consistent with these patterns but the subsource proportions based on weight differ and two additional subsources are identified; see Chapter 15.]

In comparing the PIXE-PIGME determinations with the density class distributions, it is apparent that the specific gravity range of the Admiralty source is much broader than previously indicated, overlapping with the Willaumez source (see also White and Harris 1997). The Pam Lin subsource is apparently most problematic in this regard, while Umrei overlaps only slightly with Kutau/Bao (White and Harris 1997:103). Recent direct density measurements by White and Harris place the low end of the Umrei density range at 2.378 and Pam Lin at 2.337, while the maximum density of Kutau/Bao is 2.378.

The Admiralties subsources also cannot be differentiated from one another by density, at least in the Mussau assemblages. The Umrei subsource is best represented in Density Class 3 and the Pam Lin subsource in Density Class 1, but there are exceptions to this pattern. As with the West New Britain subsources (Torrence and Victor 1995), it appears unlikely that the density method will be useful in distinguishing between geochemically and geographically distinct localities within the Admiralty region.

In the case of the Willaumez obsidians, the initial PIXE-PIGME allocations indicated Gulu as the sole subsource utilized. However, higher precision measurements, and additional source samples, now permit New Britain subsources to be distinguished with greater confidence (e.g., Bird et al. 1997; Fullagar et al. 1989; Summerhayes et al. 1993; Summerhayes et al. 1998; Torrence et al. 1992). Seven Mussau samples were reanalyzed by Peter White (University of Sydney), Roger Bird, and G. Bailey (ANSTO, Lucas Heights) under these improved conditions. Their reanalysis of seven specimens demonstrated that all were from Kutau/Bao, not Gulu; Torrence and White (personal communication, 1995), and the generally emerging picture for this region (see above; Bird et al. 1997), also suggest that the other Mussau samples are most likely from this subsource. Importantly, the breakdown of reanalyzed samples by site demonstrates that Kutau/Bao is unquestionably represented at three Mussau Lapita-age localities: EHB (2 specimens), ECB (1 specimen), and ECA Area B (4 specimens). [Ross-Sheppard's pXRF results, presented in Chapter 15, provide further evidence for Kutao/Bao material in ECA Area A and B assemblages, along with one new subsource.]

Discussion

Pre-Lapita Obsidian Use

The Lapita Homeland Project and subsequent studies have shown that the long-distance transport of obsidian witnessed in the Lapita-age sites of the region has a considerable history. Beginning in the terminal Pleistocene, obsidian from at least four West New Britain areas was used and circulated, including materials from Mopir and three Willaumez Peninsula subsources (Kutau/Bao and, to a lesser extent, Gulu and Hamilton) (Summerhayes et al. 1998). These subsources are represented on New Ireland in Matenbek Cave (EFS) at 18,000 to 20,000 BP and at Matenkupkum (EFR) possibly as early as 16,000 BP (Summerhayes and Allen 1993; Summerhayes et al. 1998). The Admiralties source was also used during the late Pleistocene but its distribution did not extend beyond this archipelago at this time (Fredericksen 1997a). During the early to mid-Holocene the distribution of Bismarck Archipelago obsidians expands to include a limited number of localities on the Papua New Guinea mainland and Nissan Island. However, throughout the late Pleistocene and into the mid-Holocene the relative abundance of particular sources can largely be explained by distance and geography (Summerhayes et al. 1998).

Changes in West New Britain Obsidian Access and Distribution

With the appearance of Lapita pottery, animal domesticates, and other new cultural traits (Kirch 1997; Spriggs 1993b, 1997), extant obsidian circulation networks begin to expand and patterns of subsource use shift. However, not all change can be attributed to cultural intrusions. Use of an important late Pleistocene and early Holocene obsidian source, Mopir, was disrupted by a massive volcanic eruption at Mount Witori around 3500 BP (Torrence et al. 1996; Summerhayes et al. 1993). Tephra fallout and pyroclastic flows blanketed local obsidian exposures, in places up to 20 m deep. For the next 2,000 years, Mopir obsidians are conspicuously absent from many archaeological sites in the region, both those associated with Lapita ceramics and otherwise (Torrence et al. 1996). The lack of Mopir obsidians in the Mussau assemblages reported here is consistent with these broader regional patterns.

In the New Britain area obsidian exploitation becomes more narrowly focused from around 3400 BP, with attention shifting to a single subsource, Kutau/Bao, a pattern that persists until around 1500 BP (Summerhayes et al. 1998). Although the quality of Gulu and Baki obsidians is more variable than those from Kutau/Bao, and the quality of Hamilton obsidian comparatively poor (Torrence et al. 1992), these subsources were used during both earlier and later periods. It is particularly unusual that on Garua Island, the occupants of one site (FAO), despite sitting directly on a Baki flow, imported Kutau/Bao obsidian in high frequencies. As these authors suggest, this example, and the abandonment of other previously utilized subsources, suggests that utilitarian needs alone do not explain Lapita obsidian exchange patterns.

With the arrival and subsequent dispersal of Lapita colonists, New Britain obsidians become more widely distributed than at any time before or after. Best (1987) records Talasea obsidian on Naigani Island (Fiji) in the eastern Pacific at 2800 BP, while Bellwood and Koon (1989) report Talasea obsidian in Sabah (Borneo) to the west sometime before 2250 BP—altogether a distributional range of 6,500 km. Willaumez materials are also represented at several intermediate nodes, including the Malo Site (Vanuatu), Isle of Pines (off New Caledonia), the Polynesian Outlier of Tikopia, and in the Reef/Santa Cruz Islands. Bellwood and Koon (1989:620) remark on the abundance of obsidian at Bukit Tengkorak in the pre-2250 BP cultural layer, where the density of obsidian was roughly 29 gm/m^3. Extrapolating from their PIXE-PIGME analyses they suggest that as much as 42% of the assemblage may be from the Willaumez region. Additionally, at least three other sources are represented, two unknowns and Umrei. Bellwood and Koon further argue that importation to the Bukit Tengkorak area from New Britain may have been more frequent than to other eastern areas of equal distance, such as Fiji and Vanuatu, where only a couple of flakes have been provenanced to the Willaumez source. Obsidian also occurs in the Reef/Santa Cruz Islands sites in quantity, with the density of materials in the early site of SZ-8 estimated at 34.6 g/m^3 (Sheppard 1993:127). Willaumez materials feature prominently in the three Reef/Santa Cruz Islands Lapita sites, with some 97% of their 972 flakes being attributed to this source (Green 1987). Despite this remarkable expansion in the distribution of West New Britain obsidians, it is in the more proximate localities, areas both west and east of the source, that importation appears most regular and dynamic during the early to middle Lapita periods.

Expanding Circulation of the Admiralty Islands Obsidian

During the late Pleistocene and early to mid-Holocene, the distribution of Admiralty obsidians was restricted to this archipelago and unconnected to the long-standing exchange systems of West New Britain. The first consequential appearance of Admiralty obsidian outside of the group coincides with the arrival of Lapita peoples (Fredericksen 1997a; Summerhayes and Hotchkis 1992). From around 3400 BP small amounts of Admiralty obsidian are found in several contexts with Lapita pottery, including in the Arawe Islands, Tuam Island (PNG), on New Ireland, Ambitle Island, in the Reef/Santa Cruz Islands, and on Malo and Tikopia Islands (e.g., Green 1987; Summerhayes and Hotchkis 1992; Summerhayes et al. 1998:Tables 6.4, 6.5; see also Allen and Bell 1988). Elsewhere Admiralty obsidians are somewhat better represented, but typically slightly later in time, as for example in the early Lapita occupation on Watom, on Nissan, and in the late Lapita occupation in the Duke of York Islands (the lower part of SDP site) (Green and Anson 1987, 1991; Spriggs 1991; White and Harris 1997). Admiralty obsidian also is found in Borneo before 2250 BP (Service 1996), and on the north coast of Papua New Guinea (Bird, Duerden, et al. 1981).

Summerhayes and Hotchkis (1992:132) suggest the loss of Mopir may explain the emergence of Admiralty obsidians. However, Torrence and others (1992; also Specht 1981) demonstrate that obsidian in the nearby Willaumez region is widespread, plentiful, and physically accessible, even in the absence of Mopir. Importantly, interaction between the Admiralty Islands and the rest of the region required voyaging out of the sight of land, which may have been a limiting factor for pre-Lapita populations. At 250 km distant, the Mussau Islands are one of the closer island groups and the Mussau obsidian record adds new insights about the broadening sphere of Admiralty materials.

In the early Mussau occupations of EHB and ECB, as much as 73% of the obsidian appears to have been drawn from Admiralty Islands subsources, and even more is suggested in the small EKO site sample. This is a striking contrast to most early Lapita assemblages elsewhere in the region where it is a more minor component. [One recent and particularly relevant exception is the early Emirau site of EQS where Summerhayes and others (2010) report that 75% of the assemblage derives from the Admiralty source.] Coupled with later increases in Admiralty obsidians elsewhere (e.g., the SDP site, Duke of York Islands, White and Harris 1997; Watom, Green and Anson 1987), the evidence suggests that the impetus for this expansion did not come from Lapita groups linked into the West New Britain exchange systems. Rather, Mussau's Lapita populations appear to have been an early and important node in the widening sphere of Admiralty obsidians, potentially facilitating further distribution to other Lapita populations to the south and east.

Altered Patterns of Admiralty Subsource Use

As suggested above, use of Admiralty obsidians was initiated in the terminal Pleistocene, as seen in Pamwak Shelter on Manus Island (Fredericksen 1994, 1997b). By the early Holocene, obsidians from the Pam Islands, an unidentified source, Wekwok/Southeast Baun, and Lou (Umrei, Umleang, Lakou, and Langanpwan) are represented as well. But based on results from Pamwak, Kohin, and Mouk, Fredericksen (1994) suggests another distinctive change in the use of Lou obsidian coincident with the appearance of Lapita, specifically increased use of Umrei. Extrapolating from the Mussau PIXE-PIGME results, 25% to 46% of the obsidian in the four Lapita-age assemblages comes from Umrei, with indications of an increase over time (Table 14.2). [Broadly similar results are reported by Ross-Sheppard in Chapter 15.] Given the long history of exploitation of Pam Islands' stone, we might anticipate that these obsidians would be among the first to become more widely distributed. Based on the PIXE-PIGME results (Table 14.2), this appears to be the case for Mussau, with Pam Lin obsidian well represented in the earliest Lapita analyzed site, EHB (from ca. 3750–3450 BP), where it constitutes 52% of the sample. Nonetheless, it is largely the Umrei subsource that was moved beyond the Admiralty Islands coincident with Lapita arrival and its superior quality could be a factor.

Presumably most of the non-local obsidian in these and other Mussau sites was obtained through exchange (see Green and Kirch 1997). Nonetheless, direct access need not necessarily be excluded. Some subsources were more likely to allow direct access by virtue of their distance from residential sites or geographic features that might have impeded resource control (e.g., indefensible locations, extensive and abundant raw materials on site or nearby, etc.). Pam Lin Islet is one such example. Too small for permanent habitation, and too distant from Lou Island (6 km) to be readily defended, the islet is easily accessible by water. While we cannot determine how the Mussau peoples obtained their obsidian, we know that through time, importation from the more distant Willaumez source declined and the small number of PIXE-PIGME analyses reported here hint that Pam Lin obsidian increased through time. This is best illustrated in the EKQ Shelter where Pam Lin is only present in the upper Stratum I, whereas the more distant Willaumez source is only represented in the lower strata.

Geography, Distance, and Social Factors

Torrence (1992) explores the possibility of functional changes in obsidian use through a technological analysis of assemblages from the Talasea region that date to both before and after the Lapita period. She argues for a shift from an "organized" to an "expedient" production system (Torrence 1992:120). Although this shift is most visible around 3,400 years ago, she suggests the process is a gradual outgrowth of increased sedentism and intensification of activities related to plant and animal management in the mid-Holocene (see also Gosden 1993). Summerhayes and others (1998) further suggest that relations between subsources and sites both before 3400 BP and after 1,500 years ago can be explained by factors of geography and distance (see also above). During the Lapita period, in contrast, obsidian source use and distributional patterns become more complex, and practical considerations appear to play a lesser role (Torrence and Summerhayes 1997; Torrence et al. 1996). On Garua Island, for example, the local Baki subsource is best represented until about 3400 BP (Torrence and Summerhayes 1997). Between 3400 and 1500 BP, there is a shift to the mainland Kutau/Bao subsource. The FAO site, located directly on top of a Baki obsidian flow, is instructive, as despite the availability of suitable local materials Kutau/Bao obsidians are imported in equivalent abundances. Summerhayes and others (1998:153) suggest this use of a non-local subsource "is highly suggestive of the operation of an exchange system in which local communities chose to obtain ordinary commodities from somewhere else in order to maintain social links with other groups."

Further evidence for the importance of social factors in Lapita exchange comes from the Reef/Santa Cruz Islands sites and Watom (Green 1987; Green and Anson 1987; Sheppard 1993). In the Reef/Santa Cruz case, Green (1987) demonstrated that Willaumez materials predominate throughout the 700-year sequence, despite the more proximate Vanuatu source some 400 km distant. Both their PIXE-PIGME and density analyses indicate an overwhelming dominance of the Willaumez source, although materials from the Admiralties, Vanua Lava, and West Fergusson (N = 1) are also represented (Green 1987; Green and Bird 1989). Based on a technological study of the same Reef/Santa Cruz assemblages, Sheppard (1993) documents "uneconomical" use of the imported obsidian, implying a predominantly non-utilitarian value for these materials. Torrence and others (1996) further observe that no "value," such as removal of cortex, was added to obsidian specimens prior to export. The Watom site echoes the Reef/Santa Cruz findings, as the most proximate source (Mopir) is never dominant and in the earliest context the most distant and difficult-to-reach source (Admiralties) is well represented.

In the Mussau case the representations of sources and subsources at four nearly contemporary sites with Lapita associations are informative. Here the closer Admiralty source is always the best represented, in all four localities. However, the spatial distribution of obsidian across the four sites suggests another social dimension of obsidian exchange—specifically that access to imports may have been partly defined by intra-community differences in social status. At ECA Area B, Kirch recovered many finely decorated ceramic specimens and unusual vessel forms, all made from non-local clays, which contrast with those from the ECB site, as well as those from the earlier sites of EHB and EKE (Hunt 1989; Kirch and Chiu, Chapter 11). The ECA obsidian also differs from the other Lapita-age assemblages, with higher percentages of Density Class 1 (which includes the Willaumez source) and a larger proportion of the Umrei subsource.

Contracting Interaction Spheres in the Post-Lapita Period

Throughout the Bismarck region, a gradual shift to more proximate obsidian sources over time signals contracting spheres of interaction and perhaps changes in the social context and importance of obsidian procurement and use. This is clearly seen in the Mussau sites, with a decline in Density Class 1 and presumably declines in access to and/or use of the West New Britain source. Similarly at Watom, obsidian in the early layer at SAC comes from Willaumez (Kutau/Bao), Mopir, and the Admiralty Islands, with nearly equal amounts of the Willaumez and Admiralty sources and significantly less from Mopir. Later in time at Watom, the quantity of Willaumez materials rises, while Mopir is constant and the Admiralty source declines (Green and Anson 1987). This pattern is repeated in the Duke of York Islands as well, with Umrei obsidian present in the earliest assemblages, and the more proximate New Britain sources dominating after 2850 BP (White and Harris 1997).

With respect to later post-Lapita patterns, White (1996) observed that while the extent of obsidian distribution between 3400 and 2500 BP was broad, the density of exchange nodes was limited. In the following 1,500-year period, White suggests that the distribution of Bismarck obsidians *within* Near Oceania expanded westward to include the New Guinea mainland. But this, and the concomitant increasing density of nodes, occurred within a larger context of a diminishing distributional range for West New Britain obsidians. These patterns suggest another significant shift in the character of obsidian procurement and exchange relationships. The late prehistoric Mussau sites reflect these regional patterns as well, with the breakdown of ties to the West New Britain area clearly signaled in the local obsidian assemblages.

Conclusions

The Mussau sites provide an opportunity to look at obsidian exploitation in a Lapita context at the margins of the two preexisting Pleistocene networks. While the Mussau sites reported here represent the earliest known human occupations in this island group, the possibility of Pleistocene populations cannot be altogether ruled out. Nonetheless, the patterns of subsource representation seen on Mussau, and the temporal patterning in assemblage composition, are more consistent with broad regional patterns of obsidian consumption in the Bismarck Archipelago than they are with patterns seen in more proximate Pleistocene sites of Manus Island. Fredericksen's (1994, 1997a) "Source X," for example, is not represented in the Mussau sites, while the Willaumez source is present from initial Lapita occupation, being found in EHB and ECB (Figure 14.1). Some aspects of subsources representation on Mussau are consistent with regional Lapita-age patterns, as for example the predominance of Kutau/Bao and Umrei at ECA Area B from around 3200 BP. However, there are also some notable exceptions, including: 1) early use of Pam Lin at EHB, which continues (and possibly increases) over time; and 2) the overall importance of Admiralty obsidians throughout the sequence.

These patterns suggest the Mussau populations were interdigitating in important ways with two initially separate regional systems. The differences between Lapita-age patterns and those of earlier periods, as discussed above, suggest that the exchange systems associated with Lapita pottery were distinct from (but not necessarily entirely unrelated to) indigenous Pleistocene ones, potentially involving different populations and/or alternative functional or social needs. Related to this, a growing body of evidence suggests that indigenous populations were becoming increasingly sedentary prior to the advent of Lapita ceramics (Gosden 1993; Torrence 1992). This sedentism appears to be largely economic in origin, tied to plant and animal management. At the same time, the obsidian data reviewed here indicate increased mobility concomitant with intrusion of Lapita peoples, and a shift in the motivations underlying exchange, from utilitarian needs to more socially based motivations.

In the post-Lapita period mobility patterns shift once again and this is well reflected in the later Mussau assemblages. In the late Mussau sites, the Admiralty source comes to dominate to the near (or complete) exclusion of the West New Britain source and obsidian consumption overall declines.

Acknowledgments

Foremost, I thank Patrick Kirch for the opportunity to be involved in the Mussau research. The PIXE-PIGME determinations were provided by Roger Bird and the long-term research efforts of Roger and his colleagues at ANSTO are gratefully acknowledged. The 1990s revision of this paper benefited from the advice and comments of Robin Torrence, Roger Green, Patrick Kirch, and Peter White. In 1995 Mary Noel Harris made direct density measurements on the original Mussau PIXE-PIGME specimens, and Peter White arranged to rerun seven samples originally assigned by PIXE-PIGME to the Gulu subsource. My thanks to them for sharing these results, which have furthered our understanding of both the source density ranges in general and subsource attributions of the Mussau materials in particular.

CHAPTER 15

Portable X-Ray Fluorescence (pXRF) Analysis of Obsidian from Talepakemalai (Site ECA)

Callan Ross-Sheppard

The obsidian assemblage excavated from the Talepakemalai (ECA) site offers a unique opportunity to investigate Lapita-period population movement, exchange networks, and resource procurement behaviors. Not only is it one of the larger obsidian assemblages recovered from the early Lapita period (alongside that of SE-RF-2 in the Eastern Solomon Islands), but also, uniquely, the Lapita occupation at Talepakemalai both persisted over a relatively long duration and was spread over a large area. These factors allow analysis of the internal spatial, and possibly temporal, variation at this site. The beach terrace excavated at Area A and the stilt house at Area B also differ markedly in their non-lithic artifact content (see other chapters herein). This variation has led to the suggestion that the Area B structure may have had a special function, and perhaps indicates social differentiation within the Talepakemalai community (Kirch 1988e). These factors allow different hypotheses relating to variability in Lapita obsidian procurement behaviors to be investigated. Talepakemalai is also an excellent location to analyze the relationship between geographic distance and economic dimensions of Lapita obsidian procurement behaviors. More specifically, Eloaua Island is situated essentially equidistant between the two main obsidian sources in Near Oceania, that located on the Willaumez Peninsula of New Britain and that in the Admiralty Islands, both of which have several geochemically distinctive subsources.

Hypotheses for the rationales behind Lapita obsidian procurement behavior have often been economic (e.g., Summerhayes 2009). Distances from source to use-locales, and tool-making qualities of specific raw materials, are readily quantified and measured attributes. Pioneering work on locating, characterizing, and assessing the quality of Near Oceanic obsidians was performed in the 1970s and 1980s by a number of scholars (e.g., Key 1968, 1969;

Ambrose 1976; Ambrose and Green 1972; Ambrose et al. 1981; Bird, Duerden, et al. 1981; Specht 1981; Ambrose and Duerden 1982; Specht et al. 1988; Fullagar et al. 1991; Torrence et al. 1992). They determined that the Admiralty Islands have several tool-quality obsidian outcrops that were accessible during the Lapita period, notably the Umrei/Umleang and Wekwok outcrops on Lou Island (Ambrose et al. 1981; Ambrose and Duerden 1982), that on Pam Lin, and the comparatively spherulitic sources on Pam Mandian (Ambrose et al. 1981) and at Mt. Hahie on Manus Island (Bird et al. 1988; Kennedy 1997). West New Britain has several obsidian sources as well, including Gulu, Baki, Kutau and Bao on the Willaumez Peninsula (Bird, Duerden, et al. 1981; Torrence et al. 1992; Torrence et al. 1996; Specht 1981; Summerhayes et al. 1998), as well as the Mopir source, located some distance inland (Fullagar et al. 1991). The materials available at the more important of these sources are described in detail by Allen (Chapter 14). Other distant but plausible sources for Lapita obsidians are found in the Banks and Fergusson Islands (see Summerhayes 2009).

However, Lapita lithic analysts have in some cases concluded that neither source representations, nor reduction behavior, seem to follow purely or even primarily economic rationales (Allen, Chapter 16; Sheppard 1993; Summerhayes et al. 1998; Torrence and Summerhayes 1997; Torrence et al. 1996). For example, the FAO and FSZ Lapita-period sites on Garua Island in West New Britain are located adjacent to the Baki obsidian outcrop. However, the predominant source represented at these sites is Kutau/Bao. Moreover, Bismarck obsidians have been identified in Lapita-period sites as far east as the Solomon Islands, Vanuatu, and Fiji in Remote Oceania (Best 1987; Galipaud et al. 2014; Nunn 2007; Reepmeyer et al. 2010; Ross-Sheppard et al. 2013; Sheppard 1993)—extreme distances to move obsidian when local materials are available (Sheppard 1993). Clearly economic factors were not necessarily of primary concern in many Lapita communities. Alternative social explanations include the use of obsidian as a specialized trade good (Torrence and Summerhayes 1997; Torrence 2004), for maintenance of interpersonal networks, and/or as insurance for long-distance voyaging communities (Green 1987; Kirch 1988c; Sheppard and Green 1991).

Temporal changes are also occasionally invoked to explain variation in source representation (and certainly also a component of many social explanations), such as shifts in exchange networks or source availability (Summerhayes 2003; Torrence 2002; Torrence and Summerhayes 1997; Torrence et al. 2000). For example, the volcanic geography of much of Near Oceania has been invoked to explain changes in source access on New Britain. The Mopir source, frequently used during the late Pleistocene and early Holocene, largely drops out of the archaeological record after the large WKII eruption of Mt. Witori on New Britain, which buried the source in a thick layer of ash (Torrence 2002; Torrence et al. 2000). Another explanation is that shifts in Lapita exchange networks resulted in obsidians from some sources seeing less transport over time (Summerhayes 2009; Summerhayes et al. 1998).

While the above explanations may not be exhaustive, they provide an initial framework for evaluating the source content of Lapita obsidian assemblages. What processes then produced the source representation in the ECA assemblage? To answer this question requires the analysis of a significant portion of the Talepakemalai obsidian assemblage. Portable XRF (pXRF) provides an ideal method for such analyses, having been demonstrated to provide sufficient resolution to differentiate the majority of Near Oceanic obsidian sources (Sheppard et al. 2010). pXRF analyses are also both inexpensive (requiring only time) and rapid enough to analyze a significant number of samples, thus insuring that infrequently used sources are represented.

Allen's (Chapter 14) initial sourcing of the Mussau obsidians indicated that the Lapita community at Talepakemalai exploited materials from both the Willaumez Peninsula region in West New Britain, and those from the Admiralty Islands source region. However, she noted some important differences in both source representation and obsidian use between Areas A and B at Talepakemalai (Chapters 14 and 16).

Methods

To assess obsidian source representation, a 31% sample from Area A and Area B was analyzed. This judgmental sample consisted of 504 specimens from an overall assemblage of 1,600 specimens, and included 328 from the earliest stratigraphic zone of Area B (Zone C) and 176 from Area A.

The specimens were neither washed nor cleaned prior to analysis. This is significant as all the specimens analyzed in this study had been previously immersed in the heavy liquid sodium metatungstate. While Allen (Chapter 14) reports that the samples were subsequently rinsed in distilled water, the initial geochemical results from this study found that residual tungsten, in concentrations ranging from trace amounts to large concentrations, was present on all samples. This problem had previously been noted by Bird (in Allen, Chapter 14) on samples analyzed by PIXE-PIGME. In the present study, macroscopic examination of the specimens with tungsten concentrations higher than 5,000 ppm revealed that all had either numerous cracks or porous surfaces. As Bird and others (1988) have identified the potential for residual tungsten to affect the accuracy of the mid-Z elements (Zr, Sr, Rb, Y), samples exhibiting tungsten concentrations greater than 4,000 ppm were excluded from further analysis and were not included in the 504 samples analyzed here.

Source characterization was carried out by analyzing 39 geological samples from the Bismarck Archipelago provided by Robin Torrence of the Australian Museum and six geological samples from the Bismarck Archipelago, Banks Islands, and Fergusson Island sources provided by Peter Sheppard of the University of Auckland. Each subsource sample was analyzed several times, to guard against non-periodic machine error.

Geochemical analysis of both the source samples and the archaeological subsample was carried out in 2013 at the University of Auckland using an Innovox Delta model analyzer, mounted in a laboratory stand (Si PIN Diode, 4-watt X-ray tube 8–40 kev, 5–200μa, Rh Anode). All analyses were conducted using the instrument's soil mode, which uses three beams that detect heavy elements, transition metals, and light elements respectively. The analysis time for each beam was set at one minute, with a total analysis time of three minutes for each sample.

To minimize the effects that uneven surfaces can have on results, the flattest surface of each specimen was positioned over the analyzer. Additionally, to reduce the effects of variation in sample size and thickness, samples smaller than 7.5 mm^2 (the size of the area where the X-rays strike the sample, as shown on the inbuilt camera), or those weighing less than 0.02 g, were excluded from the analysis. The inbuilt camera also allowed for the avoidance of phenocrysts in the majority of samples, excepting those that were highly spherulitic.

At the beginning and end of each analytical session the NIST SRM-278 powdered obsidian (Newbery Crater, Oregon) standard and flaked ANU 2000 Wekwok obsidian standard were analyzed. Table 15.1 shows a comparison between the results for the pXRF instrument used in this study and those published by Glascock and Anderson (1993) for NIST 278.

The coefficients of variation (CV) generated for each of the elements used in the statistical analyses employed in this study were under 10%. The coefficient of variation for Pb was much higher than that of other elements. How-

Table 15.1. Comparison of the pXRF results with the certified values for NIST 278 as provided by Glascock and Anderson (1993)

	NIST 278 Obsidian Standard pXRF Result				NIST SRM-278 Certified Values	
	N	**Mean**	**STD**	**CV**	**Certified**	**STD**
Ti	35	1339.17	19.16	0.014	1468.74	41.96
Mn	35	361.743	5.232	0.014	402	15.49
Fe	35	10,165.31	71.975	0.007	14,278.71	139.99
Rb	35	127.746	0.959	0.008	127.5	0.3
Sr	35	62.474	1.253	0.020	63.5	0.01
Zr	35	260.657	3.325	0.013	272	31
Pb	35	14.38	0.764	0.053	16.4	0.2

ever, this variation is likely due to the particular standards analyzed, as the amount of Pb in the standards is close to the detection limit of the instrument, which can result in quite variable results (P. Sheppard, personal communication, 2011). Pb was initially retained for the creation of bivariate plots, as it is useful in clearly discriminating between the Fergusson (D'Entrecasteaux Islands, PNG) and Banks Islands sources (Sheppard et al. 2010); however, it was excluded from the final multivariate analysis (see further discussion below).

Results

As both major and trace elements were analyzed simultaneously, all elemental data were log10 transformed. Figures 15.1 to 15.3 plot the 0.95 confidence intervals for each geological source and the individual archaeological specimens. Initial bivariate plots of the elemental data show that all major source regions can be clearly separated using the data from this instrument. Figure 15.1 plots Mn versus Pb, with 0.95 confidence ellipses for the geological samples and the archaeological specimens plotted over them. No archaeological specimens grouped with the Fergusson Islands or Banks Islands source regions, allowing these regions (and Pb results) to be excluded from further analysis. Figure 15.2 plots Sr versus Mn for the Willaumez Peninsula sources alone, while Figure 15.3 plots Zr versus Mn for the Admiralty Islands sources. The Willaumez region has two relatively distinct source groups, Kutau/Bao and Baki obsidians. The Admiralty Islands sources, in contrast, are varied and overlap to a greater extent; however, all of the archaeological samples group within the ambit of the known geological sources. The Wekwok source was excluded from this plot as there were too few Wekwok geological samples to generate a confidence ellipse.

For greater accuracy and specificity of assignment (especially among the Admiralty Islands sources), a concurrent Discriminant Function Analysis (DFA) using

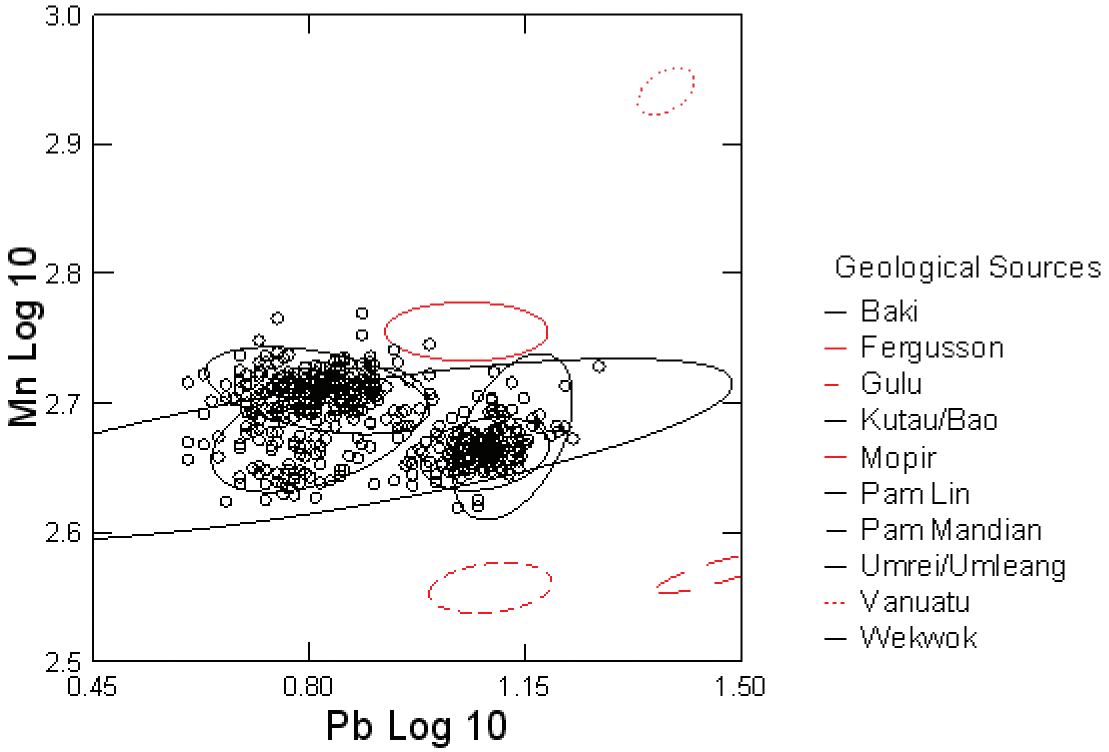

Figure 15.1. Bivariate plot of Mn versus Pb, showing 0.95 confidence ellipses for the geological sources overlain by individual archaeological specimens (symbols). (Diagram by C. Ross-Sheppard.)

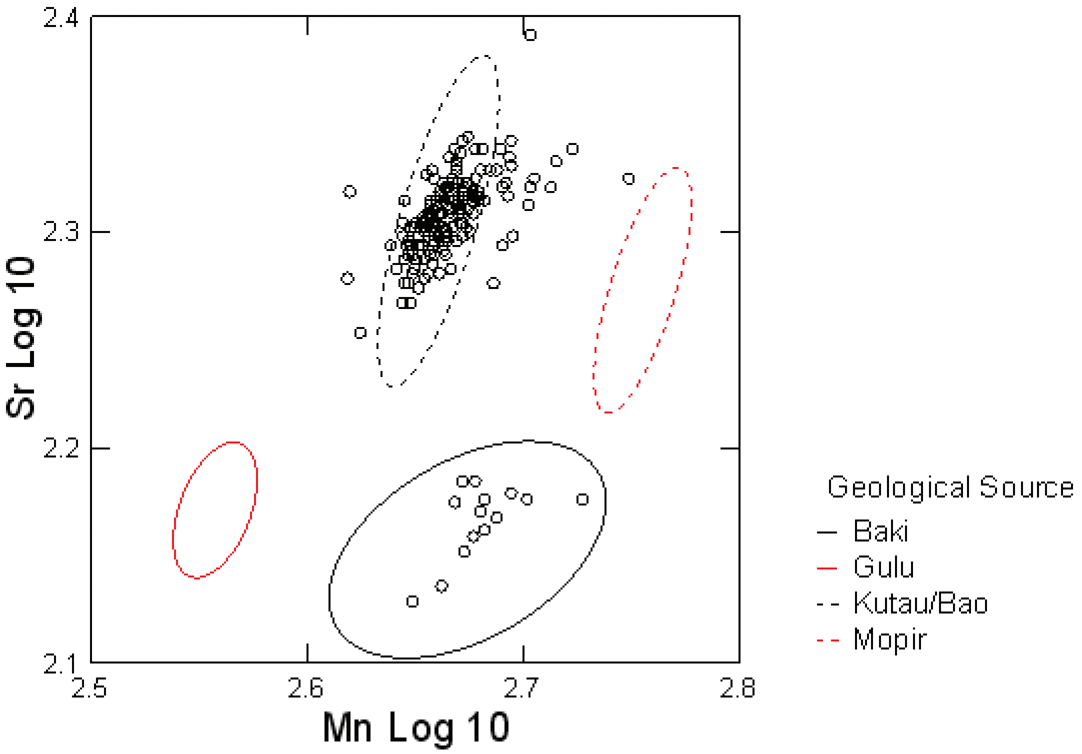

Figure 15.2. Bivariate plot of Mn versus Sr showing 0.95 confidence ellipses for the geological sources overlain by individual archaeological specimens (symbols). (Diagram by C. Ross-Sheppard.)

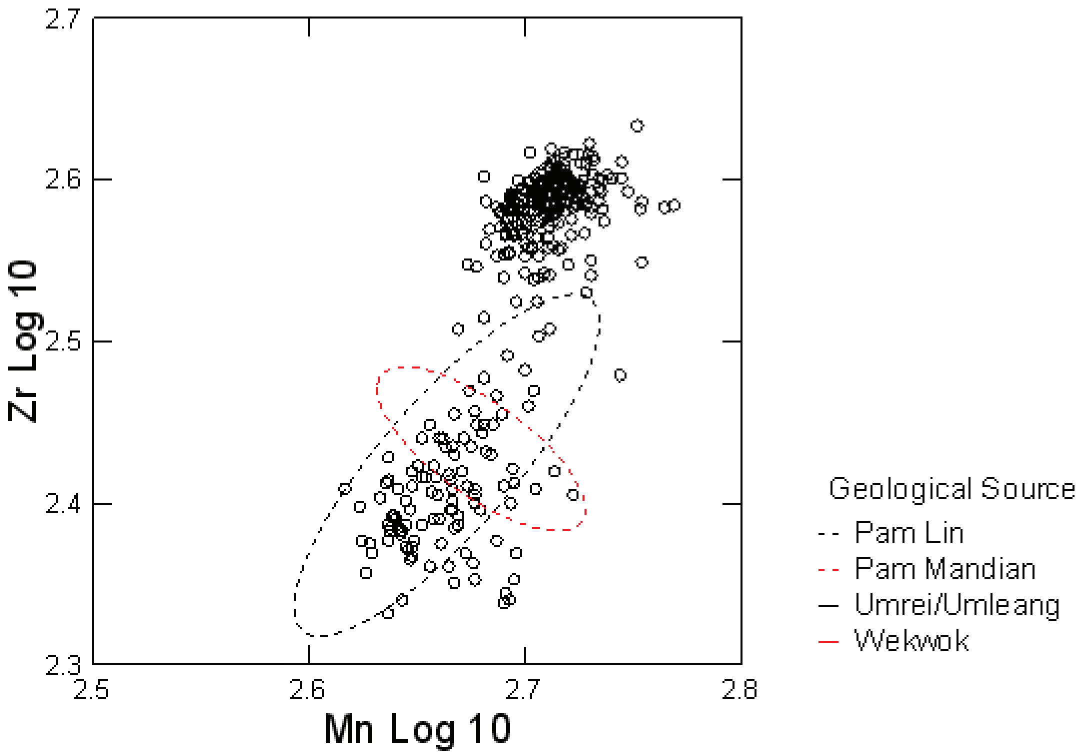

Figure 15.3. Bivariate plot of Mn versus Zr with 0.95 confidence ellipses for the geological sources overlain by individual archaeological specimens (symbols). (Diagram by C. Ross-Sheppard.)

SYSTAT 12 was performed on the sample results, with the Banks Islands and Fergusson Islands source regions excluded (Table 15.2). Both major source regions can be separated, and all sources can be discriminated. Overall, the DFA provided a 100% correct classification. In previous Near Oceania obsidian sourcing studies, the Kutau and Bao sources often group together as a single source, due to their geographic proximity and very similar geochemical profiles (Summerhayes et al. 1998:146; Torrence et al. 1992:93). Although Sheppard and others (2010) had some success in discriminating between these two sources, grouping these two sources significantly improves the accuracy of the DFA and is widely used elsewhere; thus it is followed here as well. Notably, grouping of the Kutau and Bao sources is unlikely to affect interpretations in the present study as the two sources are relatively close in terms of quality, accessibility, and distance to the Mussau Islands.

The jackknifed probability matrix, a more conservative version of the classification matrix, is given in Table 15.3 for the geological samples. One Pam Lin sample was misclassified as Pam Mandian. Although these sources are geographically very close to one another, the problem cannot be resolved in the same manner as the Kutau/Bao grouping as they differ markedly in their technological characteristics (Ambrose et al. 1981). In any case, the potential error introduced by this misclassification is relatively small, as the jackknifed matrix still has a 99% correct classification rate. The results of both the standard and jackknifed DFA indicate that these methods can accurately differentiate between the sources of interest.

After determining that the pXRF instrument could accurately distinguish the geological sources of interest, the archaeological samples were submitted to the DFA. The resulting assignments for the archaeological specimens are summarized in Table 15.4. When the archaeological specimens are plotted alone, and grouped by their assigned source, samples assigned to the same source group with each other rather than with samples assigned to other sources. This further supports the idea that the DFA is in fact accurately grouping the samples. Additionally, these samples group within, or near to, the 0.98 confidence ellipses of the geological source samples.

The majority of the assemblage derives from Admiralty Islands sources, with 328 specimens being attributed to this region, while the remaining 176 specimens plot with Willaumez Peninsula sources. This is consistent with the patterns previously identified by both the sodium metatungstate density analysis and the high resolution PIXE-PIGME results (Allen, Chapter 14).

Table 15.2. Classification matrix of Concurrent Discriminant Function Analysis on geological sources

Classification Matrix (Cases in row categories classified into columns)									
	Baki	**Gulu**	**Kutau/ Bao**	**Mopir**	**Pam Lin**	**Pam Mandian**	**Umrei/ Umleang**	**Wekwok**	**% correct**
Baki	10	0	0	0	0	0	0	0	100
Gulu	0	14	0	0	0	0	0	0	100
Kutau/Bao	0	0	27	0	0	0	0	0	100
Mopir	0	0	0	10	0	0	0	0	100
Pam Lin	0	0	0	0	4	0	0	0	100
Pam Mandian	0	0	0	0	0	6	0	0	100
Umrei/Umleang	0	0	0	0	0	0	15	0	100
Wekwok	0	0	0	0	0	0	0	2	100
Total	10	14	27	10	4	6	15	2	100

Table 15.3. Jackknifed classification matrix of Concurrent Discriminant Function Analysis on geological sources

Jackknifed Classification Matrix									
	Baki	**Gulu**	**Kutau/ Bao**	**Mopir**	**Pam Lin**	**Pam Mandian**	**Umrei/ Umleang**	**Wekwok**	**% correct**
Baki	10	0	0	0	0	0	0	0	100
Gulu	0	14	0	0	0	0	0	0	100
Kutau/Bao	0	0	27	0	0	0	0	0	100
Mopir	0	0	0	10	0	0	0	0	100
Pam Lin	0	0	0	0	3	1	0	0	75
Pam Mandian	0	0	0	0	0	6	0	0	100
Umrei/Umleang	0	0	0	0	0	0	15	0	100
Wekwok	0	0	0	0	0	0	0	2	100
Total	10	14	7	10	3	7	15	2	99

Table 15.4. Source assignments (counts) for the ECA archaeological specimens based on the Discriminant Function Analysis

Source	Baki	Kutau/ Bao	Pam Lin	Pam Mandian	Umrei/ Umleang	Wekwok	TOTAL
Area A	14	33	51	5	70	3	176
Area B	0	129	25	23	144	7	328
Total # of assigned specimens	14	162	76	28	214	10	504

Results by Area

The source composition of the Area A assemblage is shown in Figure 15.4, while that of Area B is shown in Figure 15.5. In these figures, and in the discussion that follows, weight rather than counts is the unit of measure. This contrasts with several other analyses of Lapita obsidian, which have favored counts. The argument here is that weight is a more useful metric than count if an understanding of procurement behaviors is required, as the process of core reduction may produce varying quantities of flakes, tools, or angular shatter, depending on a variety of factors. Weight, in contrast, provides a better indication of the intensity with which a source was exploited and subsequently transported to a site. This is especially important for understanding use of Lapita obsidians, as they are variable in their flaking qualities (see discussion below) and obsidians with poor fracture mechanics have the potential to end their uselives at a larger size relative to those with good fracture mechanics.

As Figures 15.4 and 15.5 demonstrate, there are striking differences between the two assemblages in terms of both the occurrence of sources and relative source abundance. The Area A assemblage contains obsidian from six sources, including four Admiralty Islands ones (Umrei/Umleang, Wekwok, Pam Mandian, and Pam Lin) and two Willaumez Peninsula sources (Kutau/Bao and Baki). The Area B assemblage is similar but lacks obsidian from the Baki source, which makes up 16% of the Area A assemblage.

In addition to the absence of Baki obsidian, there are significant differences in the relative abundance of sources in the two areas. The Area A assemblage, by weight and count, contains a relatively large amount of Pam Lin obsidian and only a very small amount of Pam Mandian material. In Area B, in contrast, Pam Mandian is an important

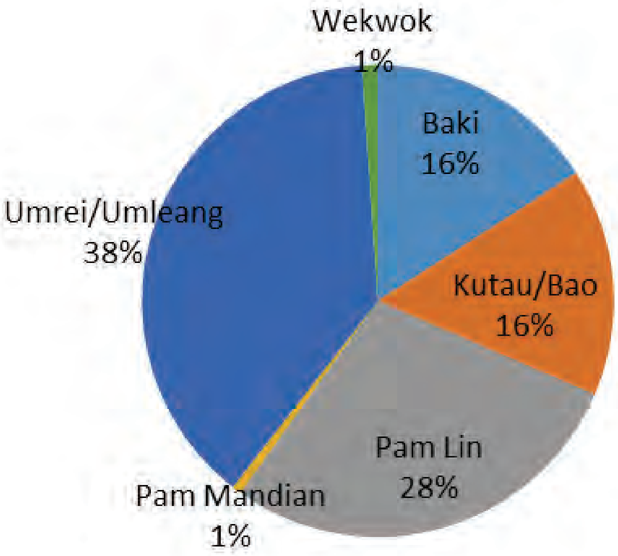

Figure 15.4. Source composition of the site ECA Area A assemblage by weight. (Diagram by C. Ross-Sheppard.)

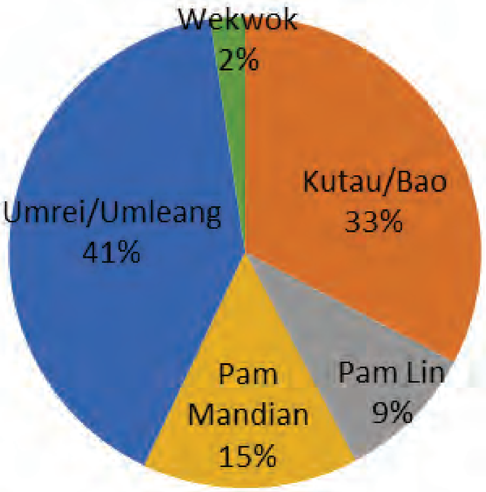

Figure 15.5. Source composition of the site ECA Area B assemblage by weight. (Diagram by C. Ross-Sheppard.)

component of the assemblage at 15%, while Pam Lin obsidians are a much smaller fraction of the assemblage at 9%. Kutau/Bao also exhibits variability in relative abundance, comprising 16% of the assemblage in Area A, but making up 33% of that from Area B.

There are also similarities between the two areas. The relative proportion of Admiralty Islands to Willaumez Peninsula obsidian is more or less the same, with Area A containing 32% of the latter obsidians compared to 68% Admiralties obsidians, while Area B contains 33% Willaumez obsidians compared to 67% Admiralty Islands material.

Discussion

The results of this study indicate that the inhabitants of Mussau, like those of other Lapita communities, were procuring or exchanging for obsidian from both the Admiralty Islands and Willaumez Peninsula source regions. However, the community at Talepakemalai was not only acquiring easily workable, high-quality obsidian, such as Kutau/Bao or Lou, but also quantities of low-quality material for toolmaking, namely Pam Mandian. Additionally, in the case of Area A, obsidian was procured from an unusual source for Lapita communities outside New Britain, the Baki source.

The results also demonstrate clear differences between the source composition of the possibly earlier Area A (3300–3200 BP) and the Area B assemblages (ca. 3200–2950 BP), the former characterized by use of a wider range of West New Britain sources, and the latter focused on the New Britain source of Kutau/Bao. The acquisition of Admiralties obsidians is more uniform across the two sites, with Pam Lin, Pam Mandian, Wekwok and Umrei/Umleang obsidians being procured. The greater representation of low-quality Pam Mandian obsidian at Area B, however, is puzzling.

These results raise two questions. Why is Baki obsidian found in Area A but not Area B? And why did the Mussau community procure comparatively large quantities of low-quality obsidians when high-quality obsidians were presumably equally accessible? Possible explanations are considered below.

Economic Models: Source Quality and Distance to Source

Torrence and others (1996, 1992) and Summerhayes and others (1998) examined the technological characteristics of different New Britain obsidians and provide a ranking of the New Britain sources. They suggest that Mopir and Kutau/Bao obsidian are ranked first equally (1996: 212–214), as they exhibit excellent fracture mechanics as well as a very low incidence of spherulitic inclusions. The Baki obsidian is ranked second, being of only marginally lower quality than that from Kutau/Bao. The occasionally spherulitic Gulu material ranks third, while the Hamilton source, with its highly spherulitic obsidian, has the poorest quality materials. With these findings in mind, the larger quantity of Kutau/Bao obsidian in Area B, relative to the proportions in the Area A assemblage, could potentially reflect better access to slightly higher quality materials. That being said, the Area B assemblage also contains a larger quantity of low-quality Pam Mandian obsidian (see Ambrose et al. 1981) and many of the samples assigned to Pam Mandian in the Area B assemblage are porous and/or appear heavily weathered. Summerhayes and others (2014) noted that several samples in the Pamwak assemblage, with a weathered glassy exterior, optically looked like pitchstone but were geochemically consistent with obsidian, and grouped with St. Andrews Straight geological sources (e.g., Lou and Pam Islands). Potentially the samples assigned here to Pam Mandian are from the same source as the Pamwak material. Notably, in DFA analyses the presence of as-yet-unidentified sources can result in samples being incorrectly attributed. However, this would have little impact on interpretations of the Talepakemalai assemblage as the distances from these two sources to Mussau are similar.

Given that the Area B assemblage contains greater quantities of both high-quality Willaumez obsidians *and* low-quality Admiralties obsidians, relative to Area A, it is difficult to argue that the Area B inhabitants had preferential access to higher-quality materials. Moreover, the variability in material quality observed at Talepakemalai supports the idea that flaking properties may have been important but not paramount, a finding that is consistent with some other Lapita-period sites (Sheppard 1993; Torrence et al. 1996:214–215).

Distance to a source, on the other hand, has been found to have some relationship to source choice in Lapita communities, in that sites located closer to a particular source tend to have more obsidian from that source (Summerhayes et al. 1998; Torrence et al. 1996). Mussau is significantly closer to the Admiralties source region than to the Willaumez Peninsula source region (ca. 250 km from Mussau to Manus as opposed to ~ 400 km from Mussau to the Willaumez Peninsula). As might be expected, in both Areas A and B Admiralty Island obsidian is better represented, suggesting that distance was a factor.

Distance, however, is not sufficient to explain the occurrence or relative abundance of the full range of sources. Particularly puzzling is the poor-quality Pam Mandian obsidian in Area B. Pam Mandian is adjacent to Pam Lin, with a very small water gap separating them (less than a kilometer), but has significantly lower-quality obsidian (Ambrose et al. 1981). Why would this obsidian be transported approximately 260 km, when better-quality material is available on nearby Pam Lin Island or, even closer to Mussau, on Lou Island? In short, the obsidian procurement activity of the inhabitants of Talepakemalai exhibits characteristics not fully explainable by economic models that emphasize distance and raw material quality.

Social Models: Social Differentiation and Specialized Exchange

If economic factors were not the exclusive drivers of obsidian importation at Talepakemalai, then what other processes might be involved? In the Bismarck Archipelago, the use of Kutau/Bao obsidian has been observed when closer, equally accessible and high-quality obsidian is available. Lapita-period assemblages from sites on Garua Island that are located quite close to Baki obsidian outcrops have assemblages dominated by Kutau/Bao obsidian. Torrence (2004) and others argue that over time Kutau/Bao obsidian became differentiated in some way from other Willaumez sources, and was potentially a "specialized" exchange good, at least within the New Britain region (see also Summerhayes et al. 1998; Torrence and Summerhayes 1997; Torrence et al. 1996). Given other indicators of status at the Area B site, this inference could explain the quantity of Kutau/Bao obsidian found here, as well as the absence of the Baki source. The supposition that social processes were at work, with certain obsidians being more valued as specialized exchange goods, could be relevant to the hypothesis that the occupants of the Area B stilt structure were in some way socially differentiated from those of other nearby sites. A potentially important consideration, however, is that the two ECA sites are not entirely comparable; although both are occupation sites, in only one case (Area B) is the obsidian assemblage directly associated with a clearly defined structure.

The obsidian sourcing evidence provides little support for the hypothesis that the occupants of the Area B stilt house had preferentially acquired higher-quality obsidians. However, it does seem to support the notion that Lapita obsidian procurement strategies had much more of a social component rather than being solely oriented around raw material quality in relation to tool manufacture (Sheppard 1993; Torrence and Summerhayes 1997). Both the absence of the Baki source in Area B, and the relatively high proportion of poor-quality Pam Mandian materials, would be less puzzling if the acquisition of tool-stone quality materials was not the only motivating factor, and exchange was embedded in some other aspect of inter-island contact. If this was the case, then we might expect to see stronger correlations with distance and less emphasis on technological qualities of the acquired raw materials. This is indeed the patterning occurring in both areas of the Talepakemalai site.

Temporal Trends

At a regional level, whether socially motivated or not, the shifts in procurement pattern seen at ECA conform to changes in Lapita obsidian procurement elsewhere. Specifically, the lack of Baki obsidian in Area B is observed elsewhere. As previously mentioned, sites on Garua Island, where the Baki outcrops are located, see a shift from the mixed procurement of Baki and Kutau/Bao obsidian prior to the appearance of Lapita toward a four-to-one predominance of Kutau/Bao obsidian during the Lapita period. The cause of this shift is as yet unknown; however, Torrence and Summerhayes (1997; also Torrence 2004) suggest it could be due to changes in access, embedded procurement strategies, or the development of Kutau/Bao obsidians as a prestige exchange item.

The presence of Baki obsidian has also been noted at another early Lapita community. Analysis of the SE-RF-2 site in the Eastern Solomon Islands identified the presence of 14 Baki specimens (Sheppard et al. 2010). Given the comparatively early dates of ECA Area A and SE-RF-2, the processes that caused procurers to switch from the Baki source may have been based on what obsidian was available. The lack of Baki obsidian in the ECA-B assemblage, as well as its absence in the supposedly later SE-SZ-8 assemblage, would argue for occasional long-distance transport (up to ~ 2000 km) of Baki obsidian mainly being a characteristic of the early Lapita period. If this is the case, then the shift to using Kutau/Bao as the sole Willaumez source at Talepakemalai might not actually be a shift in procurement behavior on the part of the inhabitants of Talepakemalai. Rather it would be merely maintaining the practice of procuring obsidians from the Willaumez peninsula. The actual shift may instead be what Willaumez obsidians were available for procurement or exchange.

More generally, however, the Talepakemalai assemblage is different from other contemporaneous Lapita assemblages in some key respects. Summerhayes (2003, 2009) notes that in the early Lapita period, Willaumez obsidian dominates almost all Bismarck Archipelago obsidian assemblages. Over time, however, "in assemblages located to the east and north of the New Britain source regions, Admiralty obsidian replaced Kutau/Bao as the major source" (2003:137; see Figure 2.3.4). These patterns are not present in the ECA Area A and Area B assemblages, both of which would be classed as Early Lapita in Summerhayes' (2009) schema. At Talepakemalai, Admiralties sources dominate throughout the sequence. However, this can be explained by distance, with Talepakemalai being the most easterly of the early Lapita assemblages, and thus the farthest from the Willaumez sources (see also Allen, Chapter 14).

Caveats: Spatial Distribution of ECA Obsidians and Possibility of Sampling Error

Two caveats should be acknowledged vis-à-vis these interpretations of the Talepakemalai assemblages. The observed differences between the Area A and Area B assemblages assumes that they are representative of the two localities. This may not be the case for two reasons. Firstly, although the ECA excavation was relatively large, the size of the site is considerable, and the excavations only represent around 0.1% of the total estimated site area (Kirch 2001a:81). This might have little effect upon the excavated assemblages if the distribution of obsidian from each knapping event was distributed homogeneously across each area. However, this is not the case. Spatial analysis of the lithic density at Area B indicated that, within the excavated area, the obsidian finds are clustered rather than evenly distributed, probably representing individual knapping events or lithic activity areas (Kirch 2001a:106). Plotting of the material sampled for this study over a map of the ECA-B excavation confirms that source distributions across the site are largely clustered. This raises the possibility that the obsidian assemblages analyzed here are not representative of the source proportions of the overall site. This is a concerning source of potential error, as some of the differences between Areas A and B are small (in terms of weight) and could be the result of the chance knapping of a single cobble in a sampled area.

Secondly, Kirch and Catterall (2001:54–55) note that ethnographic accounts, particularly those of Nevermann (1933), indicate that old settlement sites were known as local sources of obsidian in the recent past. Kirch and Catterall (2001:54) propose that this "strongly suggests that the Mussau people in Nevermann's time obtained flakes by scouring the sites of old villages or hamlets. This in turn raises the possibility that obsidian found in some archaeological contexts (especially in the post-Lapita period) could well have been recycled from earlier occupation sites." The potential for differential recycling of archaeological obsidian between the two areas analyzed here is variable, as one area is relatively inaccessible, being buried by a prograding shoreline, while the other is quite accessible but heavily disturbed by gardening activity. If recycling occurred, the expectation is that larger or higher-quality pieces would have been preferentially recycled. In this respect it is noteworthy that the obsidian specimens from Area A, on average, weigh less and are slightly smaller (see Allen, Chapter 16) than those from Area B, although other factors cannot be excluded.

Although these caveats raise the possibility that the obsidian samples from Areas A and B may not be representative, even if this were the case, it is unlikely it would change two of the more interesting patterns revealed in this study. The presence of Baki obsidian at Area A conforms to patterns seen elsewhere on New Britain. Further, there is also the long-distance movement of low-quality Pam Mandian obsidian to Mussau, when closer and better-quality sources were available. Significantly, these are precisely the patterns that support the assertion that obsidian procurement at Talepakemalai was not based on economic rationales.

In sum, both the variable representation of Baki and the presence of poor-quality Pam Mandian materials at Talepakemalai can only be explained if raw material properties, vis-à-vis tool production, were not the focal point of the procurement process. If obsidian exchange was embedded in other social aspects of inter-island contact, then we might expect to see some relationship to distance but no relationship to technological qualities, and this is indeed the patterning occurring in both areas of the Talepakemalai site. The Lapita-period community here seems to ultimately conform to the patterning of Lapita obsidian exchange exhibited elsewhere in the Lapita interaction sphere. These similarities include the shift over time to a predominance of Admiralties obsidian (as per Summerhayes 2003), the rare use of Baki obsidian and an emphasis on that from Kutau/Bao (see Torrence and Summerhayes 1997), and indications that economics were not the main rationale for Lapita obsidian procurement (e.g., Sheppard 1993, Torrence and Summerhayes 1997).

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CHAPTER 16

Obsidian Tool Production and Use at Talepakemalai (Site ECA)

Melinda S. Allen

Obsidian flakes are among the more common artifacts found in prehistoric settlements of the Bismarck Archipelago. Yet in many cases obsidian is not a local material but one imported from source areas many kilometers away. This characteristic makes obsidian ideal for investigating material use and discard patterns in relation to acquisition and transport costs. Excavation at Talepakemalai and other sites in the Mussau Islands provided an opportunity to examine the character of obsidian use during the Lapita period. Improved understanding of the origins and function of Lapita small tool traditions also helps place subsequent Remote Oceanic assemblages in their larger historical context.

The 1987 Mussau obsidian technological analysis used a cost-benefit framework and had two main aims: 1) to compare the efficiency (relative cost effectiveness) and use-intensity of obsidian tool production and consumption across different source areas and sites; and 2) to characterize the Mussau collections in a way that would facilitate comparisons with other small flake assemblages from the region at large. Use patterns relevant to two major obsidian sources were considered: the Willaumez Peninsula source roughly 430 km south of the Mussau Group and the Admiralty Islands source about 250 km to the west. The null hypothesis was that the efficiency and intensity of tool production and use would be greater in the case of the more distant Willaumez Peninsula source, assuming that obsidian from the two sources was equivalent in quality.

Tool production and use was also considered across two penecontemporaneous areas with the ECA site: Area B and Area A. Area B has three stratigraphic zones. The upper Zone A is a palimpsest made up of materials derived from the underlying Zones B and C and has been both gardened and disturbed by crabs in the recent past, while Zone B postdates Zone C but is of Lapita age. Of primary interest here is the early Zone C, a Lapita-age occupation associated with an over-water stilt house. Altogether 270 specimens from seven excavation units were analyzed from Area B, Zone C. The units were selected to represent areas that would have been both directly under and peripheral to the stilt house, and to facilitate comparisons with faunal analyses from the same seven units. A small sample (N = 20) from two units of Area B Zones A/B was analyzed for comparative purposes. At Area A, 71 specimens from a single excavation unit were analyzed. Only the uppermost levels of this single occupation site had been disturbed by contemporary gardening.

The obsidians from Areas A and B were initially attributed to either Willaumez Peninsula or the Admiralty Islands sources in a prior study (see Allen, Chapter 14 of this volume). Although macroscopic (in-hand) characteristics cannot consistently be associated with particular Western Pacific sources (Torrence et al. 1992), Green (1987) had demonstrated that these two source regions could be reliably separated based on their non-overlapping density (specific gravity) ranges. The Mussau assemblages were initially sorted into three groups using Green's method of sodium metatungstate separation, and the reliability of these groups was then evaluated using high-resolution PIXE-PIGME technology (see Allen et al., Chapter 14). The latter demonstrated that two density groups were unambiguously associated with the Admiralty Islands (Density Classes 2 and 3). The third group (Density Class 1) contained both Admiralty Island and Willaumez materials, an unexpected finding given prior studies. The PIXE-PIGME analysis identified the "problematic" component of Density Class 1 as deriving from Pam Lin, an Admiralty Island subsource that was not known from other Lapita sites at the time. Although the sample numbers were small, the more precise PIXE-PIGME analysis also suggested that up to 48% of Density Class 1 might be Pam Lin material. These confounding factors need to be kept in mind when considering the results below.

Methods

A prior study of Pacific small flake technologies by Patrick McCoy (1982) was particularly important in structuring the 1987 analysis, and the terminology and procedures used herein generally follow his work. Initially the assemblages were assessed for post-depositional damage, as indicated by the frequency and location of distinctive ring fractures, the percentage of broken flakes, and the amount of shatter.

Seven attributes relating to core reduction and flake manufacture were considered (Table 16.1). Control and care in flake production can be indicated by platform size, the amount of shatter, and the kinds of flake terminations, while flake size and the frequency of cortex may reflect the relative intensity of flake removal. With cores, platform preparation also may suggest efforts to control flake removal, while the number of flake scars, the size of abandoned cores, and the use of flakes to produce more flakes (e.g., secondary cores) may reflect the intensity of production. As noted above, the expectation was that the more proximate Admiralty source might be used less intensively relative to the more distant, and presumably more "expensive," Willaumez source. Notably the above attributes can reflect factors other than production efficiency. For example, the character of the striking platform, amount of shatter, and attributes relating to core preparation may be linked to raw material properties. Similarly, the nature of flake terminations can be tied to the percussive force used in flake removal. Thus, it is important to consider the entire suite of attributes, the relative frequency of particular characteristics, and the magnitude of differences or similarities observed across the two sources and/or different sites.

In assessing use-intensity, six core and flake attributes were considered (Table 16.2). Wear/retouch was defined as definite and continuous scarring of at least 5 mm length. Of note, some measures, such as length and invasiveness of wear, and flake size, may reflect the kind of use as much as intensity per se. As with flake production attributes, the expectation was that specimens of Admiralty Island obsidian would be used less intensively.

Results

Post-depositional Damage

Little post-depositional damage was expected on specimens from Area B, Zone C given the nature of the occupation, an over-water stilt house, and the low-energy depositional environment indicated by the geomorphological analysis. Additionally, post-occupation shoreline progradation effectively sealed and protected the Zone C deposit from subsequent disturbances to some degree. Assemblages from Area A and Area B, Zones A/B, in contrast, were anticipated to exhibit moderate to heavy damage from gardening activities.

Ring fractures on flakes were most common in Area B, Zone C (27%), followed by Zone A/B (20%) and Area A (7%), a pattern which suggests this attribute is unrelated to gardening activity or trampling. Moreover, their prevalence

Table 16.1. Expectations for intensive core reduction and controlled flake removal

Attribute	Intensive	Un-intensive
Cores		
Size	small	large
2° cores	common	uncommon
Negative scars	many	few
Platform preparation	common	uncommon
Attribute	**High control**	**Low control**
Flakes		
Platform	small &/or thin	large
Terminations	hinge or feather	step or abrupt
Shatter	infrequent	abundant

Table 16.2. Expectations for intensive versus non-intensive use

Attribute	Intensive	Non-intensive
Cores		
Wear incidence	common	uncommon
Flakes		
N utilized flakes	many	few
N wear locations per flake	many	few
Length of wear	long	short
Invasiveness of wear	great	small
Size of flakes	small	large

on cores suggests ring fractures might be associated with flake removal. Sheppard (1993:129) notes abundant ring fractures in the Reef Santa Cruz assemblages, which he attributes to "the use of rather casual free-hand hard percussion." Broken diagnostic flakes, in contrast, are more common in Area A (48%), but only marginally so (40% in both Area B zones) (Table 16.3). Of note, at Area B the percentage of broken diagnostic flakes in Zones A/B and C is the same. The percentage of shatter is also higher at Area A (32%) relative to Area B (Zone A/B = 15%; Zone C = 28%), but could reflect technological processes rather than post-depositional ones (Table 16.3). Finally, a slightly higher frequency of flakes with rounded edges in Area A also points to greater post-depositional effects relative to Area B, Zone C. Overall there is more evidence for post-depositional damage at Area A but it is less marked than anticipated at the outset.

Extraction and Reduction

Based on in-hand characteristics, at least four raw material categories were recognized and are suggestive of variation in raw material quality. These include: 1) brownish, translucent, glassy; 2) gray, grainy sperulite-ridden; 3) dark-gray, opaque, fine-grained; and 4) gray, grainy, banded specimens. The overall size of both flakes (Table 16.3) and cores (Table 16.4) is small. Cortex is found on both flakes

Table 16.3. Flake attributes by site

Attribute	ECA-B	ECA-B	ECA-A
	Zones A/B	Zone C	
N specimens	20	243	56
Mean length (mm)	17.7 ± 6.8	20.3 ± 9.3	13.7 ± 5.3
Mean width (mm)	21.2 ± 9.6	21.5 ± 9.7	15.3 ± 6.6
Mean weight (gm)	2.4 ± 2.4	3.5 ±11.7	0.9 ± 1.2
Mean platform width (mm)	5.7 ± 3.7	4.9 ± 3.8	3.6 ± 2.7
% diagnostic flakes, unbroken	45	32	20
% diagnostic flakes, broken	40	40	48
% shatter	15	28	32
% flake termination*			
hinge	53.8	50.3	34.3
step	7.7	8.3	34.3
angled	15.4	22.1	20.0
other	23.1	19.3	11.4
% flake shape*			
parallel	8.3	14.9	3.3
subparallel	33.3	17.9	16.7
divergent	25.0	35.1	43.3
convergent	16.7	19.1	23.3
other	16.7	13.0	13.4
% cortex			
none	95	82	67
1–50	5	16	33
50–100	0	2	0

*Percentage values are for flakes where these attributes could be determined.

and some cores, being most common in Area A where it occurred on 33% of the specimens, compared to Area B, Zone C where cortex occurs on 18% of the specimens. The combination of small cores and flakes, and the occurrence of cortex on both, suggest that obsidian entered the Mussau environment as small blocks or nodules.

Temporal Trends in Raw Materials

Temporal trends in patterns of obsidian importation can be assessed at Area B where there are three occupation zones (Table 16.3). Both the average weight and the mean size of specimens are reduced in Zones A/B relative to Zone C. Specimen sizes also are more uniform in the post–Zone C deposits, with fewer large specimens being recovered from Zones A/B (Table 16.3). The presence of cortex also declines through time, being slightly more common on specimens from Zone C of Area B (Table 16.3). These characteristics suggest decreasing access to raw materials, and could reflect curation and/or reuse of older materials in the two post–Zone C occupation periods.

Table 16.4. Attributes of primary cores by site and source

Attribute	ECA-B, Zone C	ECA, Area A
N by source		
Density Class 1	8	6
Density Classes 2 & 3	19	9
Mean length (mm)		
Density Class 1	28.4 ± 10.4	24.0 ± 8.4
Density Classes 2 & 3	28.8 ± 6.3	18.9 ± 5.7
Weight (gm)		
Mean	7.1 + 5.5	3.0 + 3.0
Range	28.5–1.0	0.2–7.2
N platforms		
Mean	4.3 ± 1.6	2.4 ± 1.1

Table 16.5. Flake attributes by source (ECA, Area B, Zone C only)

Attribute	Density Class 1	Density Classes 2/3
	(Willaumez/Pam Lin)	(Admiralty Islands)
N specimens	124	119
Mean length (mm)	20.9 ± 9.7	20.2 ± 9.5
Mean width (mm)	21.9 ± 9.9	21.7 ± 10.0
Mean weight (gm)	4.2 ± 15.8	3.0 ± 4.7
Mean platform width (mm)	5.7 ± 4.6	4.6 ± 3.1
% diagnostic flakes (unbroken & broken)	67.7	75.8
% flake termination		
hinge	42.0	54.1
angled	27.5	19.7
step	8.7	9.8
other	21.8	16.4
% cortex		
none	82.3	75.8
0–50	16.2	19.8
50–100	0.8	2.2

Core Reduction Technologies

Twenty-seven cores were recovered from Area B and another 15 from Area A (Table 16.4). Both primary and secondary cores are represented, the latter being comparatively large flakes where further reduction appears to reflect the removal of flakes for tool use, as opposed to use-wear. The small size of the primary cores (all less than 30 mm) might indicate intensive use but the presence of cortex on many specimens suggests that raw materials were small to begin with. Simple, direct freehand percussion is indicated and core rotation suggested. Core reduction was often initiated from more than one platform (Table 16.4) and was typically multidirectional in character. Most cores were extensively worked, as indicated by the number of negative scars. As a whole these attributes are consistent with intensive core use (see Table 16.1). However, no formally prepared platforms were observed.

As noted above, ring cracks were common on core platforms. These can indicate hard hammer reduction technologies and typically occur near the point of flake detachment; they also suggest flake removal was not particularly well controlled. There were several reasons to expect that bipolar reduction techniques might have been used by the Mussau occupants. In terms of efficiency of material use, bipolar techniques are one way to maximize small-to-very-small nodules (Parry and Kelly 1987; Shott 1989). Attributes of bipolar reduction have been previously observed in the broader region, with McCoy (1982) reporting such evidence from Tikopia and Lilley (1986) from the Vitiaz Strait. McCoy (1982) and Kobayashi (1975) suggest that bipolar flaking is indicated by a high incidence of crushed or sheared platforms, diffuse bulbs, crushed distal ends, and directionally opposed compression rings. In the Mussau case, crushed and missing platforms were recorded. However, the incidence of crushed distal ends was low, no opposing compression rings were observed, and double bulbs of percussion were few in number. Overall, little evidence was found for bipolar reduction technologies.

General Flake Characteristics

As noted above, the Mussau flakes are typically small, averaging 20 mm in length and with mean weights varying from 3.5 gms in Area B, Zone C to 0.9 gm in Area A (Table 16.3). Several flake shapes were recognized in the assemblage. Flake shape is partially controlled by the morphology of the core face, but also affected by the mode of flake removal. Flakes with parallel and subparallel sides imply a degree of control and regularity in removal (McCoy 1982).

Data relating to wear/retouch are presented in Tables 16.6 and 16.7. Three types of wear/retouch were observed in the Mussau assemblages: 1) unifacial wear; 2) bifacial wear unassociated with any distinctive morphological features; and 3) distinctive small-to-minute points on flake edges associated with bifacial wear/retouch. Unifacial wear was by far the most common. In general the patterns of retouch/use-wear are consistent with light cutting activities.

The third type of wear/retouch produced small points or gravers (Sheppard 1993:133). These are characterized by unifacial micro-scarring on two sides of the point, with wear/retouch on one side located on the ventral surface and on the opposing side located on the dorsal surface. These distinctive tools were first identified by Lawlor (1978) in the Reef/Santa Cruz Islands assemblages. They have been more formally described by Sheppard (1993, 2010), who argues that they represent formal retouch rather than use-wear. Sheppard further suggests these micro-tools were used on relatively soft materials. More recently, Kononenko and colleagues have demonstrated their use in tattooing through residue analysis and experimental use-wear studies (2011, 2012; Kononenko et al. 2016). Nineteen gravers were identified in the Mussau assemblages. These were concentrated in northern units of the site, particularly in excavation Units W199N150 (N = 4) and W195N150 (N = 5). Usually only a single graver tool was identified on any given specimen.

Specimen Attributes Across Areas A and B

Comparisons across proveniences were aimed at identifying differences in the intensity and skill of flake production (Table 16.3) and intensity of use (Table 16.6). On average, flakes and cores were smaller at Area A relative to those from Area B, Zone C (Tables 16.3 and 16.4); this is likely related to raw material properties. Among the attributes at Area B, Zone C that are suggestive of greater efficiency or control of flake production are a higher percentage of hinge terminations (Area B mean = 50.3% versus Area A mean = 34.3%) and less shatter (28% versus 32%). With respect to flake shape, divergent forms were the most common at

Table 16.6. Flake use attributes by site

Attribute	ECA-B	ECA-B	ECA-A
	Zones A/B	Zone C	Zones A/B
N specimens	20	243	56
% flakes utilized	25	23	14.3
N wear localities per flake (%)			
one	20	58	62.5
two or more	80	42	37.5
Utilized flake mean length (mm)	20.3	17.7	13.7
Utilized flake mean weight (gm)	3.5	2.4	0.9

Table 16.7. Utilized flake attributes by source (ECA, Area B, Zone C only)

Attribute	Density Class 1	Density Classes 2/3
	(Willaumez/Pam Lin)	(Admiralty Islands)
N specimens	124	119
% utilized flakes	23	24
Wear localities per flake (%)		
one	55.1	60.7
two	31.0	32.1
three	6.9	7.1
four	6.9	0

both areas: Area B, Zone C with 35.1%, and Area A with 43.3%. Parallel forms were infrequent in all contexts, but most common in Area B, Zone C (14.9%). McCoy (1982) suggests that parallel and subparallel forms indicate control and regularity in flake production. Narrower platform widths in the Area A assemblage (mean = 3.6 mm versus 4.9 mm at Area B) could indicate a high degree of control in flake removal. In general, while differences in flake production are apparent across the two sites, as a whole they do not provide a strong basis for arguing that flake production was more controlled or skillful at a particular locality.

With respect to flake use (Table 16.6), utilized flakes from Area A were smaller (mean = 13.7 mm long) compared to Area B, Zone C (17.7 mm) and fewer flakes were utilized (14.3%) relative to Area B, Zone C (23%). Most of the Area A flakes had single incidences of wear (62.5 versus 58%), while 42% of those from Area B, Zone C had multiple wear localities. These measures suggest that flakes from Area B were more fully utilized relative to those from Area A. Eight cores from Area B, Zone C also showed wear/retouch. A single wear locality was most common but one specimen exhibited four areas of wear/retouch. In general most of the wear at both sites was unifacial, but two instances of bifacial wear were observed.

The three occupation zones at Area B allow for intra-site differences to be considered (Table 16.6). In general, the evidence points to more intense flake use in thetwo upper zones (A/B). In the small Zones A/B sample, 25% of the flakes were utilized, and 80% had two or more units of wear. This, plus the smaller size of the Zone A/B flakes (mean = 17.7 mm, Table 16.3), suggests more intensive use of obsidian in post–Zone C periods. Zones A/B also differed somewhat in terms of preferred flake shape, with subparallel forms making up 33.3% of the assemblage. A larger sample from the upper zones is needed to more fully evaluate these preliminary observations.

Specimen Attributes by Source (ECA-B, Zone C)

The large sample from Area B was used to evaluate flake production and use across density classes, specifically Density Class 1 versus Density Classes 2/3 (Tables 16.5 and 16.7). Specimens of Admiralty obsidian (Density Classes 2/3) have more cortex, which probably reflects the original core properties. Flakes from the two density classes are on average similar in length and width, but those from the Admiralties are typically lighter (by weight), suggesting they are thinner. They also have narrower platform widths, a greater percentage of hinge terminations, and shatter was less common. These attributes suggest either more care and control in flake production or advantageous raw material properties.

Comparison of Area B, Zone C density classes in terms of flake use showed that an equivalent number were utilized (23–24%) (Table 16.7). Similarly, the incidence of wear was comparable. Just over half of the flakes exhibited a single wear unit, although a third were characterized by two wear localities. One notable difference was the greater use of Admiralty obsidian for gravers. This again might relate to raw material properties (workability). Overall, while there is some variability, use of the two sources appear quite similar and the differences that are evident may relate mainly to the original form of the raw material.

Discussion

Flake Production and Use by Site on Mussau

The Mussau obsidian technological analysis identified some inter-area differences within site ECA. At Area A cores were smaller relative to those from Area B, and appear to have been used less intensively (possibly because of smaller size), with a lower number of striking platforms. Perhaps for related reasons, flakes also were smaller at Area A. The comparatively smaller platforms and thinner flakes seen at Area A could reflect greater care in flake removal, but might also relate to raw material properties.

At Area B, Zone C, other flake attributes suggest skill and care in flake production. These include the proportion of challenging flake shapes, hinge termination, and possibly more limited amounts of shatter. Indications are that both cores and flakes were more fully utilized at Area B. These attributes could reflect more limited access to raw materials (unlikely given other indicators of occupation status), the nature of on-site activities, or the skills of the residents in obsidian flake production.

Flake Production and Use by Source on Mussau

The Area B assemblages allowed for assessment of potential differences in raw material use. While some variation in source use was apparent, the differences do not appear consequential. Smaller cores with more cortex predominated at Area A, potentially resulting in smaller flakes (on average). Flake weight was also lower for Density Class 2/3 flakes at Area B. With respect to tool use, the two sources were used in similar ways and intensities. Both the number of utilized flakes and the number of wear localities were comparable across density classes. The Admiralty Island source was more commonly used for producing the distinctive gravers, but overall the number of gravers recovered is small and these differences may not be significant.

Regional Comparisons

There are few detailed technological studies of Lapita-age obsidian assemblages with which to compare the Mussau results. Three important analyses are on materials from SZ-8, RF-2, and RF-6 in the Reef/Santa Cruz Islands (Sheppard 1993), the site of Makekur on Adwe Island in Arawe Group (Halsey 1995 in Sheppard 2010), and the SCA site on Watom (Green and Anson 1998). The analyses of Torrence (1992), Fredericksen (1994), and Fullagar (1992) also are useful for understanding long-term changes in obsidian use in the Near Oceanic region.

Overall, the Mussau obsidian flake assemblages are consistent with the larger Pan-Oceanic "small tool tradition" (after McCoy 1982) associated with use of volcanic glasses and obsidians. Work by Fullagar (1992), Torrence (1992), Fredericksen (1994), and others indicates that this tradition was well established in Near Oceania prior to the arrival of Lapita peoples. However, as Torrence (1992) demonstrates, simple expedient tools are a hallmark of the

Lapita period. More complex retouched tools are characteristic of sites in the region both before and after the Lapita period (Fullagar and Torrence 1991; Torrence 1992, 1993). Prior to Lapita, relatively large (10–25 cm) retouched tools with a "protrusion or stem at one end" were widespread and common in the Bitokara Mission sites of the Talasea region. Similar stemmed tools are found elsewhere in the Talasea region in deposits contemporary with Lapita pottery, but are much smaller (3–5 cm) and are not known from Lapita contexts outside of this area. Around the time that Lapita pottery appears, Torrence (1992) records a shift from staged tool production (different stages of tool production being carried out at different sites) to more casual and expedient production of small, largely unmodified flakes—a change which Torrence (1992) and Fullagar (1992) suggest is tied to increasing sedentism and not necessarily a result of a population intrusion. Fullagar (1992) observed other temporal changes in small flake tools (obsidian and chert) as well, including a decline in the amount of retouch and increasingly generalized use on a range of plant and animal materials, as indicated by residue analysis.

This expedient small flake technology was subsequently carried into Remote Oceania where in some contexts it is transferred to volcanic glasses (e.g., Hawai'i). More complex technologies and tool forms fail to develop in most places, in part because true obsidians are limited and volcanic glasses generally occur in forms that limit the size and complexity of tool forms (e.g., glassy selvages on lava flows). Even in New Zealand, where relatively thick obsidian flows are available, complex obsidian tools comparable to those of Near Oceania in the late prehistoric and pre-Lapita period generally do not develop, although the stemmed blades of Rapa Nui are an exception.

As evidenced in the Mussau case, exchange elsewhere apparently involved circulation of small unmodified nodules of obsidian (see Sheppard 1993:125; Torrence 1992:122), a pattern which is consistent with raw material forms in several source areas (e.g., Torrence et al. 1992; Specht et al. 1988) and with more recent ethnographically recorded practices (Torrence 1992:122–123 and references therein). Archaeologically, the form of raw materials is indicated by the small size of cores and flakes and the presence of cortex. At ECA, the frequency of cortex in Area A (33%) was consistent with patterns recorded in the Reef/Santa Cruz Islands where it occurred on 29.4% to 32% of the specimens. However, cortex was less well represented in Area B (18%) and could reflect preferential access by Area B occupants to usable obsidian or importation of decorticated nodules.

Reduction strategies elsewhere have been described as involving extensive working of these small nodules, marked by multifacial, multi-platform cores, presumably through core rotation (McCoy 1982; Sheppard 1993; Hanslip 2001). These analyses also suggest use of freehand direct percussion technologies and possibly some bipolar reduction. In all cases, there is little evidence for core preparation or standardized reduction strategies. The Mussau findings are consistent with these patterns, although evidence for bipolar reduction was not identified. As Sheppard (1993) notes, bipolar flaking is difficult to identify from debitage. In his analysis of the Reef/Santa Cruz assemblages Sheppard commented on the ambiguous nature of the evidence and concluded that it is "most probable that some pieces of material were reduced in a bi-polar manner as is common in a very large number of lithic industries worldwide" (Sheppard 1993:129).

Core reduction was generally aimed at producing small flakes, with size being at least partly tied to the raw material form. Mean flake size in the Mussau assemblages was consistent with findings elsewhere. Flakes averaged between 20.3 mm (Area B, Zone C) and 13.7 mm (Area A). On Tikopia, mean flake length was 18.6 mm (Kirch and Yen 1982), in the Reef/Santa Cruz assemblages it varied from 19.6 (SZ-8) to 13.7 mm (RF-6) mm (Sheppard 1993), and in the Arawe Islands ranged between 22.3 and 18.1 mm (Halsey 1995 in Sheppard 2010). Remarkably, despite considerable variation in the distances to sources from these four localities, variability in flake size appears to be more strongly tied to internal factors. For example, in the Reef/Santa Cruz sites, temporal variation in flake size appears to reflect decreasing access to obsidian, while on Mussau differences in flake size are spatially distinctive and appear to relate to either variation in site functions or status differences of site occupants.

Other aspects of flake production also appear relatively consistent across the region. Green and Anson (1998) report little effort to produce preferred flake shapes at Watom. Similar patterns were found on Mussau, where divergent forms were the most common (35 to 43%), and parallel (3.3 to 14.9%) and subparallel (16.7 to 17.9%) forms (which require the greatest control and expertise to produce) were less frequent (Table 16.3). Of note, however, McCoy (1982) characterizes similar frequencies of parallel and subparallel forms (16.6%) on Tikopia as "relatively high" and suggests this evidences "a modicum of control and regularity" in flake production.

Simple flake tools also dominate other Lapita-age assemblages. The minute but distinctive gravers described by Lawlor (1978) and Sheppard (1993) also have been identified in the Mussau assemblages, at Makekur (Hanslip 2001), and in New Caledonia and elsewhere in smaller numbers (Sheppard 2010). In the Reef/Santa Cruz case, gravers were more common at both the SZ-8 and RF-2 sites, where they constituted 13–15% of the overall assemblage. At ECA, Area B they constitute a significantly smaller percentage of the overall Zone C assemblage (8%).

Other kinds of wear were not particularly common in the Mussau assemblages, averaging about 23–24%. The most typical type of wear is unifacial. In the Reef/Santa Cruz assemblages between 12% and 31% of specimens from the three sites were classified as retouched tools and unifacial wear was common. Between 3.5% and 8.5% of the Arawe Islands assemblage evidenced retouch. In addition to the gravers and simple retouched flakes, Sheppard (1993) identified utilized chunks and points (see also Hanslip 2001). Sheppard suggests the Reef/Santa Cruz flakes were used in a variety of cutting and light scraping activities, while Fullagar's (1992:140) analysis of flakes from West New Britain site FHC indicates use in processing of animal flesh, skin, wood, other plant materials, and bone. The high incidence of unifacial wear is most consistent with scraping activities, while the limited invasiveness of micro-scarring observed on Mussau specimens is consistent with use on relatively soft materials.

A key issue in recent studies has been the role of obsidian in Lapita exchange, and its social and utilitarian value in particular. Sheppard (1993) proposed that the social value of obsidian was maximized during exchange events, but once specimens entered the use context, obsidian became a low-value commodity. This, he argued, was reflected in the absence of economizing behavior associated with obsidian reduction and tool use in the Reef/Santa Cruz sites. Moreover, in the use context, its discard was similar to that of other utilitarian debris. Specifically, few differences were seen in the discard patterns of obsidian, chert, and pottery sherds, "materials with radically difference transport costs" (Sheppard 1993:133). Green and Anson (1998) also suggest that the patterns of random discard seen at Watom imply a low value for obsidian once it entered the domestic realm.

The Mussau findings are consistent with the idea that the cultural value of obsidian was multidimensional in character and dynamic over the life history of a given specimen. Based on a variety of evidence, Kirch (2001a:102–103) argued that Zone C of Area B at ECA was associated with relatively high-status individuals. The evidence for this includes the abundance and quality of decorated ceramics, the representation of multiple exotic ceramic sources, and the relative abundance of obsidian. In all of these dimensions, Area B, Zone C at ECA contrasts with the other Mussau Lapita sites. The sourcing study of Allen (Chapter 14 in this volume) further demonstrated that Area B, Zone C contained a higher percentage of the more distant Willaumez Peninsula obsidian, and the highest-quality Admiralty subsource, Umrei. The present study indicates that Area B is further distinguished by the lower incidence of cortex, which might reflect some kind of core modification prior to arrival at the site.

Tool production characteristics, in contrast, indicate no marked differences in the way the two sources were treated in either of the Mussau sites examined here. Contrary to expectations, more intensive use of the Willaumez source was not forthcoming. Rather, the weak patterning observed suggests that, if anything, the Admiralty source was used more economically; however, on current evidence the patterning cannot be separated from intrinsic differences in raw material properties. Overall, the evidence suggests that once in a use context, the origins of a specimen had little discernible impact on how the generally simple tools were produced and used.

Conclusions

The technological analysis reported in this chapter demonstrates that the Mussau obsidian assemblages are similar to other small tool assemblages in the broader region. Admiralty Islands obsidians appear to have arrived in

Mussau as corticated nodules that were smaller than those from the Willaumez source. Willaumez source cores, in contrast, may have been partially decorticated prior to arrival. Small flakes were removed from small cores using direct freehand percussion techniques, with cores frequently rotated in the process. Admiralty obsidians may have been slightly easier to work in terms of controlled flake production. As Sheppard (1993, 2010) has suggested for other sites, once obsidians entered the Mussau environment there appears to have been little distinction in the ways that particular source materials were used. No significant differences in use-intensity were observed for the two sources in the Mussau case. Retouch/wear indicates that the resulting flakes were often used for light cutting and scraping activities, although minute gravers were also produced on occasion and evidence from elsewhere has indicated their use in tattooing (Torrence et al. 2018). While obsidian use appears to have been undifferentiated by source, inter-site differences in the intensity of obsidian use were apparent. In particular, specimens from Area B, Zone C exhibited more wear instances per specimen relative to Area A. There is also modest evidence to support the idea that the Area B occupants might have been more skilled in knapping.

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CHAPTER 17

Petrography of Manuports from Mussau Archaeological Sites

William R. Dickinson

Manuports, defined as rocks that were transported by humans from some locality to an archaeological site, but were otherwise not artificially modified, can provide important data regarding resource use and exchange or contacts between communities. This chapter reports on the petrography of 60 lithic manuports from Mussau archaeological sites, together with the petrography of 12 rock samples from the high island of Mussau for geologic control, to shed light on the geologic nature of the locales from which the manuports were derived. Although a few of the studied manuports came from Mussau Island, most were apparently derived from elsewhere in the Bismarck Archipelago.

Geological Control Samples

Geological control samples were collected by Patrick Kirch during a reconnaissance survey of parts of Mussau Island in 1985 (see Chapter 1). The 12 rock samples from Mussau fall into three groups (Table 17.1), derived respectively from the plutonic igneous bedrock of interior Mussau (Group A), related extrusive volcanic or hypabyssal dike rocks (Group B), and limestone (Group C) derived from uplifted reef terraces that surround the igneous core of Mussau (see Chapter 2).

The largest number (N = 7) of rock samples form a generically related suite of plutonic gabbro and diorite (Group A of Table 17.1) with allotriomorphic granular texture (mainly anhedral crystals of subequal size). The plutonic rocks are composed of varying proportions of plagioclase feldspar and clinopyroxene, the latter mantled generally or partly by magmatic reaction rims of brown hornblende, which also occurs sparingly as separate interstitial grains. The color index (percentage of ferromagnesian minerals) varies between about 30 and 50, with a color index of 40 commonly taken as the division between diorite (< 40) and gabbro (> 40). Most specimens are gabbro, and two are troctolitic (olivine-bearing) gabbro (Table 17.1). From the general geology of the Bismarck Archipelago (see Chapter 13), the gabbro and diorite of Mussau probably represent a subvolcanic intrusive complex exposed by deep erosion of a cogenetic volcanic edifice.

Table 17.1. Classification of geological control samples from Mussau Island

Rock Group	Sample Numbers	Comments
A. Plutonic gabbro and diorite	#1, #2, #3, #4A, #6, #8, #9	including troctolitic (olivine-bearing) gabbro (#2, #8)
B. Hypabyssal intrusive or volcanic	#4B, #5, #7	some with fluidal fabrics (#5, #7)
C. Reef terrace limestone	#10, #10B	biomicritic wackestone

The finer-grained igneous rocks (Group B of Table 17.1), displaying aphanitic textures dominated by plagioclase laths and microlites, may all derive from mafic dikes of basalt or basaltic andesite intruding the plutonic bedrock of Mussau, although an extrusive volcanic origin cannot be excluded for at least the two with fluidal fabrics (Table 17.1) defined by oriented plagioclase laths and microlites.

The limestone samples (Group C of Table 17.1) are biomicritic wackestone with varied fragments of skeletal allochems imbedded in cemented lime-mud matrix. Their textures are appropriate for raised reef-flat deposits.

Manuport Petrography

The Mussau manuports fall into four generic classes (I–IV of Table 17.2), although about 60% are of volcanic affinity (Class II).

Class I (intrusive plutonic) manuports (N = 9) include a majority (Classes IAB) that are indistinguishable from the control set of Mussau gabbro-diorite (Group A of Table 17.1), and were doubtless derived from the high island of Mussau. Other plutonic manuports (Class IC) are hornblende diorite (and gabbro), with hypidiomorphic granular texture, composed of subhedral plagioclase and green hornblende crystals of roughly equal size. The green hornblende contrasts with the brown hornblende of Mussau bedrock, and the Class IC manuports were apparently derived from intrusive igneous rocks exposed elsewhere in the Bismarck Archipelago, where intrusive complexes are present on Manus, Lavongai or New Hanover, New Ireland, and New Britain (Dickinson 2000).

Class II (volcanogenic) manuports (N = 37) include a variety of volcanic and related hypabyssal igneous rocks not generically dissimilar to the volcanic-hypabyssal rock samples (Group B of Table 17.1) from Mussau, but so heterogeneous that all or most are inferred to derive from elsewhere. The dominant andesitic (to basaltic) extrusive rocks (Classes IIABC) could derive from any of the Eocene-Miocene volcanic assemblages exposed on the larger islands (Manus, Lavongai, New Ireland, New Britain) of the Bismarck Archipelago, with the andesite and diorite porphyries (Classes IIDE) derived from associated subvolcanic intrusions. The andesite and andesite porphyry manuports (Classes IIBCD) display felted or fluidal microlitic groundmasses, whereas diorite porphyry manuports (Class IIE) have coarser-grained groundmasses, but all jointly define a compositional spectrum of generically similar igneous rocks. Samples described as porphyritic andesite (Class IIC) and as andesite porphyry (Class IID) differ only in their percentages of phenocrysts (taken arbitrarily as > 50% for andesite porphyry). Samples of related volcaniclastic rocks (Classes IIFG) were formed by reworking volcaniclastic detritus from volcanic assemblages, and represent rocks that also occur widely on the larger islands of the Bismarck Archipelago. One manuport (Class IIH) is a distinctly more felsic rock possibly derived from one of the small rhyolitic islands within the Admiralty bimodal zone (see Chapter 13) lying to the south of Manus, although local exposures of felsic volcanic rocks are also present on the larger Bismarck islands.

Class III manuports of metavolcanic rock (N = 9) could readily derive from contact aureoles and zones of hydrothermal alteration surrounding the multiple subvolcanic intrusions present on the larger Bismarck islands, and the manuports composed of hybrid volcanic-calcareous sandstone (Class IVA) could derive from widespread sedimentary sequences redeposited from volcanic source rocks as integral parts of Eocene-Miocene volcanogenic assemblages widely exposed on the same Bismarck islands.

Table 17.2. Classification of manuports from Mussau archaeological sites

Subclass	Number	Samples	Comments
Class I: Intrusive plutonic			
A. Mussau gabbro-diorite	4	ECA-17-10-004 ECB-00-00-004 EHBOI-04-001 EKP-3-3-1	gabbro gabbro gabbro gabbro
B. Mussau troctolitic gabbro	2	ECA-19-01-004 ECA-18-03-002	olivine-bearing olivine-bearing
C. Hornblende diorite-gabbro	3	ECA-37-08-032 ECB-00-00-002 EHB-0-6-4	diorite gabbro diorite
Class II: Varied volcanogenic			
A. Aphanitic basalt	5	ECA-40-11-051 (20) ECA-37-03-013 (19) ECA-3-2-3 ECB-10-2-1 EHB-4-7-2	[All Class IIA samples display intergranular to intersertal groundmass textures with twinned plagioclase laths rather than microlites]
B. Aphanitic andesite	11	ECA-16-01-007 ECA-16-02-003 ECA-31-12-017 (52) ECA-48-07-002 ECA-50-07-004 ECA-54-06-001 ECB-00-00-006 ECB-7-1-49 ECB-10-2-2 ECB-15-1-5 EKS-4-3-1	green hornblende microphenocrysts plagioclase microphenocrysts uniformly aphanitic rock containing sparse amygdules clinopyroxene microphenocrysts containing sparse amydules plagioclase microphenocrysts plagioclase microphenocrysts containing sparse amygdules plagioclase microphenocrysts plagioclase microphenocrysts
C. Porphritic andesite	5	ECA-23-01-008 (16) ECA-62-2-3 ECB-15-1-4 ECB-16-6-5 EKS-0-0-31	plagioclase phenocrysts plagioclase phenocrysts plagioclase phenocrysts clinopyroxene phenocrysts plagioclase phenocrysts
D. Andesite porphyry	6	ECA-34-05-75 ECA-37-08-33 ECA-51-02-001 ECB-0-0-19 ECB-14-4-1 EHB-6-1-5	clinopyroxene phenocrysts clinopyroxene phenocrysts plagioclase phenocrysts plagioclase phenocrysts plagioclase phenocrysts oxyhornblende phenocrysts
E. Diorite porphyry	3	ECA-19-05-002 ECA-37-05-068 ECA-52-04-003	[All Class IIE samples display sugary phaneritic groundmasses with abundant phenocrysts]
F. Andesitic breccia	3	ECA-24-04-005 ECA-40-08-007 EKC-0-0-21	[All Class IIF samples are fragmental pyroclastic rocks with abundant clasts of volcanic rock]
G. Andesitic sandstone	3	ECA-50-04-004 ECB-16-2-6 ECB-17-3-9	[All Class IIG samples were derived from moderately sorted volcaniclastic strata]
H. Felsic vitrophyre	1	EKR-0-0-7 (48)	spherulitic volcanic glass with sparse plagioclase phenocrysts
Class III: Altered volcanic			
A. Silicified	3	ECA-3-01-005 (44) ECA-48-07-014 (58) ECA-57-04-001 (61)	[All Class IIA samples are chalcedonic (cherty) rocks derived from volcanic or volcaniclastic protoliths]
B. Metasomatic	2	ECA-34-09-29 ECB-17-1-2	altered rock difficult to identify dominantly bow-tie prehnite
C. Metamorphic	4	ECA-09-04-005 (56) ECA-46-04-005 (54) ECA-3-4-009 (60) ECB-9-3-1 (63)	actinolitic metavolcanic rock amphibolite from volcanic protolith actinolitic metavolcanic rock metamorphic epidote-amphibolite

Table 17.2. Classification of manuports from Mussau archaeological sites *(continued)*

Class IV: Sedimentary-metasedimentary			
A. Hybrid sandstone	2	ECA-53-04-001 (30) ECB-18-1-4 (28)	[both are volcanic sandstones with admixed calcareous bioclasts]
B. Quartzolithic sandstone	2	ECA-55-01-043 (11) EKQ-0-0-20 (29)	[quartz grains dominant but with varied lithic fragments as well]
C. Metamorphic slate	1	EKU-0-0-20	foliated metasedimentary slate

Rare Class IVB manuports of quartzolithic sandstone were probably derived from outside the Bismarck Archipelago, within which no bedrock sources for the abundant quartz or the subordinate lithic fragments of chert, argillite, and foliated (slate-phyllite) tectonite are known. The same judgment applies to the single manuport (Class IVC) of metasedimentary slate. The exotic Class IVBC manuports most logically derive from the geologically varied nearby landmass of New Guinea, although it is by no means a unique source for them. Although the rare exotic manuports might conceivably reflect transport by early occupants from sites outside the Bismarck Archipelago, consideration should be given to the likelihood that they arrived on Bismarck beaches encased in the roots of trees washed into the sea and carried thereby to Mussau without human agency. Von Kotzebue (1967) long ago reported the occurrence of odd, adventitiously acquired stones that arrive by that means far out to sea in the Radak chain of the Marshall Islands:

> The sea throws up on the reefs of Radack [*sic*] the trunks of [both] northern firs and trees of the torrid zone . . . It provides the inhabitants not only with timber for boats but . . . they receive in a similar manner another treasure, hard stones for whetting. They are sought for in the roots and hollows of the trees which the sea throws up . . . the stones belong to the chiefs, to whom they must be delivered, on payment of a reward; punishment being inflicted in case of concealment [von Kotzebue, 1967:154–155].

Distribution of Manuports by Site

The distribution of analyzed manuports by site is summarized in Table 17.3. The greater diversity of petrographic types in site ECA is largely a reflection of the fact that the sample size of analyzed manuports is greatest for that site. Of 17 petrographic types recognized, all but two are represented in the sample from site ECA. Site ECB has 10 of the 17 types represented, while EHB has just four of the types represented.

Manuport Origins

Tracing the origins of manuports and the origins of ceramic tempers (Chapter 12) present different kinds of problems. Sand production and dispersal is an integrative process that mingles detritus from a finite but large area of geographically associated bedrock exposures, whereas manuport collection is a selective process that samples only one bedrock outcrop at a time. Much more specific geologic information is required for manuport sourcing than for temper sourcing.

Each manuport representing a point source of bedrock was presumably chosen for some unique property related to intended use, and no manuport necessarily represents a typical sample of local bedrock. Given the immense aggregate size of the Bismarck Archipelago, and the overall similarity of geologic relations over much of the extent of all its larger islands, attempts to find specific outcrop sources for individual manuports may well present an insurmountable challenge. Petrographic study of the Mussau manuports indicates, however, that they were derived from a wide array of locales on multiple Bismarck islands, as does temper analysis for the Mussau ceramic assemblage. The two parallel petrographic investigations jointly support the conclusion that Mussau inhabitants maintained extensive cultural ties across a wide region of the northern Bismarck Archipelago.

Table 17.3. Distribution of manuports by archaeological site

Manuport General Class	Subclass	ECA	ECB	EHB	Other Sites	Totals
I. Intrusive plutonic	A. Mussau gabbro-diorite	1	1	1	1	4
	B. Mussau troctolitic gabbro	2				2
	C. Hornblende diorite-gabbro	1	1	1		3
II. Varied volcanogenic	A. Aphanitic basalt	3	1	1		5
	B. Aphanitic andesite	6	4		1	11
	C. Porphyritic andesite	2	2		1	5
	D. Andesite porphyry	3	2	1		6
	E. Diorite porphyry	3				3
	F. Andesitic breccia	2			1	3
	G. Andesitic sandstone	1	2			3
	H. Felsic vitrophyre				1	1
III. Altered volcanic	A. Silicified	3				3
	B. Metasomatic	1	1			2
	C. Metamorphic	3	1			4
IV. Sedimentary-metasedimentary	A. Hybrid sandstone	1	1			2
	B. Quartzolithic sandstone	1			1	2
	C. Metamorphic slate				1	1
Totals		33	16	4	7	60

CHAPTER 18

Lapita and Its Transformations in the Mussau Islands

Patrick Vinton Kirch

The preceding seventeen chapters have presented in full the results of our three field seasons in Mussau, and of many subsequent years of laboratory study of the rich collections we uncovered there. In this concluding chapter, I return to the five themes that oriented our project from its outset: Lapita origins, including the chronology of its arrival in the Bismarcks; Lapita subsistence and economy; long-distance exchange between Lapita communities; the nature of Lapita society, including evidence for rank or hierarchy; and, lastly, the transformation of Lapita into new forms of material culture. For each of these themes I summarize what I believe to be the main contributions of the Mussau Project, and put these into the context of more recent and continuing research on Lapita. My goal is not a broad synthesis of the entire Lapita cultural complex, but rather a summation of Lapita and its transformations in the Mussau Islands, a key locality within the Bismarck Archipelago, widely regarded as the "homeland" region within which the early Lapita culture emerged prior to its remarkable expansion into Remote Oceania.

Lapita Origins and Chronology

When the Lapita Homeland Project was launched in 1985, a major goal was to address the fierce debate between two competing hypotheses: on the one hand, the hypothesis of an indigenous Melanesian origin of the Lapita cultural complex, perhaps extending back over a long time period (Allen 1984; Terrell 1986; White et al. 1988); on the other, the hypothesis that Lapita was the archaeological manifestation of a rapid expansion of Austronesian-speaking peoples out of island Southeast Asia into the Near Oceania region (Bellwood 1979, 1980; Diamond 1988; Green 1979a). Advocates of the indigenous Melanesian origin hypothesis tended to favor strictly archaeological data, while the hypothesis of Lapita as a manifestation of Austronesian expansion was favored by those (including myself) who championed a holistic anthropological approach that incorporated perspectives from historical linguistics and biological anthropology along with archaeological evidence (e.g., Kirch 2010; see also Kirch and Green 2001). The debate has continued in recent years, with John Terrell in particular continuing to argue that Lapita did not involve a demic expansion out of Southeast Asia (Terrell 2018; Specht et al. 2014), even as others have recognized that archaeological, linguistic, and biological lines of evidence all reinforce some kind of demic intrusion as essential to the Lapita phenomenon (e.g., Summerhayes 2007a, 2007b, 2010).

A major contribution of the 1985 Lapita Homeland Project was the demonstration of Pleistocene occupation of New Ireland predating the Lapita phenomenon by more than 30,000 years (Allen and Gosden 1991; Allen et al. 1989). Subsequently, Fredericksen and others (1993) showed that pre-Lapita people had extended their range to Manus (Admiralty Is.) by the late Pleistocene, an important discovery as Manus is too far west of New Ireland to be intervisible, thus implying considerable voyaging ability even during this early time period. Whether the main island of Mussau was similarly discovered and inhabited prior to the advent of Lapita, however, remains an open question. We had hoped that our excavations in the two rockshelter sites of EKQ and EKP on the main island of Mussau (see Chapter 4) might address that question, but neither site proved to have pre-Lapita deposits. For the present, we can only say that there is no evidence on the offshore islets of Eloaua, Emananus, Boliu, or Emussau for any human presence prior to Lapita. Extensive excavations and testing not only in open sites but also in rockshelters on Eloaua revealed no cultural materials underlying the Lapita-age deposits. The implication—at least for the offshore islets—is that Lapita pottery-making people settled here on "virgin" sands. That some pre-Lapita population may have been present on the main island of Mussau, as it was in Manus, remains a possibility that will have to be tested by future research there.

With respect to Lapita origins, the distinctive ceramics themselves have long offered the most compelling evidence for a connection to the island Southeast Asian region (Gifford and Shutler 1956; Golson 1971, 1972). In all of the fieldwork conducted both by the Lapita Homeland Project and subsequently in the Bismarck Archipelago, no evidence for any pre-Lapita ceramics has ever been uncovered; it is impossible to avoid the conclusion that the Lapita ceramic complex arrived in Near Oceania fully developed. The earliest ceramics in Mussau are those from the EHB site on Emananus, which includes a variety of vessel forms including pedestal bowls, cylinder stands, carinated and non-carinated bowls, and jars, decorated with a high frequency of fine dentate stamping. The red-slipped, everted-rim plainware jars from Area A at ECA and from the EKE site on Boliu Island are also early in the sequence, as best we can determine from the radiocarbon chronology. The EHB vessel forms bear strong similarities with Neolithic assemblages in the Philippines, Sabah, and Sulawesi (Bellwood 2017: 276–287; Carson et al. 2013; Kirch 1995:270–282; Solheim 1964:154–156, Plate 37; Van Heekeren 1972), including non-restricted bowls supported on pedestals, as well as a variety of jar forms. The red-slipped pottery of the Uattamdi rockshelter on Kayoa Island west of Halmahera, dated to between 1300 and 800 BC (Bellwood 2017:279; Bellwood 2019), is also remarkably similar to the ceramics from Area A at ECA, and to the EKE plainware. (Some years ago I was able to examine the Uattamdi ceramics in Bellwood's laboratory in Australia, remarking to him that if his sherds were placed together with those from ECA Area A, they would be impossible to tell apart.) The lower deposits at the Bukit Tengkorak site in southeastern Sabah, dated to 1300–1000 BC, produced "red-slipped pottery with plain or incised pedestals, a single superbly decorated incised vessel with a matching lid, and lots of shell items including adzes, bracelets, and a possible fish-hook shank, together with shell manufacturing debris" (Bellwood 2017:281–282, Figure 8.4). Especially notable at Bukit Tengkorak is the presence of small chips of obsidian from both Manus and Talasea (New Britain), establishing that there was some form of contact between Bukit Tengkorak and the Bismarck Archipelago (Bellwood and Koon 1989). While neither the Uattamdi nor the Bukit Tengkorak ceramics are exact matches for the Mussau Lapita pottery, the assemblages are nonetheless remarkably similar, are of approximately the same age, and clearly belong to closely related traditions. Carson and others (2013) have summarized in broad terms the "pottery trail" that marks the expansion of Austronesian-speaking peoples out from Taiwan and the Philippines into both Near and Remote Oceania; our Mussau ceramics are without doubt a part of that trail.

To be sure, one must always be cautious when equating pots with people—or with languages. And while both the ceramic evidence and that of other associated material culture all points to an island Southeast Asian origin of Lapita, it is to the direct evidence of human skeletal remains that one turns for independent confirmation of a demic intrusion of people accompanied by their pots, adzes, and fishhooks. A limited set of cranial and postcranial bones along with isolated teeth (total 33 NISP) were recovered from our excavations at Talepakemalai (see Chapter 6). Soon after the completion of our initial fieldwork, a morphometric analysis of the Mussau teeth led to a tentative affinity assessment "that the Mussau Lapita people were slightly more like Indonesians than like Melanesians on the basis of dental morphology" (Kirch et al. 1989:74–75), lending more support to the "out of Southeast Asia" hypothesis. Later attempts to extract aDNA from the Talepakemalai skeletal and dental remains were unfortunately unsuccessful (Hagelberg 1997; L. Matisoo-Smith, personal communication, 2012). Although the teeth and bones from the ECA site are morphologically well preserved, it appears that the waterlogged depositional context was not favorable to the preservation of DNA.

Recent analysis of Lapita skeletal remains from Remote Oceania, however, has now provided overwhelming support for the hypothesis that the early Lapita people possessed a Southeast Asian genetic makeup. The evidence derives both from traditional morphometric analysis of cranial traits (Valentin et al. 2016), and from sequencing of aDNA from Lapita burials in Vanuatu and Tonga (Spriggs and Reich 2019). Skoglund and others (2016) sequenced whole-genome aDNA from three individuals from the Teouma Lapita cemetery site on Efate Island, Vanuatu, and from a fourth individual from the Talasiu site on Tongatapu Island in Western Polynesia. These individuals, who are believed to be representative of the population of "First Remote Oceanians," had almost no Papuan ancestry in their genomes. Rather, "they are similar to indigenous Taiwanese populations such as the Ami and Atayal as well as to populations from the Philippines such as the Kankanaey, who have no detectable Papuan ancestry" (Skoglund et al., 2016:511). Subsequently, aDNA sequencing of additional individuals from later Lapita sites in Vanuatu has demonstrated a significant influx of Papuan genes that appears to derive from the Bismarcks, and in particular from New Britain (Lipson et al. 2018; Posth et al. 2018). This later influx of Papuan ancestry presumably reflects the processes of "integration" that Green (1991b) included in his "Triple-I" model of Lapita.

Before leaving the topic of origins per se, it is worth commenting briefly on the supporting evidence of historical linguistics. The Mussau language, along with that of nearby Tench Island, forms a distinct St. Matthias group within the Oceanic subgroup of the widespread Austronesian family (Ross 1988; Blust 2013). It is still not clear whether this St. Matthias language group falls into a cluster together with the languages of the Admiralties (see Chapter 2). Regardless of Mussau's relationship to the Admiralty languages, however, the fact that it forms a distinct subgroup of Oceanic (and quite possibly a first-order subgroup) is significant in terms of the history of the Oceanic languages and their relationship to Lapita. As initially proposed by Pawley and Green (1984), and reiterated by Kirch (1997), Proto-Oceanic arguably was the language spoken by the initial Lapita communities in the Bismarck Archipelago. The differentiation of Proto-Oceanic into the several first-order subgroups of Oceanic (including the Mussau group) fits well with a model of the spread of Lapita from the Bismarcks into Remote Oceania (initially the southeastern Solomons and Vanuatu) and with the development of a *dialect chain* along this voyaging corridor, a chain that subsequently began to break at key links between island clusters.

The question of Lapita origins also subsumes the issue of the chronology of Lapita in the Bismarck Archipelago: when did Lapita first make its appearance, and in what form? Did the cultural complex have a long gestation period in the Bismarcks, prior to its expansion out of Near Oceania westward into the previously uninhabited islands of Remote Oceania? Anson (1986:164)—placing much weight on a single radiocarbon date obtained by Brian Egloff from the ECA site on Eloaua (see Chapter 1)—had suggested that such an "earlier Lapita period" in the Bismarcks had a duration of at least several centuries. The validity of this early date (upon which much rested in 1985) was a problem we specifically set out to tackle in 1985.

Based on the initial set of radiocarbon dates obtained from the Mussau excavations in 1985 and 1986, Kirch and Hunt (1988b) proposed that the earliest Lapita sites there dated to 3550–3450 BP. With additional dates and careful calibration, Kirch (2001b:213) later qualified this initial estimate, suggesting that the EHB site might date as early as 3550 BP, with the main phase of stilt-house occupation at Talepakemalai (ECA) dating to 3300–3100 BP, and with the shift to exclusively incised ceramics taking place between 3100 and 2800 BP. Over the past two decades, various authors have drawn upon the published Mussau dates as well as radiocarbon dates from other Bismarck Archipelago Lapita sites, to debate the chronological sequence for Lapita in the Bismarcks region (Denham et al. 2012; Rieth and Athens 2017; Specht 2007; Specht and Gosden 1997, 2019). Two studies in particular applied Bayesian modeling to the corpus of Bismarck Archipelago Lapita dates, putting the initial appearance of Lapita in Mussau at 3740–3250 BP (Denham et al. 2012), or at 3304–3177 BP (Rieth and Athens 2017). Most recently, Specht and Gosden argued for an even younger "possible start of Lapita pottery around 3250–3150 BP," based in part on new dates from the Arawe Islands, "which proved to be younger than expected and raise questions about the starting date for Lapita pottery in the Bismarck Archipelago as a whole" (2019:169, 187).

Neither Specht and Gosden (2019), nor the other authors who have recently reexamined Lapita chronology in Near Oceania, had the benefit of access to the new suite of 24 Mussau dates reported in Chapter 5. These new dates—all relatively high-precision AMS and most on short-lived taxa—when combined with the earlier corpus of 51 dates in a program of Bayesian modeling and calibration, permit a refined estimation of Lapita chronology in Mussau. The earliest Lapita site in Mussau—on the evidence of ceramic seriation as well as radiocarbon dating—is clearly EHB on Emananus. The three shell dates from EHB are very consistent (see Table 5.6), and while questions concerning the appropriate ΔR reservoir correction factor remain unresolved, these provide a modeled starting boundary range of 4413–3366 BP for the site. The modeled dates themselves are 3901–3361 BP (ANU-5088), 3865–3325 BP (ANU-5089), and 3847–3385 BP (UCIAMS-185995). To be sure, these are long time spans, and the site itself is unlikely to have been occupied for a long period. Accepting the present reservoir correction, however, it seems apparent that EHB was established not later than about 3350–3325 BP. The largely plainware Lapita occupation on the paleobeach ridge at ECA on Eloaua, as well as that at the EKE site on Boliu Island, probably overlapped with the occupation of EHB; the earliest deposits along the W200 and W250 transects at ECA can be assigned to the period from about 3300–3200 BP.

The main stilt-house occupations at ECA have been constrained by the new dates and Bayesian modeling to a span of approximately 3200–2950 BP. The Area B stilt house and the Zones C3–C2 deposits with numerous pedestal-footed bowls and fine dentate-stamped decoration have a Bayesian-modeled starting boundary of 3234–3089 BP and ending boundary of 3155–3020 BP. This time span accords closely with the latest "eyeballed" estimate (i.e., not making use of Bayesian modeling) of Specht and Gosden (2019) of 3250–3150 BP for similar Lapita materials at the Makekur site in the Arawe Islands.

The ceramic assemblage recovered from Zone C1 at ECA Area B evidences substantial changes in Lapita pottery, including decreased frequency of fine dentate stamping along with increases in coarse dentate stamping and incising, and declines in the frequency of pedestal-footed vessels and bowls accompanied by increases in the frequency of jars and flat-bottom dishes. The time frame for these changes has a Bayesian-modeled starting boundary of 3061–2836 BP and ending boundary of 2919–2724 BP. Further transformations in the Lapita ceramic complex are evident in the Area C assemblage, with an almost complete lack of dentate stamping and dominance of incised decoration. This final phase of occupation at Talepakemalai is bracketed by a Bayesian-modeled starting boundary of 3154–2970 BP and ending boundary of 2778–2492 BP.

Based on our enlarged set of radiocarbon dates combined with Bayesian modeling, the entire Lapita sequence in Mussau now appears to span a period of between 650 and 500 years. It begins with the emplacement of the EHB site on Emananus Island, and likely contemporaneous plainware sites on Eloaua (ECA Area A) and Boliu (EKE), followed by a period of two to three centuries when the main stilt-house village at ECA was in use. The sequence ends with the late ECA Area C occupation, by which time the ceramic complex had been so completely transformed that it would not even be recognized as "classic" dentate-stamped Lapita. Recent work by others has also placed the initial expansion of Lapita populations out of the Bismarck

Archipelago and into Remote Oceania as having occurred at around 3000 BP (Sheppard et al. 2015), or toward the later part of the main occupation phase at Talepakemalai (equivalent to Zones C1–B2 at Area B of site ECA).

Soon after the Lapita Homeland Project was completed, Roger Green (1991b) advanced his well-known "Triple-I Model" of Lapita origins, in which *intrusion*, *innovation*, and *integration* were proposed as the three processes by which Lapita emerged as a distinctive cultural complex. Our Mussau Project findings, bolstered by more recent contributions (especially of the sequencing of aDNA from Remote Oceanic Lapita individuals), all point to the intrusion of a biologically Southeast Asian group of people around 3350–3325 BP, who emplaced small settlements on Emananus, Eloaua, and Boliu islands. Linguistically, these people would have been speakers of Proto-Oceanic, a branch of the larger Austronesian language family. They brought with them the art of ceramic production, making a variety of vessels whose forms were derived from an older Island Southeast Asian pottery tradition. These initial Austronesian settlers in Mussau were likely part of a larger stream of immigrants into the Bismarcks, who rapidly explored and who also established settlements in the Admiralty Islands, at points around the coasts of New Britain and New Ireland, and on other small islands in the region. The processes of innovation and integration that Green also identified would have taken place over the course of the following three centuries, as the Austronesian immigrants interacted with and borrowed from the indigenous Papuan populations already resident in the Bismarck Archipelago. The outcome by 3000 BP was a fully developed Lapita cultural complex poised to expand eastward into Remote Oceania.

Lapita Economy

Prior to the Lapita Homeland Project, Lapita faunal analyses had almost exclusively focused on sites in Remote Oceania; even then, inconsistency in methods of recovery and analysis made inter-site comparisons difficult (Butler 1988; Nagaoka 1988). Green (1979a) noted abundant evidence for shellfish gathering and fishing at Lapita sites both in Western Polynesia and in the Reef-Santa Cruz Islands, but admitted to having to fall back on such indirect indications as site location and the presence of domestic animals such as pig and chicken to make the case that the Lapita economy also included horticulture. This shortage of direct evidence for plant cultivation made it difficult to entirely rule out Groube's (1971) hypothesis that the initial Lapita colonizers of Remote Oceania had been "strandloopers" who moved rapidly from island to island, exploiting rich marine resources and perhaps also seabirds. Of course, to the extent that one was willing to accept the argument that Lapita people had been speakers of the Proto-Oceanic language—and thereby adduce the extensive linguistic evidence for early Oceanic crop plants and horticultural techniques—the case for Lapita horticulture seemed fairly robust. But not all archaeologists in the Pacific have been so open to working holistically between academic disciplines; indeed, some continue to insist on privileging strictly archaeological evidence (e.g., Specht et al. 2014:119).

In the years since our Mussau excavations were carried out, most work on Lapita subsistence has focused on sites in Remote Oceania, rather than in the Near Oceanic region of the Bismarck Archipelago. In addition to traditional zooarchaeological analysis of midden assemblages, this has included new approaches such as isotopic analysis of human diet (Kinaston et al. 2014) and extraction of phytolith and starch grains from dental calculus (Tromp 2016), particularly from the Teouma site in Vanuatu. These studies have added to the evidence that colonizing Lapita populations in Remote Oceania were horticulturalists who brought crop plants with them, while continuing to exploit natural resources, both terrestrial (such as tortoises in Vanuatu, Hawkins et al. 2016) and marine. For Lapita in Near Oceania, however, the only significant contribution to our understanding of its subsistence base has been that for the Kamgot site on Anir Island (Summerhayes et al. 2019). Summerhayes and others write that the Kamgot evidence reinforces Kirch's (1997) perspective on Lapita's "transported landscapes" (Summerhayes et al. 2019:398), summarizing Lapita subsistence at Kamgot as follows: "These early colonists cleared gardens they created for taro, yam and bananas, and the nut-bearing trees that provided a ready supply of food. They introduced animals such as dog and pig, and they utilized the outer reef resources as evidenced from the earliest Lapita levels" (2019:398).

The evidence reported in this volume, in Chapters 6 through 10, significantly enhances our understanding of Lapita subsistence in Near Oceania. The substantial assemblages of invertebrate fauna (2.47 metric tons of mollusk analyzed), vertebrate fauna (56,034 NISP), and anaerobically preserved plant remains (7,926 NISP) from Talepakemalai and other Mussau sites constitute the most extensive and diverse set of such materials from any Lapita sites in the Bismarck Archipelago, providing abundant direct evidence for a dual maritime-horticultural economy. The sophisticated range of strategies both for exploiting the resources of reefs, lagoons, and the open sea, and for cultivating a wide range of annual and perennial crops on land, testifies to both the innovation and integration components of Green's Triple-I model of Lapita. They also mesh extremely well with historical linguistic reconstructions of Proto-Oceanic—and thereby inferred Lapita—economic life, including an extensive vocabulary of words for crop plants and horticultural techniques (Ross et al. 2008, 2011).

The biodiversity of the inshore and marine environments of New Guinea and the Bismarck Archipelago ranks among the highest anywhere in the world, an aspect of the natural environment that must have been attractive to humans arriving on the shores of Mussau's islets in the later second millennium BC. More than 100 species of mollusk are represented in our faunal assemblages, although a relatively small number of these contributed the bulk of the shell midden (among these are the gastropods *Lambis lambis/L. chiragra* and *Strombus luhuanus*, and the bivalves *Andara antiquata*, *Chama* sp., and *Hyotissa hyotis*). The sheer density of shell midden in the Talepakemalai site is staggering, some 27.9 kg/m^3 at Area B. At ECA Area C the density is much lower, but even at 6.3 kg/m^3 this is an impressive quantity of mollusks. While most of these mollusks were presumably gathered for their edible meat, some, such as the large cone shells *Conus leopardus* and *C. litteratus*, as well as the top shell of *Trochus niloticus*, were important as raw material for the manufacture of shell artifacts including rings and fishhooks. In spite of continuous exploitation of the Mussau reefs and lagoons over several centuries, there is no evidence that human predation pressure led to significant impacts on the mollusk populations. The minor temporal shifts that are evident are more readily attributed to habitat changes, such as that resulting from the mid-to-late Holocene drop in sea level and exposure of tidal flats (see Chapter 9). The Lapita population of southwest Mussau appears to have exploited these reefs and lagoons sustainably, thanks to the sheer extent and high biomass of the surrounding reefs and lagoons.

Gathering of mollusks, crustacea, or seaweeds required no sophisticated material culture (other than baskets or bags to hold the take), but in the case of fishing several kinds of gear and fishing strategies are evident. Fishhooks recovered at Talepakemalai and the other Mussau Lapita sites include small angling hooks presumably intended for taking smaller reef fish, as well as larger hooks that were likely employed by handline from canoes, in search of larger, benthic fishes such as groupers (Serranidae). The presence of net weights along with the bones of substantial numbers of herbivorous taxa that normally do not respond to hooks indicates the use of netting strategies. Spearing was also likely employed. Of particular interest are the trolling lures, confirming that trolling for prized offshore carnivores such as scombrids (tunas) was a strategy already developed by the early Lapita people. Although not abundant, the bones of scombrids are present in our faunal assemblages (see Chapter 7). The Mussau trolling lures, made of a single piece of *Trochus* shell, provide early prototypes for two-piece trolling rigs that were elaborated later in Remote Oceania.

Butler's analysis of the fish faunal assemblages was constrained for the most part to a family level of identification, due to the high species-level diversity and lack of comparative reference material for the hundreds of potential taxa present in the Bismarcks region; nonetheless, Butler documented a wide range of fish taken by Lapita fishers in Mussau (Chapter 7). Some 27 families of fishes are represented in the 4,687 NISP of fishbones identified, including inshore herbivores and omnivores, inshore carnivores, and offshore carnivores. Butler's analysis demonstrates strong consistency in the fish being caught across both sites and temporal periods. Rather than "opportunistic" fishing as has recently been suggested for some Oceanic fisheries (Cannon et al. 2019), Butler argues that the fish faunal assemblage from Mussau speaks to a range of fishing strategies that consistently targeted particular taxa, based on extensive ecological knowledge. Historical linguistic evidence again offers independent confirmation, with lexical reconstructions for more than 60 folk taxonomic categories of fishes in the Proto-Oceanic lexicon, the language spoken by the early Lapita people in the region (Ross et al. 2011).

Aside from fishing and shellfish gathering, the Mussau Lapita people captured large numbers of sea turtles (*Chelonia mydas*); prior to Lapita arrival on these shores it is likely that large turtle populations seasonally laid their eggs in the beach sands of Eloaua, Emananus, and the other offshore islets. The effects of continued exploitation of these creatures may have led to diminished numbers later in time, as turtle bones are not common in the post-Lapita sites.

An unexpected aspect of the vertebrate faunal record at Talepakemalai and other Lapita sites in Mussau is the prevalence of two or possibly more species of porpoise (the melon-headed dolphin and Risso's dolphin), which make up roughly 10% of the non-fish vertebrate fauna at ECA. How these large marine mammals were captured is not clear, although it could have been either by driving them into large nets, or possibly by spearing. Significant numbers of porpoise bones at Area B in site ECA may be an indication of feasting, a topic further addressed later in this chapter (see Lapita Society).

There is also evidence for limited hunting of wild terrestrial food resources. The spotted cuscus (*Spilocuscus maculatus*) was occasionally taken, as well as some medium-sized lizards. Seabirds are represented by seven species, mostly larids; there are also ten species of landbirds in the faunal assemblage. Some birds, such as a *Ducula* sp., may have been taken primarily for their plumage. Of particular interest, from Talepakemalai, is the Nicobar pigeon (*Caloenas nicobarica*), which ethnographically was known to have been raised in a semi-domesticated fashion on Tench Island, some 100 km east of Mussau.

Three domestic animals are widely associated with Austronesian-speaking peoples: the pig (*Sus scrofa*), dog (*Canis familiaris*), and jungle fowl or chicken (*Gallus gallus*). There is robust historical linguistic evidence for both the pig (Proto-Oceanic **boRok*, 'pig') and the jungle fowl (Proto-Oceanic **manuk*, 'fowl,' **kokorako*, 'rooster') (Ross et al. 2011:238, 284–285) having been kept by Proto-Oceanic speakers. The evidence for dogs is more equivocal; no Proto-Oceanic term for 'dog' can be reconstructed with confidence (2011:240). Specht and others (2014:113, 115), in a review of Lapita subsistence, claim that "evidence for the presence of pigs in the Early Lapita phase is ambiguous," and that the presence of dogs "in Early Lapita contexts is arguable." This negative assessment of the evidence for domestic animals in early Lapita contexts can now be put to rest, on the basis of evidence both from Mussau and from the Kamgot site (Summerhayes et al. 2019).

Pigs, dogs, and jungle fowl are all represented at Talepakemalai, while chicken is also present at ECB. Pig bones occur at all of the Mussau Lapita sites (see Table 6.1). While pigs were undoubtedly part of the Mussau domestic economy in Lapita times, they were not abundant, and contributed only a minor component to the diet, along with their tusks being used as ornaments. In the post-Lapita sites, in contrast, pig bones are present in much greater numbers, corresponding with ethnographic accounts of pigs being the main domestic animal in Mussau (Nevermann 1933:68). While dogs are represented by only six specimens from ECA, these are in secure contexts (particularly one bone from Zone C3 of Area B); dogs have also been reported from the Komgat Lapita faunal assemblage on Anir Island (Summerhayes et al. 2019), reinforcing the evidence from Mussau that dogs were indeed present in early Lapita contexts in the Bismarck Archipelago, contrary to the claim of Specht and others (2014).

One of the most remarkable finds at Talepakemalai was the abundant presence of anaerobically preserved seeds and other macroscopic plant parts that provide unambiguous evidence for Lapita arboriculture or tree cropping (Kirch 1989), evidence that was partially matched by similar finds at the waterlogged Arawe Islands Lapita sites on New Britain (Matthews and Gosden 1997). Topping the rank-ordered list of taxa is *Canarium indicum*, followed by coconut (*Cocos nucifera*), *Pangium edule*, *Spondias dulcis*, *Dracontomelon dao*, *Inocarpus fagifer*, and *Pandanus* spp., all important tree crops with edible fruits or seeds. Although present in lower frequencies, also notable are *Burckella obovata*, *Corynocarpus cribbianus*, *Dracontomelon dao*, *Pometia pinnata*, and *Terminalia catappa*. The presence of a *Syzigium* sp., possibly *S. malaccense*, is indicated by preserved wood. This assemblage of edible tree crops, along with other taxa with industrial uses, leaves no doubt that arboriculture was a significant component of the Lapita economy in Mussau. Given considerable archaeobotanical evidence for pre-Lapita domestication and use of these tree crops in Near Oceania (Specht et al. 2014), it appears likely that the initial Austronesian-speaking immigrants to Mussau and the Bismarcks encountered local populations already cultivating these tree crops. This arboricultural aspect of the Lapita cultural complex can therefore be ascribed to the *integration* component of Green's (1991b) Triple-I model.

There is strong reason, however, to believe that the Mussau Lapita gardeners planted more than tree crops, based on the abundant presence of both pearl-shell peeling knives and cowrie-shell scrapers at Talepakemalai and other sites (see Chapter 13). The peeling knives would have been effective for removing the inedible outer skins of taro or other aroids (*Colocasia*, *Alocasia*, *Cyrtosperma* spp.) as well as of yams (*Dioscorea* spp.), while the cowrie-shell scrapers could have been used for scraping tubers and/or preparing breadfruit (*Artocarpus altilis*) for cooking. Words for *Colocasia* taro (**talo*), the greater yam (**qupi*), *Alocasia* taro (**piRaq*), and breadfruit (**kuluR*) are all well attested in the Proto-Oceanic vocabulary (Ross et al. 2008), reinforcing our interpretation of the use of these implements for preparing the tubers and fruit and of these crops.

The rich faunal and archaeobotanical assemblages from Talepakemalai and other Mussau Lapita sites, along with the evidence provided by material culture such as fishing gear and food preparation tools, contribute to a robust picture of the early Lapita economy as one well adapted to a tropical island ecology, drawing equally upon exploitation of rich inshore and marine resources and on perennial tree and annual root crops. The three domestic animals well known to be associated with Austronesian peoples—the pig, dog, and jungle fowl—were also part of this economic base. To those trained in the classic holistic tradition of anthropology in which historical linguistic evidence is accorded equal value to the archaeological record, it is reassuring that this archaeologically based reconstruction of Lapita economy meshes extremely well with the extensive linguistic evidence from the Proto-Oceanic lexicon (Ross et al. 2008, 2011).

Long-Distance Exchange

In his pioneering excavations of Lapita sites in the Reef-Santa Cruz Islands of the southeastern Solomon Islands, Roger Green recovered obsidian flakes that he immediately recognized as long-distance imports. Collaborating with Wal Ambrose, Green determined that the source of this obsidian was Talasea in New Britain, a distance of some 2,000 km (Ambrose and Green 1972; Green 1974a). This astonishing discovery put the topic of long-distance exchange at the forefront of Lapita studies, where it has remained for many decades (e.g., Sheppard 1993; Specht 2002; Summerhayes 2003, 2004, 2009, 2010). Moreover, it was the presence of materials such as the New Britain obsidian, metavolcanic (green stone) adzes, and a kind of schistose "glitter" in the Reef-Santa Cruz sites that prompted Green to propose that the Bismarck Archipelago had been the probable homeland region in which the Lapita cultural complex emerged (Green 1979a).

Our own efforts in the Mussau Project to define the Mussau Lapita exchange system and understand how this evolved over time have encompassed detailed analyses of ceramics (Chapter 11), ceramic temper or non-plastic inclusions (Chapter 12), obsidian (Chapters 14 and 15), manuports (Chapter 17), and shell artifacts (Chapter 13). What emerges is only an incomplete portrait of a very complex system, one that was constantly reconfiguring itself. That the portrait of this elaborate exchange network remains incomplete is due to at least two limitations. First, the archaeological record of exchange is restricted to certain durable, material objects that have survived the vagaries of time and preservation. Based on what we know of ethnographically documented exchange systems in Oceania, other kinds of perishable materials (foodstuffs, mats or other woven objects, etc.) were likely also involved but have left no material traces. Second, the Bismarck Archipelago is geologically complex and diverse, yet incompletely described or understood. Thus while we can *characterize* the diversity in a range of ceramic temper types, obsidian, or imported rocks, tracing these to specific *sources* is unfortunately still often not possible.

Keeping these caveats in mind, we can briefly review the material evidence for long-distance exchange in Mussau, beginning with the pottery. The offshore islands of Mussau are of exclusively coralline geology, lacking either the clay or terrigenous sand temper necessary to produce ceramics. Thus all of the Lapita ceramics (or at least the raw materials for their manufacture) must have been imported to the offshore islands, with the closest sources of these raw materials situated on the main island of Mussau. Energy-dispersive X-ray microanalysis of the clay fabric in 175 sherds from

Talepakemalai (ECA Areas A and B), ECB, EHB, EKQ, and EKU, carried out by Hunt (1989), identified 16 discrete clusters representing as many potential clay sources (see Chapter 11). One cluster was linked to a known clay source on Mussau Island, and two other clusters to known potting clay sources in the Admiralty Islands (Mbuke and Hus). The remaining 13 clusters all represent other discrete clay sources that could have been located anywhere in the Bismarcks region. While this analysis did not pinpoint clay sources other than on Mussau and in the Admiralties, it did reveal the high diversity of clay sources represented in the Mussau ceramic assemblage. Area B at Talepakemalai and site ECB have the greatest numbers of clay sources represented, with 11 and 12 clay groups respectively. The Mbuke clay source in the Admiralties is represented by sherds from Area A at ECA, ECB, and EKQ, suggesting that this source continued to be important over a considerable time period. The Hus source, in contrast, is represented only at the post-Lapita EKU site.

Dickinson's petrographic analysis of the non-plastic inclusions in a sample of 61 sherds from Talepakemalai (ECA Areas B and C) and EHB revealed a similar pattern of diversity in temper sources (see Chapter 12). The greatest temper diversity occurs at Area B of Talepakemalai, with nine discrete temper groups represented; Area C has five temper groups, four of which are also found at Area B, and one which is unique to Area C. Site EHB has four temper groups, all of which are also present at ECA Area B. Given our incomplete knowledge of the geology of the Bismarck-New Guinea region, it is not possible to define specific source areas for these temper groups. However, Dickinson points to probable sources in the Admiralty Islands (Manus), New Ireland and its offshore islands (the Lihir group), New Britain, and even on the New Guinea mainland.

Taken together, Hunt's analysis of clay and Dickinson's analysis of temper confirm a pattern of initial high diversity in sources of pottery imported to Mussau in the earlier Lapita period, followed by a reduction in diversity by the late Lapita period (Table 18.1). Importing of pots from the Admiralty Islands seems to have occurred throughout prehistory (including during the post-Lapita period), but other sources are surely also indicated, even if we cannot at present pin them down to specific geographic locales.

Table 18.1. Characteristics of Mussau exchange in Early Lapita, Late Lapita, and Post-Lapita Periods

Variable	Early Phase (ca. 3200 BP)	Late Phase (ca. 2800 BP)	Post-Lapita Phase (ca. 800 BP)
Imports	Pottery: 9 temper groups, 12 clay groups; Mbuke source in Manus plus other unknown sources in Bismarcks region Obsidian: 6 sources (2 New Britain, 4 Admiralties) Manuports: 17 types from multiple sources Chert Metavolcanic adzes	Pottery: 5 temper groups, reduced diversity Obsidian: 5 sources (1 New Britain, 4 Admiralties)	Pottery: 3 clay groups, low frequency, primarily from Manus (Hus source) Obsidian: Admiralties only
Exports	Shell valuables and fishhooks	Limited shell valuables?	Pigs?
Magnitude	High volumes of pottery and obsidian imported; high volumes of shell artifacts exported	Greatly reduced volumes of imports; export volume low or nonexistent	Very small quantities of materials imported; exports unknown
Diversity	Greatest	Reduced	Least
Network size	Large number of participating nodes	Reduced number of nodes	Restricted to Manus and possibly New Ireland
Directionality	Multiple flows both in and out of Mussau	Reduced directionality	Restricted flow from Manus to Mussau
Centralization	Not centralized	Not centralized	Highly focused on Mussau
Complexity	High	Reduced	Simple

Aside from ceramics, another significant import to Mussau throughout the Lapita period was obsidian, obtained from two source regions in the Admiralty Islands (with four specific sources within this island group) and at Talasea on New Britain (with two specific sources). While obsidian from both regions was imported to Mussau in both early and later Lapita periods, the geographically closer Admiralties sources were always more frequently represented. The presence of obsidian from particular sources also changed over time, with the Baki source at Talasea present only in the earlier Lapita period (see Chapter 15). In the post-Lapita sites, only the Admiralties sources are represented.

The quantity of obsidian imported to Mussau also varied over time. The early EHB site has a density of 42.6 flakes/m^2, Area A at Talepakemalai has a density of 77.3 flakes/m^2, and Area B has a density of 86.2 flakes/m^2, suggestive of an increase in the quantity of obsidian imported from the early to middle Lapita phases. At ECA Area C, however, the density drops to just 25.7 flakes/m^2, indicative of a decrease in the volume of imported obsidian.

A third category of materials imported to Mussau consists of manuports, unmodified stones of various sizes that do not naturally occur in the coralline geological context of the offshore islets, and therefore had to have been brought to the islands intentionally. Our excavations yielded 120 of these manuports, and 60 of these were petrographically examined by Dickinson (see Chapter 17). His analysis revealed a wide variety of rock types, including intrusive plutonics, basalts, andesites, diorites, altered volcanics, sandstone, and metamorphic slate. Some of the intrusive plutonics match geological control samples from main Mussau Island, but most of the other rocks probably derived from elsewhere in the Bismarck Archipelago. As with the terrigenous pottery tempers, we are not able to identify specific source areas, but multiple locales are indicated.

A handful of other objects can also be identified as imports. These include some flakes of siliceous chert, flakes of a greenish metavolcanic stone, and flakes of basalt or other metavolcanics. In addition, at Talepakemalai we recovered two partial adzes of a greenish fine-grained stone, possibly metamorphic sandstone (see Chapter 13).

With pottery (and/or the raw materials for ceramic production), obsidian, manuports, and miscellaneous objects such as metavolcanic adzes and chert flowing into Mussau from other locales dispersed around the Bismarck Archipelago, what exports may have balanced the exchange equation? There is a range of possibilities, including turtles, birds' feathers, and woven mats or similar objects, about which one could endlessly speculate. There is one category of objects, however, for which we do have good empirical evidence: the manufacture of shell "valuables," particularly large rings made from the spires of *Conus litteratus* and *C. leopardus* (see Chapter 13). There is abundant evidence from Talepakemalai that these objects were being produced in substantial numbers during the earlier phase of occupation represented by the deposits at Areas A and B and the adjacent portions of the W200 and W250 transects. The differential representation of *Conus* spires (used to make the rings) versus rejected bases provides evidence that roughly half of the finished objects were exported out of Mussau. A "back-of-the-envelope" calculation suggests that between 100 and 200 such large cone-shell rings could have been manufactured each year at Talepakemalai over a time span of perhaps two centuries.

The manufacturing detritus of shell ring production declines markedly in the later period deposits at Talepakemalai. Only a limited amount of worked *Conus* shell was found in the vicinity of Area C, indicating that the production of shell valuables was no longer a major activity at the site by the late Lapita period.

The changing nature of the long-distance exchange networks in which the Mussau communities participated is summarized in Table 18.1, in terms of early versus late Lapita and post-Lapita time periods. The table draws upon a set of variables originally defined by Plog (1977), which are useful for thinking about the nature of long-distance exchange networks. While collapsing several centuries of Lapita exchange interactions into "early" and "late" periods risks essentializing these categories, the approach is heuristic in pointing to the major changes that occurred over the course of this time span. Early Lapita exchange in the Bismarcks—as viewed from the perspective of Mussau—was highly complex and diverse, decentralized with multiple nodes, and had high volumes of imports and exports. Ceramics from twelve or more source areas, obsidian from two regions and six subsources, manuports from multiple sources, chert, and metavolcanic adzes are among the imports to Mussau in the earlier time period. Known exports included a high volume of shell valuables of various types, especially cone-shell rings, and possibly also fishhooks. By the late Lapita period (represented by Area C at ECA and by EKQ) this exchange network had become much less complex and diverse, still decentralized but with a reduced number of nodes, and a greatly reduced magnitude of imports and exports. Ceramics were now imported from just five sources, while most of the obsidian was coming from the Admiralty Islands. There is only limited evidence for shell-valuable production and likely very little, perhaps even no, export of these items out of Mussau.

Unfortunately, the present gap in the Mussau archaeological record from around 2700 BP to 1200 BP does not allow us to trace the continued evolution of exchange during this period, but we pick up the record again in the period after 1200 BP up to the ethnographic present. In this late, post-Lapita period long-distance exchange seems to have been almost exclusively between Mussau and the Admiralties, although some contact with New Ireland is possible. Small quantities of ceramics were imported from Manus (the Hus source is indicated), along with some obsidian. What items might have balanced this flow from Mussau to Manus is not known, although given the evidence for intensive pig husbandry in Mussau, the export of pigs is one possibility. In any case, by this late post-Lapita period the exchange network was very much simplified, reduced in its scale and number of nodes, with only a modest quantity of goods moving between Mussau and Manus.

Lapita Society

The issue of Lapita social organization follows logically from that of long-distance exchange. Jonathan Friedman some time ago proposed that early Oceanic societies were organized as “prestige-good systems” characterized by, among other things, generalized exchange and a “monopoly over prestige-good imports that are necessary for marriage and other crucial payments, i.e., for the social reproduction of kin groups” (1982:184). Certainly the evidence for complex long-distance exchange that includes a considerable emphasis on a variety of specialized shell valuables lends material support for Friedman’s hypothesis. It has also been suggested that early Oceanic societies—as with Austronesian societies more generally—were organized as what have been termed “house societies,” deriving from Claude Lévi-Strauss’ proposal of the *société à maison* (1982) and subsequently widely applied by ethnographers of Austronesian societies (e.g., Carsten and Hugh-Jones 1995; Fox 1993; Fox and Sather 1996; Kirch 1996; McKinnon 1991; Waterson 1990, 1993, 1995). In such a house society, the fundamental social unit is a group of people who affiliate to a “house” that endures through time, carries a proper name, is associated with an estate of land, and has its own prerogatives and rituals. Kirch (1997:132–144, 188–191) proposed that the Lapita peoples ordered their social world around such “houses” in which ancestors played a central role, with the anthropomorphic representations displayed on early Lapita pottery linked to a cult of ancestors. Chiu (2003, 2005) likewise employed the house society construct in her analysis of the probable meanings of the motifs on Lapita pottery. Kirch and Green (2001) argued that Ancestral Polynesian Society, which developed out of the eastern branch of Lapita in the Tonga-Samoa region in the late first millennium BC, had a well-developed “house society” system of social organization and residence.

To what extent does the archaeological record from Mussau support these hypotheses, or otherwise expand our understanding of Lapita society? First, from the spatial scale of the Lapita settlements in Mussau, it is evident that social groups were relatively small. The early EHB site is only about 1,000 m^2 in area, while the ECB site occupies about 3,000 m^2. These small settlements were clearly “hamlets” with no more than a few houses. Talepakemalai or ECA covers a much larger area, at least 82,000 m^2, but not all of this was occupied contemporaneously. The maximum spatial extent of the stilt-house village at Talepakemalai during the earlier Lapita period cannot have been larger than about 50,000 m^2. This may be considered a “village” rather than a “hamlet,” but nevertheless would accommodate only a few “houses” in the sense of social units.

During the earliest Lapita phase in Mussau, the settlement pattern was one of several dispersed small hamlets, on Emananus, Eloaua, and Boliu islands (and perhaps on other islets as well), each most likely the locus of a single social group. The EHB site, however, stands apart among these small hamlets, for it is the only site of this early phase to have a high frequency of decorated pottery. In contrast, the paleobeach ridge hamlet at Talepakemalai and the

EKE hamlet on Boliu Island are dominated by red-slipped plainwares. This suggests that EHB may have had a special function, possibly as a locus for ritual or aggregations of some kind, possibly by the collective occupants of all of the small hamlets dispersed around the offshore islets of Mussau.

By the time of the main Area B occupation at Talepakemalai, a somewhat larger village had developed, with stilt houses arrayed over the shallow reef flat along the Eloaua Island shore. The stilt house at Area B, however, again stands out in several ways. Not only does it have an unusual concentration of particularly finely decorated pottery (including vessels with anthropomorphic faces, pedestal-footed vessels, cylinder stands, etc.), but also a high concentration of shell valuables as well as imported obsidian. Human cranial fragments and long bones suggest that ancestral skeletal remains were kept in the house, possibly in some of the ceramic vessels; excavations at the Teouma cemetery site in Vanuatu have shown that the early Lapita colonists in Remote Oceania used ceramic vessels as funerary containers (Bedford et al. 2006). The unique anthropomorphic bone sculpture (Figure 13.63) and the ceramic drum from Area B are both objects likely to have been associated with ritual activities. The faunal remains from Area B are also noteworthy, with a high concentration of mollusks, turtle and porpoise bone, and distinctively large parrotfish (*Bolbometopon* sp.), all of which are suggestive of feasting. It seems, then, that the Area B stilt house may have replaced the earlier EHB site as an aggregation center for the Lapita community in Mussau, a setting for ritual activities and periodic feasting in association with the keeping of ancestral remains.

While we are moving into more speculative terrain here, it is not unreasonable to suggest that the ritual activity at that Area B stilt house was focused around some form of ancestor cult. The pottery itself, of course, offers some of the strongest evidence that the Lapita people placed some emphasis on the veneration of ancestors, including their skeletal remains, which as we know from the Teouma site were kept or buried in ceramic containers (Bedford et al. 2006; Valentin et al. 2011). The anthropomorphic faces on Lapita pottery, especially on pedestal-footed bowls, flat-bottom dishes, and cylinder stands, arguably depicted or represented ancestors, or possibly ancestral skulls as Spriggs (2019) has recently suggested. As I pointed out some time ago, "a fundamental characteristic of 'house societies' is the worship or ritual recognition of ancestors, who are often depicted iconically through anthropomorphic representations in which the face is central" (Kirch 1997:144). In many Austronesian societies, representations of ancestors are carved on house posts; this might have been the case in Lapita houses as well, though no examples have been preserved. Another striking motif present in the Mussau ceramic assemblage from Area B is what we have termed the "double long-beaked bird" (see Chapter 11), which appears as a secondary motif ornamenting the rims and bases of many of the elaborate pedestal bowls that also carry human face motifs. Could this be the representation of a totemic bird, the symbol perhaps, of a particular "house" or clan? Chinnery (1925:205–206) reported that Mussau society was divided into two exogamous clans, the E Veli clan with the *valusu* pigeon as its totem, and the Saitalai clan with the *sava* eagle as its totem. Could this two-clan system with avian totems trace its roots back to Lapita? We will probably never know for certain, but it is an intriguing hypothesis.

An unexpected find at Talepakemalai was that of several anaerobically preserved stems of the wild kava plant *Piper wichmanii*, from which the domesticated form *Piper methysticum* was later derived, putatively in Vanuatu (Lebot and Levesque 1989). Ross and others (2008:396) reconstruct a Proto-Oceanic word **kawaRi*, which they argue applied to certain "potent roots" including *P. wichmanii*, *Zingiber zerumbet*, and various fish poison plants. The *P. wichmanii* stems at Talepakemalai are significant as the earliest indication in the archaeobotanical record of experimentation with this psychoactive plant, which later would become of widespread ritual importance in Oceania.

It is tempting to imagine a scene of ritual activity at the Talepakemalai Area B stilt house sometime in the late second millennium BC, cult leaders possibly in trance states induced by the consumption of kava, surrounded by elaborate ceramic vessels holding the remains of ancestors, and accompanied by the rhythmic beat of ceramic drums. The scene would have been followed by communal feasting on shellfish, turtles, porpoise meat, and large *Bolbometopon* parrotfish. We can envision further that such occasions may also have witnessed the ritualized exchange of valuables with visiting parties who had sailed to Mussau from other Lapita communities in the Bismarck region. But we have now crossed over from historical reconstruction to the realm of speculation, even if that speculation is prompted by threads of material evidence.

The Late Transformation of Lapita

By 2800–2700 BP, major changes had taken place, transforming the local Mussau culture in ways that make it almost unrecognizable as Lapita. Certainly that is true of the pottery, for if Lapita is classically defined by the presence of dentate-stamped ceramics, then the late assemblages at ECA Area C and in the EKQ rockshelter stand out with their very small numbers of dentate-stamped sherds. Rather, these assemblages are dominated by pottery decorated with fine incised lines, or by notching or pinching of the jar rims. But change was not limited to the decoration, for the vessel shapes were now largely limited to thin-walled globular jars with restricted necks and everted rims. Gone were the elaborate bowls on pedestals, the large carinated jars, the flat-bottom dishes, and the cylinder stands that had been such prominent components of the ceramic complex just three to four centuries earlier. Of course, these changes did not happen suddenly; we can see the shift in emphasis from dentate stamping to incising occurring in the sequence at ECA Area B, as well as the changes in frequency of vessel forms.

Based on other research subsequent to the Lapita Homeland Project, these changes in the Mussau ceramic complex were precursors to similar transformations in other local ceramic sequences in the Bismarck Archipelago. Garling's work in the Tanga Islands (Garling 2003, 2007; Cath-Garling 2017), part of the chain of islands lying off the northeast coast of New Ireland, documents a "transitional" ceramic tradition characterized by globular jars with everted rims and decorated with both incising and applied relief. Garling's radiocarbon dates, however, point to a time period of around 2250–2050 BP for these assemblages, somewhat later than the ECA Area C and site EKQ assemblages. Similar assemblages with incised and/or applied relief decoration are known from the Lasigi, Lossu, and Fissoa sites on New Ireland, these again dating to the late first millennium BC (Cath-Garling 2017, Table 2.1; Golson 1991, 1992; White and Downie 1980).

Other changes during the late Lapita period in Mussau were those affecting long-distance exchange, as has been discussed previously. In addition to the simplification of the exchange network at this time, of particular note is the decline in the production and use of shell valuables. Exchange relations appear to have become more narrowly focused on the Admiralty Islands during this later period, setting the stage for close connections between these two island groups that would continue down to the ethnographic present.

Other aspects of the archaeological record, in contrast, show little or no evidence of changes from early to late Lapita. The settlement pattern remained one of stilt houses in small hamlets over the reef flat, with some use of rockshelters. The subsistence system also appears to be quite stable, with continued marine exploitation and fishing combined with horticulture dominating the economic base.

It is regrettable that in spite of three seasons of intensive fieldwork on the offshore islets, we were unable to locate any sites to fill in the temporal gap between approximately 2700 and 1200 BP; it seems entirely possible that the offshore islets were actually abandoned during this period, although that would need to be confirmed with further field studies. When we do pick up the Mussau archaeological record again beginning around 1200 BP and continuing to the European-contact period, we find that a number of additional changes had also occurred. For one, pottery appears no longer to be manufactured locally in Mussau; the limited ceramics present (such as at site EKU) are imports, primarily if not exclusively from the Admiralty Islands. The late-period, post-Lapita sites also exhibit several major changes in material culture, notably the abundant presence of adzes made from the ventral margins of *Tridacna* shells and from *Terebra* shells. There are also substantial numbers of *Trochus*-shell armrings, but none of the other kinds of shell valuables that were present in Lapita times.

These late sites also exhibit changes in the subsistence system. While both shellfish gathering and fishing continued, neither porpoise nor turtle are now common in the midden deposits. Rather, pig bones become very frequent, signaling an intensification of pig husbandry and the importance of pig exchange and feasting in pre–European contact Mussau society.

Concluding Remarks

The 1985–1988 fieldwork in Mussau uncovered what is still one of the most extensive and diverse archaeological records of the Lapita cultural complex. This record spans the period from initial arrival of Proto-Oceanic speakers bearing their island Southeast Asian pottery, through several centuries of interaction with other communities around the arc of the Bismarck Archipelago, combined with local innovations, to a late phase in which several aspects of the Lapita culture—most notably the pottery—were significantly transformed. That it would take more than three decades to complete the analysis of the rich material finds recovered during three seasons of excavation and survey, and to bring our project to its proper conclusion in this monograph, was certainly not anticipated at the outset. During the years that have passed, however, our collective understanding of Lapita and its significance for Oceanic history and anthropology have evolved and become more nuanced. At periodic Lapita conferences, we have debated the chronology of the cultural complex, the meaning of Lapita iconography, the various models that have been advanced to account for Lapita exchange, the question of whether Lapita dispersal "leapfrogged" over the main Solomon Islands, and many other topics (Kirch 2019). If there is a silver lining to the long delay in bringing the rich Mussau materials to final publication, it is that we are now perhaps more able to clearly understand how Mussau fits into the larger pattern of Lapita in the Bismarcks and the southwest Pacific.

Our hypotheses, our models, our interpretations of Lapita will continue to evolve, for like any science, archaeology is a "self-correcting system" (cf. Mayr 1997). But the empirical record of Mussau Lapita established through our fieldwork and laboratory studies, thoroughly documented in this volume, along with the physical collections curated in the National Museum and Art Gallery of Papua New Guinea, will no doubt continue to provide a solid evidential basis for the debates and discussions that future generations of scholars will engage in.

References Cited

Allen, J.

1977 Fishing for Wallabies: Trade as a Mechanism for Social Interaction, Integration and Elaboration on the Central Papuan Coast. In *The Evolution of Social Systems*, edited by J. Friedman and M. J. Rowlands, pp. 419–456. Duckworth Publications, London.

1984 In Search of the Lapita Homeland: Reconstructing the Prehistory of the Bismarck Archipelago. *Journal of Pacific History* 19:186–201.

1991 Introduction. In *Report of the Lapita Homeland Project*, edited by J. Allen and C. Gosden, pp. 1–8. Occasional Papers in Prehistory No. 20. Australian National University, Canberra.

2017 Stone, Shell and Bone Artefacts on Motupore. In *Excavations on Motupore Island*, Vol. 2, by J. Allen, pp. 399–450. University of Otago Working Papers in Anthropology No. 4. Department of Anthropology and Archaeology, University of Otago, Dunedin, New Zealand.

Allen, J. (editor)

[1986] *Lapita Homeland Project: Report of the 1985 Field Season*. La Trobe University, Melbourne, Australia.

Allen, J., and C. Gosden (editors)

1991 *Report of the Lapita Homeland Project*. Occasional Papers in Prehistory No. 20. Department of Prehistory, Australian National University, Canberra.

Allen, J., C. Gosden, and J. P. White

1989 Human Pleistocene Adaptations in the Tropical Island Pacific: Recent Advances from New Ireland, a Greater Australian Outlier. *Antiquity* 63:548–561.

Allen, J., J. Specht, W. Ambrose, and D. Yen

1984 *Lapita Homeland Project: Report of the 1984 Field Season*. Piranha Publications 2. Australian National University, Canberra.

Allen, M. S.

1992a Temporal Variation in Polynesian Fishing Strategies: The Southern Cooks in Regional Perspective. *Asian Perspectives* 31:183–204.

1992b Dynamic Landscapes and Human Subsistence: Archaeological Investigations on Aitutaki Island, Southern Cook Islands. PhD dissertation, Department of Anthropology, University of Washington, Seattle.

1998 Holocene Sea-Level Change on Aitutaki, Cook Islands: Landscape Change and Human Response. *Journal of Coastal Research* 14:10–22.

2017 Spatial Variability and Human Eco-Dynamics in Central East Polynesian Fisheries. In *Oxford Handbook of Zooarchaeology*, edited by U. Albarella, M. Rizzetto, H. Russ, K. Vickers, and S. Viner-Daniels, pp. 737–756. Oxford University Press, Oxford, UK.

Allen, M. S., and G. Bell

1988 Lapita Flaked Stone Assemblages: Sourcing, Technological, and Functional Studies. In *Archaeology of the Lapita Cultural Complex: A Critical Review*, edited by P. V. Kirch and T. L. Hunt, pp. 83–98. The Burke Museum, Seattle, Washington.

Allen, M. S., and A. E. Morrison

2013 Modelling Site Formation Dynamics: Geoarchaeological, Chronometric and Statistical Approaches to a Stratified Rockshelter Sequence, Polynesia. *Journal of Archaeological Science* 40:4560–4575.

Ambrose, W. R.

n.d. A Note on Obsidian Density Measurement for Separating Melanesian Obsidian Sources. Unpublished manuscript in Department of Prehistory, Australian National University. Canberra.

1976 Obsidian and Its Prehistoric Distribution in Melanesia. In *Ancient Chinese Bronzes and Southeast Asian Metal and Other Archaeological Artifacts*, edited by B. Barnard, pp. 351–378. National Gallery of Victoria, Melbourne, Australia.

Ambrose, W. R., J. R. Bird, and P. Duerden

1981 The Impermanence of Obsidian Sources in Melanesia. In *Archaeological Studies of Pacific Stone Resources*, edited by F. Leach and J. Davidson, pp. 1–19. BAR International Series 104. British Archaeological Reports, Oxford, UK.

Ambrose, W. R., and P. Duerden

1982 PIXE Analysis in the Distribution and Chronology of Obsidian Use in the Admiralty Islands. In *Archaeometry: An Australian Perspective*, edited by W. Ambrose and P. Duerden, pp. 83–89. Department of Prehistory, Research School of Pacific Studies, Australian National University, Canberra.

Ambrose, W. R., and R. C. Green

1972 First Millennium BC Transport of Obsidian from New Britain to the Solomon Islands. *Nature* 237:31.

Amesbury, J. R.

2007 Mollusk Collecting and Environmental Change during the Prehistoric Period in the Mariana Islands. *Coral Reefs* 26:947–958.

Amesbury, S. S., F. A. Cushing, and R. K. Sakamoto

1986 *Guide to the Coastal Resources of Guam*, Vol. 3, *Fishing on Guam*. University of Guam Marine Laboratory Contribution Number 173. University of Guam Press, Guam.

Anderson, A.

1979 Prehistoric Exploitation of Marine Resources at Black Rocks Point, Palliser Bay. In *Prehistoric Man in Palliser Bay*, edited by B. F. Leach and H. Leach, pp. 49–65. National Museum of New Zealand Bulletin 21. National Museum of New Zealand, Wellington.

1981 A Model of Collecting on the Rocky Shore. *Journal of Archaeological Science* 8:109–120.

Anson, D.

1983 Lapita Pottery of the Bismarck Archipelago and Its Affinities. PhD dissertation, Department of Anthropology, University of Sydney, Australia.

1986 Lapita Pottery of the Bismarck Archipelago and Its Affinities. *Archaeology in Oceania* 21:157–165.

Ash, J.

1987 Holocene Sea Levels in Northern Viti Levu, Fiji. *New Zealand Journal of Geology and Geophysics* 30:431–435.

Aswani, S., and R. J. Hamilton

2004 Integrating Indigenous Ecological Knowledge and Customary Sea Tenure with Marine and Social Science for Conservation of Bumphead Parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Solomon Islands. *Environmental Conservation* 31:69–83.

Athens, S., T. M. Rieth, and T. S. Dye

2014 A Paleoenvironmental and Archaeological Model-Based Assessment for the Colonization of Hawai‘i. *American Antiquity* 79:144–155.

Avias, J.

1950 Poteries canaques et poteries préhistoriques en Nouvelle-Calédonie. *Journal de la Société des Océanistes* 6:111–140.

Bafmatuk, F., B. Egloff, and R. Kaiku

1980 Islanders: Past and Present. *Hemisphere* 25:77–81.

Barrau, J.

1958 *Subsistence Agriculture in Melanesia*. Bernice P. Bishop Museum Bulletin 219. Bishop Museum Press, Honolulu, Hawaii.

1965a Witnesses of the Past: Notes on Some Food Plants of Oceania. *Ethnology* 4:282–294.

1965b Histoire et préhistoire horticoles de l'Océanie tropicale. *Journal de la Société des Océanistes* 21:55–78.

Bedford, S., M. Spriggs, and R. Regenvanu

2006 The Teouma Lapita Site and the Early Human Settlement of the Pacific Islands. *Antiquity* 80:812–828.

Bellwood, P.

1979 *Man's Conquest of the Pacific*. Oxford University Press, Oxford, UK.

1980 The Peopling of the Pacific. *Scientific American* 243(5):74–85.

1985 *Prehistory of the Indo-Malaysian Archipelago*. Academic Press, Sydney.

2017 *First Islanders: Prehistory and Human Migration in Island Southeast Asia.* Wiley Blackwell, Oxford.

2019 The Earthenware Pottery from the North Moluccan Excavations. In *The Spice Islands in Prehistory: Archaeology in the Northern Moluccas, Indonesia*, edited by P. Bellwood, pp. 81–106. Terra Australis 50. Australian National University, Canberra.

Bellwood, P., and P. Koon

1989 "Lapita Colonists Leave Boats Unburned!" The Question of Lapita Links with Island Southeast Asia. *Antiquity* 63:613–622.

Bennett, M. A.

1974 *Basic Ceramic Analysis*. Eastern New Mexico University Contributions in Anthropology Vol. 6(1). Eastern New Mexico University, Portales.

Best, S.

1984 Lakeba: The Prehistory of a Fijian Island. PhD dissertation, Department of Anthropology, University of Auckland, New Zealand.

1987 Long Distance Obsidian Travel and Possible Implications for the Settlement of Fiji. *Archaeology in Oceania* 22:27–31.

Bird, J. R., and L. H. Russell

1976 Application of Prompt Nuclear Analysis Techniques to the Study of Artifacts Including Southwest Pacific Obsidians. In *Ancient Chinese Bronzes and Southeast Asian Metal and Other Archaeological Artifacts*, edited by B. Barnard, pp. 317–336. National Gallery of Victoria, Melbourne, Australia.

Bird, J. R., W. R. Ambrose, L. H. Russell, and M. D. Scott

1981 *The Characterization of Melanesian Obsidian Sources and Artefacts Using the Proton Induced Gamma-Ray Emission (PIGME) Technique*. Australian Atomic Energy Commission Report No. E510. Australian Atomic Energy Commission, Lucas Heights, Australia.

Bird, J. R., W. Ambrose, N. Shahgholi, and C. Kannemeyer

1988 Melanesian Obsidian. In *Archaeometry: Australasian Studies*, edited by J. R. Prescott, pp. 107–114. Department of Physical and Mathematical Physics, Adelaide University, Adelaide, Australia.

Bird, J. R., P. Duerden, W. R. Ambrose, and B. F. Leach

1981 Pacific Obsidian Catalogue. In *Archaeological Studies of Pacific Stone Resources*, edited by B. F. Leach and J. Davidson, pp. 31–43. BAR International Series 104. British Archaeological Reports, Oxford, UK.

Bird, J. R., L. H. Russell, and M. D. Scott

1978 Obsidian Characterization with Elemental Analysis by Proton Induced Gamma-Ray Emission. *Analytical Chemistry* 50:2082–2084.

Bird, R., R. Torrence, G. R. Summerhayes, and G. Bailey

1997 New Britain Sources. *Archaeology in Oceania* 32:61–67.

Blake, D. H., and A. Ewart

1974 Petrography and Geochemistry of the Cape Hoskins Volcanoes, New Britain, Papua New Guinea. *Journal of the Geological Society of Australia* 21:319–331.

Bleeker, P.

1983 *Soils of Papua New Guinea*. Australian National University Press, Canberra.

Bloom, A. L.

1980 Late Quaternary Sea Level Change on South Pacific Coasts: A Study in Tectonic Diversity. In *Earth Rheology, Isostasy and Eustasy*, edited by N. A. Morner, pp. 505–516. John Wiley and Sons, New York.

1983 Sea Level and Coastal Changes. In *Late Quaternary Environments of the United States, Vol. 2, The Holocene*, edited by H. E. Wright, pp. 42–53. University of Minnesota Press, Minneapolis.

Blust, R.

1978 *The Proto-Oceanic Palatals*. Polynesian Society Memoir No. 43. The Polynesian Society, Wellington, New Zealand.

1984 A Mussau Vocabulary, with Phonological Notes. *Pacific Linguistics* A-69:159–208.

1985 The Austronesian Homeland: A Linguistic Perspective. *Asian Perspectives* 26:45–67.

2013 *The Austronesian Languages: Revised Edition*. Asia-Pacific Linguistics, Open Access Monographs. Australian National University, Canberra. http://hdl.handle.net/1885/10191

Bouffandeau, L., P. Béarez, S. Bedford, F. Valentin, M. Spriggs, and E. Nolet

2018 Fishing at Arapus-Mangaasi, Efate, Vanuatu (2800–2200 BP): New Methodological Approaches and Results. *Journal of Archaeological Science: Reports* 18:356–369.

Bronk Ramsey, C.

2009 Bayesian Analysis of Radiocarbon Dates. *Radiocarbon* 51:337–360.

Brown, C. M.

1982 Explanatory Notes on the Kavieng Geological Sheet. *1:250,000 Geological Series, Sheet SA/56-9, Kavieng*. Department of Minerals and Energy, Geological Survey of Papua New Guinea, Port Moresby, Papua New Guinea.

Brown, F. B. H.

1935 *Flora of Southeastern Polynesia*. Bernice P. Bishop Museum Bulletin 130. Bishop Museum Press, Honolulu, Hawaii.

Buck, C. E., J. A. Christen, and G. N. James

1999 BCal: An On-Line Bayesian Radiocarbon Calibration Tool. *Internet Archaeology* 7. http://intarch.ac.uk/journal/issue7/buck/

Buck, P. H.

1957 *Arts and Crafts of Hawaii*. Bernice P. Bishop Museum Special Publication 45. Bishop Museum Press, Honolulu, Hawaii.

Butler, V. L.

1988 Lapita Fishing Strategies: The Faunal Evidence. In *Archaeology of the Lapita Cultural Complex: A Critical Review*, edited by P. V. Kirch and T. L. Hunt, pp. 99–116. The Burke Museum, Seattle.

1994 Fish Feeding Behavior and Fish Capture: The Case for Variation in Lapita Fishing Strategies. *Archaeology in Oceania* 29:81–90.

2017 Fish Remains from Tangatatau Rockshelter. In *Tangatatau Rockshelter: The Evolution of an Eastern Polynesian Socio-Ecosystem*, edited by P. V. Kirch, pp. 103–137. Monumenta Archaeologica 40. Cotsen Institute of Archaeology Press, University of California, Los Angeles.

Campbell, M.

2016 Body Part Representation and the Extended Analysis of New Zealand Fishbone. *Archaeology in Oceania* 51:8–30.

Campbell, S. F.

1983 Attaining Rank: A Classification of Kula Shell Valuables. In *The Kula: New Perspectives on Massim Exchange*, edited by J. W. Leach and E. Leach, pp. 229–248. Cambridge University Press, Cambridge, UK.

Cannon, A., R. Wildenstein, D. Y. Cannon, and D. V. Burley

2019 Consistency and Variation in the Focus, Intensity and Archaeological Histories of Lapita and Post-Lapita Fisheries in Ha'apai, Kingdom of Tonga. *The Journal of Island and Coastal Archaeology* 14:515–540.

Carson, M. T., H. Hung, G. Summerhayes, and P. Bellwood

2013 The Pottery Trail from Southeast Asia to Remote Oceania. *Journal of Island and Coastal Archaeology* 8:17–36.

Carsten, J., and S. Hugh-Jones

1995 Introduction. In *About the House: Lévi-Strauss and Beyond*, edited by J. Carsten and S. Hugh-Jones, pp. 1–46. Cambridge University Press, Cambridge, UK.

Casteel, R. W.

1972 Some Biases in the Recovery of Archaeological Faunal Remains. *Proceedings of the Prehistoric Society* 36:382–388.

1976/1977 A Consideration of the Behavior of the Minimum Number of Individuals Index: A Problem in Faunal Characterization. *Ossa* 3/4:141–151.

Cath-Garling, S.

2017 *Evolutions or Revolutions? Interaction and Transformation at the "Transition" in Island Melanesia*. University of Otago Studies in Archaeology No. 27. University of Otago, Dunedin, New Zealand.

Catterall, C. P.

1986 Human Exploitation of Shellfish. *Oceanus* 29(2):105.

1998 Molluscs on Coral Reefs. In *Mollusca: The Southern Synthesis. Fauna of Australia. Vol. 5*, edited by P. L. Beesley, G. J. B. Ross, and A. Wells, pp. 33–36. CSIRO Publishing, Melbourne, Australia.

Catterall, C. P., and I. R. Poiner

1983 Age and Sex-Dependent Patterns of Aggregation in the Tropical Gastropod *Strombus luhuanus*. *Marine Biology* 77:171–182.

1987 The Influence of Human Gathering on the Shellfish of Some North-Eastern Australian Intertidal Flats. *Oikos* 50:114–122.

Cernohorsky, W. W.

1978 *Tropical Pacific Marine Shells*. Pacific Publications, Sydney.

Chappell, J.

1982 Sea Levels and Sediments: Some Features of the Context of Coastal Archaeological Sites in the Tropics. *Archaeology in Oceania* 17:69–78.

1987 Late Quaternary Sea-Level Changes in the Australian Region. In *Sea-Level Changes*, edited by M. J. Tooley and I. Shennan, pp. 296–331. Basil Blackwell, Oxford, UK.

Chinnery, E. W. P.

1925 *Notes on the Natives of E Mira and St. Matthias*. Territory of New Guinea, Anthropological Report No. 2. [Place of publication not given.]

Chiu, S.

2003 The Socio-Economic Functions of Lapita Ceramic Production and Exchange: A Case Study from Site WKO013A, Kone, New Caledonia. PhD dissertation, Department of Anthropology, University of California, Berkeley.

2005 Meanings of a Lapita Face: Materialized Social Memory in Ancient House Societies. *Taiwan Journal of Anthropology* 3:1–47.

2007 Detailed Analysis of Lapita Face Motifs: Case Studies from Reef/Santa Cruz Lapita Sites and New Caledonia Site 13A. In *Oceanic Explorations: Lapita and Western Pacific Settlement*, edited by S. Bedford, C. Sand, and S. P. Connaughton, pp. 241–264. Australian National University, Canberra.

2015 Where Do We Go from Here? Social Relatedness Reflected by Motif Analysis. In *The Lapita Cultural Complex in Time and Space: Expansion Routes, Chronologies and Typologies*, edited by C. Sand, S. Chiu, and N. Hogg, pp. 185–206. Academia Sinica, Taipei, Taiwan.

Chiu, S., and C. Sand

2005 Recording of the Lapita Motifs: Proposal for a Complete Recording Method. *Archaeology in New Zealand* 48:133–150.

Christensen, C. C., and P. V. Kirch

1986 Nonmarine Molluscs and Ecological Change at Barbers Point, Oʻahu, Hawaiʻi. *Bishop Museum Occasional Papers* 26:52–80.

Claassen, C.

1998 *Shells*. Cambridge Manuals in Archaeology. Cambridge University Press, Cambridge, UK.

Clark, G., and K. Szabó

2009 The Fish Bone Remains. In *The Early Prehistory of Fiji*, edited by G. Clark and A. J. Anderson, pp. 213–230. Terra Australis 31. Australian National University, Canberra.

Clark, J., and J. Terrell

1978 Archaeology in Oceania. *Annual Review of Anthropology* 7:293–319.

Cushing, D. H.

1975 *Marine Ecology and Fisheries*. Cambridge University Press, Cambridge.

Danneil, C.

1901 Die ersten Nachrichten über die Inselgruppe St. Matthias und deren Bewohner. *Internationales Archiv für Ethnographie* 14:112–126.

Davidson, J.

1979 Samoa and Tonga. In *The Prehistory of Polynesia*, edited by J. Jennings, pp. 82–109. Harvard University Press, Cambridge, Massachusetts.

Denham, T., C. B. Ramsey, and J. Specht

2012 Dating the Appearance of Lapita Pottery in the Bismarck Archipelago and Its Dispersal to Remote Oceania. *Archaeology in Oceania* 47:39–46.

Diamond, J.

1988 Express Train to Polynesia. *Nature* 336:307–308.

Dickinson, W. R.

1994 Natural Beach Placer Analogous to Prehistoric Island Tempers. *Journal of the Polynesian Society* 103:217–219.

1998a Geomorphology and Geodynamics of the Cook–Austral Island–Seamount Chain in the South Pacific Ocean: Implications for Hotspots and Plumes. *International Geology Review* 40:1039–1075.

1998b Petrographic Temper Provinces of Prehistoric Pottery in Oceania. *Australian Museum Records* 50:263–276.

1999 Holocene Sea-Level Record on Funafuti and Potential Impact of Global Warming on Central Pacific Atolls. *Quaternary Research* 51:124–132.

2000 Petrography of Sand Tempers in Prehistoric Watom Sherds and Comparison with Other Temper Suites of the Bismarck Archipelago. *New Zealand Journal of Archaeology* 20:161–182.

2001 Paleoshoreline Record of Relative Holocene Sea Levels on Pacific Islands. *Earth Science Reviews* 55:191–234.

2006 *Temper Sands in Prehistoric Oceanian Pottery: Geotectonics, Sedimentology, Petrography, Provenance.* Geological Society of America Special Paper 406. Geological Society of America, Boulder, Colorado.

2014 Beach Ridges as Favored Locales for Human Settlement on Pacific Islands. *Geoarchaeology* 29:249–267.

Dickinson, W. R., D. V. Burley, P. D. Nunn, A. Anderson, G. Hope, A. de Biran, C. Burke, and S. Matararaba

1998 Geomorphic and Archaeological Landscapes of the Sigatoka Dune Site, Viti Levu, Fiji: Interdisciplinary Investigations. *Asian Perspectives* 37:1–31.

Dickinson, W. R., D. V. Burley, and R. Shutler, Jr.

1994 Impact of Hydro-Isostatic Holocene Sea-Level Change on the Geologic Context of Island Archaeological Sites, Northern Ha'apai Group, Kingdom of Tonga. *Geoarchaeology* 9:85–111.

Dickinson, W. R, and R .C. Green

1998 Geoarchaeological Context of Holocene Subsidence at the Ferry Berth Site, Mulifanua, Upolu, Western Samoa. *Geoarchaeology* 13:239–263.

Dickinson, W. R., and R. Shutler, Jr.

1979 Petrography of Sand Tempers in Pacific Island Potsherds. *Bulletin of the Geological Society of America* 90:993–995, 1644–1701.

2000 Implications of Petrographic Temper Analysis for Oceanian Prehistory. *Journal of World Prehistory* 14:203–266.

Donovan, L. J.

1973 A Study of the Decorative System of the Lapita Potters in Reefs and Santa Cruz Islands. MA thesis, Department of Anthropology, University of Auckland, New Zealand.

Doran, J. E., and F. R. Hodson

1975 *Mathematics and Computers in Archaeology*. Harvard University Press, Cambridge, Massachusetts.

Duerden, P., J. R. Bird, M. D. Scott, E. Clayton, and L. H. Russell

1980 PIXE-PIGME Studies of Artifacts. *Nuclear Instruments and Methods* 168:447–452.

Duerden, P., D. D. Cohen, E. Clayton, J. R. Bird, W. R. Ambrose, and B. F. Leach

1979 Elemental Analysis of Thick Obsidian Samples by Proton Induced X-Ray Emission Spectrography. *Analytic Chemistry* 51:2350–2354.

Dumas, P., H. Jimenez, C. Peignon, L. Wantiez, and M. Adjeroud

2013 Small-Scale Habitat Structure Modulates the Effects of No-Take Marine Reserves for Coral Reef Macroinvertebrates. *PloS One* 8(3): e58998.

Dunnell, R. C.

1971 *Systematics in Prehistory*. The Free Press, New York.

Dye, T.

1983 Fish and Fishing on Niuatoputapu. *Archaeology in Oceania* 53:242–271.

Egloff, B. J.

1975 Archaeological Investigations in the Coastal Madang Area and on Eloaue Island of the St. Matthias Group. *Records of the Papua New Guinea Museum and Art Gallery* 5:15–31.

Emory, K. P., W. J. Bonk, and Y. H. Sinoto

1959 *Hawaiian Archaeology: Fishhooks*. Bernice P. Bishop Museum Special Publication 47. Bishop Museum Press, Honolulu.

Exon, N. F., and M. S. Marlow

1988 Tripartite Study of the New Ireland–Manus Region, Papua New Guinea: An Introduction. In *Geology and Offshore Resources of Pacific Island Arcs—New Ireland and Manus Region, Papua New Guinea*, edited by M. S. Marlow, S. V. Dadisman, and N. F. Exon, pp. 1–9. Circum-Pacific Council for Energy and Mineral Resources Earth Science Series Vol. 9. Circum-Pacific Council for Energy and Mineral Resources, Houston.

Exon, N. F., W. D. Stewart, M. J. Sandy, and D. L. Tiffin

1986 Geology and Offshore Petroleum Prospects of the Eastern New Ireland Basin, Northeastern Papua New Guinea. *Journal of Australian Geology and Geophysics* 10:39–51.

Exon, N. F., and D. L. Tiffin

1984 Geology and Petroleum Prospects of Offshore New Ireland Basin in Northern Papua New Guinea. In *Transactions of the Third Circum-Pacific Energy and Mineral Resources Conference, August 22–28, Honolulu, Hawaii*, edited by S. T. Watson, pp. 623–630. Circum-Pacific Council for Energy and Mineral Resources, Houston.

Fairbridge, R. W.

1961 Eustatic Changes in Sea Level. *Physics and Chemistry of the Earth* 4:99–185.

Faulkner, P.

2009 Focused, Intense and Long-Term: Evidence for Granular Ark (*Anadara granosa*) Exploitation from Late Holocene Shell Mounds of Blue Mud Bay, Northern Australia. *Journal of Archaeological Science* 36:821–834.

Felgate, M. W.

2001 A Roviana Ceramic Sequence and the Prehistory of Near Oceania: Work in Progress. In *The Archaeology of Lapita Dispersal in Oceania*, edited by G. R. Clark, A. J. Anderson, and T. Vunidilo, pp. 39–60. Terra Australis 17. Australian National University, Canberra.

Firth, R.

1936 *We, the Tikopia: A Sociological Study of Kinship in Primitive Polynesia*. American Book Co., New York.

Fitzpatrick, S. M., and O. Kataoka

2005 Prehistoric Fishing in Palau, Micronesia: Evidence from the Northern Rock Islands. *Archaeology in Oceania* 40:1–13.

Flannery, K. L.

1982 The Golden Marshalltown: A Parable for the Archeology of the 1980s. *American Anthropologist* 84:265–278.

Flannery, K. L. (editor)

1986 *Guila Naquitz: Archaic Foraging and Early Agriculture in Oaxaca, Mexico.* Academic Press, Orlando, Florida.

Flannery, T. F., and J. P. White

1991 Animal Translocations: Zoogeography of New Ireland Mammals. *National Geographic Research and Exploration* 7:96–113.

Folk, R. L.

1974 *Petrology of Sedimentary Rocks*. Hemhill Publishing Co, Austin, Texas.

Fowler, H. W.

1955 *Archaeological Fishbones Collected by E. W. Gifford in Fiji*. Bernice P. Bishop Museum Bulletin 214. Bishop Museum Press, Honolulu, Hawaii.

Fox, J. J.

1993 Comparative Perspectives on Austronesian Houses: An Introductory Essay. In *Inside Austronesian Houses: Perspectives on Domestic Designs for Living*, edited by J. J. Fox, pp. 1–29. Australian National University, Canberra.

Fox, J. J., and C. Sather (editors)

1996 *Origins, Ancestry and Alliance: Explorations in Austronesian Ethnography*. Australian National University, Canberra.

Francis, G.

1988 Stratigraphy of Manus Island, Western New Ireland Basin, Papua New Guinea. In *Geology and Offshore Resources of the Pacific Island Arcs—New Ireland and Manus Region, Papua New Guinea*, edited by M. S. Marlow, S. V. Dadisman, and N. F. Exon, pp. 31–40. Circum-Pacific Council for Energy and Mineral Resources, Houston.

Fredericksen, C.

1994 Patterns in Glass: Obsidian and Economic Specialization in the Admiralty Islands. PhD dissertation, Department of Prehistory, Australian National University, Canberra.

1997a The Maritime Distribution of Bismarck Archipelago Obsidian and Island Melanesian Prehistory. *Journal of the Polynesian Society* 106:375–393.

1997b Changes in Admiralty Islands Obsidian Source Use: The View from Pamwak. *Archaeology in Oceania* 32:68–97.

Fredericksen, C., M. Spriggs, and W. Ambrose

1993 Pamwak Rockshelter: A Pleistocene Site on Manus Island, Papua New Guinea. In *Sahul in Review: Pleistocene Archaeology in Australia, New Guinea and Island Melanesia*, edited by M. A. Smith, M. Spriggs, and B. Fankhauser, pp. 144–154. Occasional Papers in Prehistory No. 24. Department of Prehistory, Australian National University, Canberra.

Friedman, J.

1981 Notes on Structure and History in Oceania. *Folk* 23:275–295.

1982 Catastrophe and Continuity in Social Evolution. In *Theory and Explanation in Archaeology*, edited by C. Renfrew, M. Rowlands, and B. Seagraves, pp. 175–196. Academic Press, New York.

Frimigacci, D.

1975 La préhistoire Neo-Calédonien. Thèse de 3eme Cycle. Université Paris I, Paris.

1980 Localisation éco-géographique et utilisation de l'espace de quelques sites Lapita de Nouvelle-Calédonie. *Journal de la Société des Océanistes* 36:5–11.

Frost, E. L.

1979 Fiji. In *The Prehistory of Polynesia*, edited by J. Jennings, pp. 61–81. Harvard University Press, Cambridge, Massachusetts.

Fujimoto, K., T. Miyagi, T. Kikuchi, and T. Kawana

1996 Mangrove Habitat Formation and Response to Holocene Sea-Level Changes on Kosrae Island, Micronesia. *Mangroves and Salt Marshes* 1:47–57.

Fullagar, R.

1992 Lithically Lapita: Functional Analysis of Flaked Stone Assemblages from West New Britain Province, Papua New Guinea. In *Poterie Lapita et Peuplement*, edited by J. C. Galipaud, pp. 135–143. ORSTOM, Noumea (New Caledonia).

Fullagar, R., W. R. Ambrose, R. Bird, J. Specht, R. Torrence, and N. Baker

1989 Stocktaking the Rocks: Obsidian Sources in West New Britain, Papua New Guinea. In *Proceedings of the Sixth Australian Conference on Nuclear Techniques of Analysis*, pp. 187–189. Australian Institute of Nuclear Science and Engineering, Lucas Heights, Australia.

Fullagar, R., G. R. Summerhayes, B. Ivuyo, and J. Specht

1991 Obsidian Sources at Mopir, West New Britain Province, Papua New Guinea. *Archaeology in Oceania* 26:110–114.

Fullagar, R., and R. Torrence

1991 Obsidian Exploitation at Umleang, Lou Island. In *Report of the Lapita Homeland Project*, edited by J. Allen and C. Gosden, pp. 113–143. Occasional Papers in Prehistory No. 20. Australian National University, Canberra.

Galipaud, J.-C., C. Reepmeyer, R. Torrence, S. Kelloway, and P. White

2014 Long-Distance Connections in Vanuatu: New Obsidian Characterisations for the Makué Site, Aore Island. *Archaeology in Oceania* 49:110–116.

Garanger, J.

1972 *Archéologie des Nouvelles-Hébrides*. Publication de la Société des Océanistes No. 30. Société des Océanistes, Paris.

Garling, S. J.

2003 Tanga Takes to the Stage: Another Model "Transitional" Site? New Evidence and a Contribution to the "Incised and Applied Relief Tradition" in New Ireland. In *Pacific Archaeology: Assessments and Prospects*, edited by C. Sand, pp. 213–233. Cahiers de l'Archéologie en Nouvelle-Calédonie Vol. 15. Département Archéologie, Service des Musées et du Patrimoine de Nouvelle-Calédonie, Nouméa.

2007 Post-Lapita Evolutions or Revolutions? Interaction and Exchange in Island Melanesia: The View from the Tanga Islands. PhD dissertation, Department of Archaeology and Natural History, Australian National University, Canberra.

Gifford, E. W., and D. Shutler, Jr.

1956 Archaeological Excavations in New Caledonia. *Anthropological Records* 18:1–125.

Giovas, C. M.

2018 Impact of Analytic Protocols on Archaeofish Abundance, Richness, and Similarity: A Caribbean–Pacific Crossover Study. In *Zooarchaeology in Practice*, edited by C. Giovas and M. LeFebvre, pp. 59–89. Springer, Cham, Switzerland.

Giovas, C. M., S. M. Fitzpatrick, M. Clark, and M. Abed

2010 Evidence for Size Increase in an Exploited Mollusc: Humped Conch (*Strombus gibberulus*) at Chelechol ra Orrak, Palau from ca. 3000–0 BP. *Journal of Archaeological Science* 37:2788–2798.

Giovas, C. M., S. M. Fitzpatrick, O. Kataoka, and M. Clark

2016 Prey Body Size and Anthropogenic Resource Depression: The Decline of Prehistoric Fishing at Chelechol ra Orrak, Palau. *Journal of Anthropological Archaeology* 41:132–146.

Glascock, M., and M. Anderson

1993 Geological Reference Materials for Standardization and Quality Assurance of Instrumental Neutron Activation Analysis. *Journal of Radioanalytical and Nuclear Chemistry* 174:229–242.

Golson, J.

1971 Lapita Ware and Its Transformations. *Pacific Anthropological Records* 12:67–76.

1972 Both Sides of the Wallace Line: New Guinea, Australia, Island Melanesia, and Asian Prehistory. In *Early Chinese Art and Its Possible Influence in the Pacific Basin*, edited by N. Barnard, pp. 533–595. Intercultural Arts Press, New York.

1977 No Room at the Top: Agricultural Intensification in the New Guinea Highlands. In *Sunda and Sahul: Prehistoric Studies in Southeast Asia, Melanesia and Australia*, edited by J. Allen, J. Golson, and R. Jones, pp. 601–638. Academic Press, London.

1990 Kuk and the Development of Agriculture in New Guinea: Retrospection and Introspection. In *Pacific Production Systems: Approaches to Economic Prehistory*, edited by D. E. Yen and J. M. J. Mummery, pp. 139–147. Occasional Papers in Prehistory No. 18. Department of Prehistory, Australian National University, Canberra.

1991 Two Sites at Lasigi. In *The Report of the Lapita Homeland Project*, edited by J. Allen and C. Gosden, pp. 244–259. Occasional Papers in Prehistory 20. Department of Prehistory, Australian National University, Canberra.

1992 The Pottery from Lasigi, New Ireland. In *Poterie Lapita et peuplement: Actes du Colloque LAPITA*, edited by J.-C. Galipaud, pp. 155–167. ORSTOM, Nouméa, New Caledonia.

Gordon, E.

1993 Screen Size and Differential Faunal Recovery: A Hawaiian Example. *Journal of Field Archaeology* 20:453–460.

Gosden, C.

1993 Understanding the Settlement of Pacific Islands in the Pleistocene. In *Sahul in Review: Pleistocene Archaeology in Australia, New Guinea, and Island Melanesia*, edited by M. A. Smith, M. Spriggs, and B. Fankhauser, pp. 131–136. Occasional Papers in Prehistory No. 24. Department of Prehistory, Australian National University, Canberra.

Gosden, C., J. Allen, W. Ambrose, D. Anson, J. Golson, R. Green, P. Kirch, I. Lilley, J. Specht, and M. Spriggs

1989 Lapita Sites of the Bismarck Archipelago. *Antiquity* 63:561–586.

Gosden, C., and J. Webb

1994 The Creation of a Papua New Guinean Landscape: Archaeological and Geomorphological Evidence. *Journal of Field Archaeology* 21:29–51.

Gosline, W. A., and V. E. Brock

1960 *Handbook of Hawaiian Fishes*. University of Hawaii Press, Honolulu.

Granadeiro, J. P., and M. A. Silva

2000 The Use of Otoliths and Vertebrae in the Identification and Size-Estimation of Fish in Predator–Prey Studies. *Cybium* 24:383–393.

Grayson, D. K.

1984 *Quantitative Zooarchaeology*. Academic Press, New York.

Green, R. C.

1974a Sites with Lapita Pottery: Importing and Voyaging. *Mankind* 9:253–259.

1974b A Review of Portable Artifacts from Western Samoa. In *Archaeology in Western Samoa*, Vol. 2, edited by R. C. Green and J. Davidson, pp. 245–275. Auckland Institute and Museum, Auckland, New Zealand.

1976 Lapita Sites in the Santa Cruz Group. In *Southeast Solomon Islands Cultural History: A Preliminary Survey*, edited by R. C. Green and M. M. Cresswell, pp. 245–265. Royal Society of New Zealand, Wellington.

1978 *New Sites with Lapita Pottery and Their Implications for an Understanding of the Settlement of the Western Pacific.* Working Papers in Anthropology No. 51. Department of Anthropology, University of Auckland, New Zealand.

1979a Lapita. In *The Prehistory of Polynesia*, edited by J. Jennings, pp. 27–60. Harvard University Press, Cambridge, Massachusetts.

1979b Early Lapita Art from Polynesia and Island Melanesia: Continuities in Ceramic, Barkcloth, and Tattoo Decorations. In *Exploring the Visual Art of Oceania*, edited by S. Mead, pp. 13–31. University of Hawaii Press, Honolulu.

1982 Models for the Lapita Cultural Complex: An Evaluation of Some Current Proposals. *New Zealand Journal of Archaeology* 4:7–20.

1985 Comment: Spriggs' "The Lapita Cultural Complex." *Journal of Pacific History* 20:220–224.

1986 Lapita Fishing: The Evidence of Site SE-RF-2 from the Main Reef Islands, Santa Cruz Group, Solomons. In *Traditional Fishing in the Pacific: Ethnographical and Archaeological Papers from the 15th Pacific Science Congress*, edited by A. Anderson, pp. 119–132. Pacific Anthropological Records 37. Bernice P. Bishop Museum, Honolulu, Hawaii.

1987 Obsidian Results from the Lapita Sites of the Reef/Santa Cruz Islands. In *Archaeometry: Further Australasian Studies*, edited by W. R. Ambrose and J. M. Mummery, pp. 239–249. Australian National University, Canberra.

1991a Near and Remote Oceania: Disestablishing "Melanesia" in Culture History. In *Man and a Half: Essays in Pacific Anthropology and Ethnobiology in Honour of Ralph Bulmer*, edited by A. Pawley, pp. 491–502. The Polynesian Society, Auckland, New Zealand.

1991b The Lapita Cultural Complex: Current Evidence and Proposed Models. In *Indo-Pacific Prehistory 1990: Proceedings of the 14th Congress of the Indo-Pacific Prehistory Association*, edited by P. Bellwood, pp. 295–305. Indo-Pacific Prehistory Association, Canberra, Australia.

1992 Definitions of the Lapita Cultural Complex and Its Non-Ceramic Component. In *Poterie Lapita et peuplement: Actes du Colloque LAPITA*, edited by J.-C. Galipaud, pp. 7–20. ORSTOM, Nouméa, New Caledonia.

1997 Working with Wal: From Innovative Technician to Valued Archaeological Researcher. *Archaeology in Oceania* 32:54–60.

Green, R. C., and D. Anson

1987 The Lapita Site of Watom: New Evidence from Excavations in 1985. *Man and Culture in Oceania* 3, special issue: 121–131.

1991 The Reber-Rakival Lapita Site on Watom: Implications of the 1985 Excavations at the SAC and SDI Localities. In *Report of the Lapita Homeland Project*, edited by J. Allen and C. Gosden, pp. 170–181. Department of Prehistory, Research School of Pacific Studies, Australian National University, Canberra.

1998 Excavations at Kainapirina (SAC), Watom Island, Papua New Guinea. *New Zealand Journal of Archaeology* 20:29–94.

Green, R. C., and J. R. Bird

1989 Fergusson Island Obsidian from the D'Entrecasteaux Group in a Lapita Site of the Reef Santa Cruz Group. *New Zealand Journal of Archaeology* 11:87–99.

Green, R. C., and M. M. Cresswell (editors)

1976 *Southeast Solomon Islands Cultural History: A Preliminary Survey*. Royal Society of New Zealand Bulletin 11. Royal Society of New Zealand, Wellington.

Green, R. C., and P. V. Kirch

1997 Lapita Exchange Systems and Their Polynesian Transformations: Seeking Explanatory Models. In *Prehistoric Long-Distance Interaction in Oceania: An Interdisciplinary Approach*, edited by M. I. Weisler, pp. 19–37. New Zealand Archaeological Association Monograph 21. New Zealand Archaeological Association, Auckland.

Green, R. C., and J. S. Mitchell

1983 New Caledonian Culture History: A Review of the Archaeological Sequence. *New Zealand Journal of Archaeology* 5:19–68.

Green, R. C., and A. K. Pawley

1998 Architectural Forms and Settlement Patterns. In *The Lexicon of Proto-Oceanic: The Culture and Environment of Ancestral Oceanic Society. Vol. 1, Material Culture*, edited by M. Ross, A. Pawley, and M. Osmond, pp. 37–66. Pacific Linguistics C-152. Australian National University, Canberra.

Greenspan, R. L.

1998 Gear Selectivity Models, Mortality Profiles, and the Interpretation of Archaeological Fish Remains: A Case Study from the Harney Basin, Oregon. *Journal of Archaeological Science* 25:973–984.

Groube, L.

1971 Tonga, Lapita Pottery, and Polynesian Origins. *Journal of the Polynesian Society* 80:278–316.

Habe, T.

1964 *Shells of the Western Pacific in Color*. Vol. II. Hoikusha Publishing Co, Osaka, Japan.

Hagelberg, E.

1997 Ancient and Modern Mitochondrial DNA Sequences and the Colonization of the Pacific. *Electrophoresis* 18:1529–1533.

Hallmann, N., G. Camoin, A. Eisenhauer, A. Botella, G. A. Milne, C. Vella, E. Samankassou, V. Pothin, J. Fleury, and J. Fietzke

2018 Ice Volume and Climate Changes from a 6000-Year Sea Level Record in French Polynesia. *Nature Communications* 9:285. DOI 10.1038/s41467-017-02695-7.

Hamilton, W. D., and A. M. Krus

2018 The Myths and Realities of Bayesian Chronological Modeling Revealed. *American Antiquity* 83:187–203.

Hanslip, M. D.

2001 Expedient Technologies? Obsidian Artefacts in Island Melanesia. PhD dissertation, Department of Prehistory, Australian National University, Canberra.

Harries, H. C.

1978 The Evolution, Dissemination, and Classification of *Cocos nucifera* L. *Botanical Review* 44:265–320.

Harries, H., and C. R. Clement

2014 Long-Distance Dispersal of the Coconut Palm by Migration Within the Coral Atoll Ecosystem. *Annals of Botany* 113:565–570.

Harris, M., and M. Weisler

2017 Prehistoric Human Impacts to Marine Mollusks and Intertidal Ecosystems in the Pacific Islands. *The Journal of Island and Coastal Archaeology* 13:235–255.

Hartert, E.

1924 The Birds of St. Matthias Island. *Novitates Zoologicae* 31:261–278.

Hawkins, S., T. H. Worthy, S. Bedford, M. Spriggs, G. Clark, G. Irwin, S. Best, and P. Kirch

2016 Ancient Tortoise Hunting in the Southwest Pacific. *Nature, Scientific Reports* 6:38317. DOI: 10.1038/srep38317.

Hayden, B.

1983 Social Characteristics of Early Austronesian Colonizers. *Indo-Pacific Prehistory Association Bulletin* 4:123–134.

Hedrick, J. D.

1971 Lapita-Style Pottery from Malo Island. *Journal of the Polynesian Society* 80:15–19.

Heming, R. F.

1979 Undersaturated Lavas from Ambitle Island, Papua New Guinea. *Lithos* 12:173–186.

Herald, E. S.

1961 *Living Fishes of the World*. Doubleday, Garden City, New York.

Hiatt, R. W., and D. W. Strasburg

1960 Ecological Relationships of the Fish Fauna on Coral Reefs of the Marshall Islands. *Ecological Monographs* 30:65–127.

Hinton, A.

[1972] *Shells of New Guinea and the Central Indo-Pacific*. The Jacaranda Press, Milton, Queensland, Australia.

[1977] *Guide to the Shells of Papua New Guinea*. Robert Brown & Associates, Port Moresby, Papua New Guinea.

Hiroa, T. R. (P. H. Buck)

1930 *Samoan Material Culture*. Bernice P. Bishop Museum Bulletin 75. Bishop Museum Press, Honolulu, Hawaii.

1944 *Arts and Crafts of the Cook Islands*. Bernice P. Bishop Museum Bulletin 179. Bishop Museum Press, Honolulu, Hawaii.

Hockey, P. A. R., and A. L. Bosman

1986 Man as an Intertidal Predator on Transkei: Disturbance, Community Convergence and Management of a Natural Food Resource. *Oikos* 46:3–14.

Hohnen, P. D.

1978 *Geology of New Ireland, Papua New Guinea*. Bureau of Mineral Resources, Geology and Geophysics, Bulletin 194 (PNG 12). Australian Government Printing Service, [Canberra].

Hunt, T. L.

1989 Lapita Ceramic Exchange in the Mussau Islands, Papua New Guinea. PhD dissertation, Department of Anthropology, University of Washington, Seattle.

Isla, F. I.

1989 Holocene Sea-Level Fluctuation in the Southern Hemisphere. *Quaternary Science Reviews* 8:359–368.

Ivens, W. G.

1927 *Melanesians of the South-east Solomon Islands*. Kegan Paul, Trench, Trubner & Co., London.

Jackson, M. L.

1958 *Soil Chemical Analyses: An Advanced Course*. Madison, Department of Soil Science, University of Wisconsin.

Jaques, A. L.

1980 Explanatory Notes on the Admiralty Islands Geological Sheet. *1:250,000 Geological Series. Sheet SA/55-10, -11, Admiralty Islands*. Department of Minerals and Energy, Geological Survey of Papua New Guinea, Port Moresby, Papua New Guinea.

1981 Quaternary Volcanism on Manus and M'Buke Islands. In *Cooke-Ravian Volume of Volcanological Papers*, edited by R. W. Johnson, pp. 213–219. Papua New Guinea Geological Survey Memoir 10. Papua New Guinea Geological Survey, Port Moresby.

Johannes, R. E.

1981 *Words of the Lagoon: Fishing and Marine Lore in the Palau District of Micronesia*. University of California Press, Berkeley.

Johnson, R. W.

1982 Papua New Guinea. In *Andesites: Orogenic Andesites and Related Rocks*, edited by R. S. Thorpe, pp. 225–244. Wiley, New York.

Johnson, R. W., and R. W. Arculus

1978 Volcanic Rocks of the Witu Islands, Papua New Guinea: The Origin of Magmas Above the Deepest Part of the New Britain Benioff Zone. *Bulletin Volcanologique* 41:609–655.

Johnson, R. W., D. E. Mackenzie, I. E. Smith, and G. A. M. Taylor

1973 Distribution and Petrology of Late Cenozoic Volcanoes in Papua New Guinea. In *The Western Pacific: Island Arcs, Marginal Seas, Geochemistry*, edited by P. Coleman, pp. 523–533. Crane, Russak & Company and University of Western Australia Press, New York.

Johnson, R. W., and I. S. E. Smith

1974 Volcanoes and Rocks of St. Andrews Strait, Papua New Guinea. *Geological Society of Australia Journal* 21:333–351.

Johnson, R. W., I. S. E. Smith, and S. R. Taylor

1978 Hot-Spot Volcanism in St. Andrew Strait, Papua New Guinea. *BMR Journal of Australian Geology and Geophysics* 3:55–69.

Johnson, R. W., D. A. Wallace, and D. J. Ellis

1976 Feldspathoid-Bearing Potassic Rocks and Associated Types from Volcanic Islands off the Coast of New Ireland, Papua New Guinea: A Preliminary Account of Geology and Petrology. In *Volcanism in Australasia*, edited by R. W. Johnson, pp. 297–316. Elsevier Scientific Publishing, Amsterdam.

Jones, S.

2009 *Food and Gender in Fiji*. Lexington Books, New York.

Kahn, J., C. Nickelsen, J. Stevenson, N. Porch, E. Dotte-Sarout, C. C. Christensen, L. May, J. S. Athens, and P. V. Kirch

2014 Mid- to Late-Holocene Landscape Change and Anthropogenic Transformations on Mo'orea, Society Islands: A Multi-Proxy Approach. *The Holocene* 25:333–347.

Kailola, P. J.

1987a *The Fishes of Papua New Guinea: A Revised and Annotated Checklist*. Vol. 1, *Myxinidae to Synbranchidae*. Department of Fisheries and Marine Resources Research Bulletin 41. Department of Fisheries and Marine Resources, Port Moresby, Papua New Guinea.

1987b *The Fishes of Papua New Guinea: A Revised and Annotated Checklist*. Vol. 2, *Scorpaenidae to Callionymidae*. Department of Fisheries and Marine Resources Research Bulletin 41. Department of Fisheries and Marine Resources, Port Moresby, Papua New Guinea.

Kamminga, J.

1982 *Over the Edge*. Occasional Papers in Anthropology 12. Museum of Anthropology, University of Queensland, St. Lucia, Australia.

Kennedy, A. K., S. R. Hart, and F. A. Frey

1990 Composition and Isotopic Constraints on the Petrogenesis of Alkaline Arc Lavas: Lihir Island, Papua New Guinea. *Journal of Geophysical Research* 95:6929–6942.

Kennedy, J.

1997 The Loneliness of an Obsidian Source in Southwest Manus. *Archaeology in Oceania* 32:85–96.

Kennedy, J., F. Wadra, U. Akon, R. Busasa, J. Papah, and M. Piamnok

1991 Site Survey of Southwest Manus: A Preliminary Report. *Archaeology in Oceania* 26:114–118.

Key, C. A.

1968 Trace Element Identification of the Source of Obsidian in an Archaeological Site in New Guinea. *Nature* 219:360.

1969 The Identification of New Guinea Obsidians. *Archaeology and Physical Anthropology in Oceania* 4:47–55.

Kinaston, R., H. Buckley, F. Valentin, S. Bedford, M. Spriggs, S. Hawkins, and E. Herrscher

2014 Lapita Diet in Remote Oceania: New Stable Isotope Evidence from the 3000-Year-Old Teouma Site, Efate Island, Vanuatu. *PLoS ONE* 9(3): e90376. DOI:10.1371/journal.pone.0090376.

Kira, T.

1962 *Shells of the Western Pacific in Color*. Hoikusha Publishing Co., Osaka, Japan.

Kirch, P. V.

1978 The Lapitoid Period in West Polynesia: Excavations and Survey in Niuatoputapu, Tonga. *Journal of Field Archaeology* 5:1–13.

1979 Subsistence and Ecology. In *The Prehistory of Polynesia*, edited by J. Jennings, pp. 286–307. Harvard University Press, Cambridge, Massachusetts.

1981 Lapitoid Settlements of Futuna and Alofi, Western Polynesia. *Archaeology in Oceania* 16:127–143.

1982a Advances in Polynesian Prehistory: Three Decades in Review. *Advances in World Archaeology* 1:51–87.

1982b The Ecology of Marine Exploitation in Prehistoric Hawaii. *Human Ecology* 10:455–476.

1984 *The Evolution of the Polynesian Chiefdoms*. Cambridge University Press, Cambridge, UK.

1985 Research proposal to the National Geographic Society for Mussau field project. On file, Oceanic Archaeology Laboratory, University of Hawai'i, Manoa.

1986a Lapita, Island Colonization, and Oceanic Cultural Origins. Research proposal submitted to the National Science Foundation, July 1, 1986. Burke Museum, University of Washington, Seattle.

[1986b] Archaeological Fieldwork on Eloaua and Emananus Islands, St. Matthias Group, New Ireland Province. In *Lapita Homeland Project: Report of the 1985 Field Season*, edited by J. Allen, pp. 14–19. La Trobe University, Melbourne, Australia.

1987a Lapita and Oceanic Cultural Origins: Excavations in the Mussau Islands, Bismarck Archipelago, 1985. *Journal of Field Archaeology* 14:163–180.

1987b Lapita, Island Colonization, and Oceanic Cultural Origins, Phase II. Research proposal submitted to the National Science Foundation, December 1, 1987. Burke Museum, University of Washington, Seattle.

1988a *Niuatoputapu: The Prehistory of a Polynesian Chiefdom*. Thomas Burke Memorial Washington State Museum Monograph No. 5. The Burke Museum, Seattle, Washington.

1988b The Talepakemalai Site and Oceanic Prehistory. *National Geographic Research* 4:328–342.

1988c Long-Distance Exchange and Island Colonisation: The Lapita Case. *Norwegian Archaeological Review* 21:103–117.

1988d A Brief History of Lapita Archaeology. In *Archaeology of the Lapita Cultural Complex: A Critical Review*, edited by P. V. Kirch and T. L. Hunt, pp. 1–8. Thomas Burke Memorial Washington State Museum Research Report No. 5. The Burke Museum, Seattle, Washington.

1988e Problems and Issues in Lapita Archaeology. In *Archaeology of the Lapita Cultural Complex: A Critical Review*, edited by P. V. Kirch and T. L. Hunt, pp. 157–165. Thomas Burke Memorial Washington State Museum Research Report No. 5. The Burke Museum, Seattle, Washington.

1989 Second Millennium BC Arboriculture in Melanesia: Archaeological Evidence from the Mussau Islands. *Economic Botany* 43:225–240.

1990a Specialization and Exchange in the Lapita Complex of Oceania (1600–500 BC). *Asian Perspectives* 29:117–133.

1990b La colonisation du Pacifique. *La Recherche* 21:1226–1235.

1991a Prehistoric Exchange in Western Melanesia. *Annual Review of Anthropology* 20:141–165.

1991b Lapitoid Settlements of Futuna and Alofi, Western Polynesia. *Archaeology in Oceania* 16:127–143.

1993 The To'aga Site: Modelling the Morphodynamics of the Land–Sea Interface. In *The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa*, edited by P. V. Kirch and T. L. Hunt, pp. 31–42. Archaeological Research Facility, Contribution No. 51. University of California, Berkeley.

1995 The Lapita Culture of Western Melanesia in the Context of Austronesian Origins and Dispersal. In *Austronesian Studies Relating to Taiwan*, edited by P. J.-K. Li, C. Tsang, Y.-K. Huang, D. Ho, and C. Tseng, pp. 255–294. Academia Sinica, Taipei.

1996 Tikopia Social Space Revisited. In *Oceanic Culture History: Essays in Honor of Roger Green*, edited by J. Davidson, G. Irwin, F. Leach, A. Pawley, and D. Brown, pp. 257–274. New Zealand Journal of Archaeology Special Publication, Dunedin.

1997 *The Lapita Peoples: Ancestors of the Oceanic World*. Blackwell Publishers, Oxford, UK.

2000 *On the Road of the Winds: An Archaeological History of the Pacific Islands Before European Contact*. University of California Press, Berkeley.

2001a Three Lapita Villages: Excavations at Talepakemalai (ECA), Etakosarai (ECB), and Etakengaroasa (EHB), Eloaua and Emananus Islands. In *Lapita and Its Transformations in Near Oceania: Archaeological Investigations in the Mussau Islands, Papua New Guinea, 1985–1988*, edited by P. V. Kirch, pp. 68–145. University of California Archaeological Research Facility Contribution No. 59. University of California, Berkeley.

2001b A Radiocarbon Chronology for the Mussau Islands. In *Lapita and Its Transformations in Near Oceania: Archaeological Investigations in the Mussau Islands, Papua New Guinea, 1985–1988*, edited by P. V. Kirch, pp. 196–222. University of California Archaeological Research Facility Contribution No. 59. University of California, Berkeley.

2010 Peopling of the Pacific: A Holistic Anthropological Perspective. *Annual Review of Anthropology* 39:131–148.

2019 Five Decades of Lapita Archaeology: A Personal Retrospective. In *Debating Lapita: Distribution, Chronology, Society and Subsistence,* edited by S. Bedford and M. Spriggs, pp. 483–495. Terra Australis 52. Australian National University, Canberra.

Kirch, P. V. (editor)

2001 *Lapita and Its Transformations in Near Oceania: Archaeological Investigations in the Mussau Islands, Papua New Guinea, 1985–1988*. University of California Archaeological Research Facility Contribution No. 59. University of California, Berkeley.

Kirch, P. V., M. S. Allen, V. L. Butler, and T. L. Hunt

1987 Is There an Early Far Western Lapita Province? Sample Size Effects and New Evidence from Eloaua Island. *Archaeology in Oceania* 22:123–127.

Kirch, P. V., and C. Catterall

2001 The Mussau Islands: Natural and Cultural Environments. In *Lapita and Its Transformations in Near Oceania: Archaeological Investigations in the Mussau Islands, Papua New Guinea, 1985–1988*, edited by P. V. Kirch, pp. 28–56. Contributions of the University of California Archaeological Research Facility No. 59. University of California, Berkeley.

Kirch, P. V., and T. S. Dye

1979 Ethno-Archaeology and the Development of Polynesian Fishing Strategies. *Journal of the Polynesian Society* 88:53–76.

Kirch, P. V., and R. C. Green

2001 *Hawaiki, Ancestral Polynesia: An Essay in Historical Anthropology*. Cambridge University Press, Cambridge, UK.

Kirch, P. V., and T. L. Hunt

1988a The Spatial and Temporal Boundaries of Lapita. In *Archaeology of the Lapita Cultural Complex: A Critical Review*, edited by P. V. Kirch and T. L. Hunt, pp. 9–32. Thomas Burke Memorial Washington State Museum Research Report No. 5. The Burke Museum, Seattle, Washington.

1988b Radiocarbon Dates from the Mussau Islands and the Lapita Colonization of the Southwestern Pacific. *Radiocarbon* 30:161–169.

Kirch, P. V., and T. L. Hunt (editors)

1988 *Archaeology of the Lapita Cultural Complex: A Critical Review*. Thomas Burke Memorial Washington State Museum Research Report No. 5. The Burke Museum, Seattle, Washington.

Kirch, P. V., T. L. Hunt, M. Weisler, V. Butler, and M. S. Allen

1991 Mussau Islands Prehistory: Results of the 1985–86 Excavation. In *Report of the Lapita Homeland Project*, edited by J. Allen and C. Gosden, pp. 144–163. Occasional Papers in Prehistory No. 20. Department of Prehistory, Research School of Pacific Studies, Canberra.

Kirch, P. V., and S. J. O'Day

2003 New Archaeological Insights into Food and Status: A Case Study from Pre-Contact Hawaii. *World Archaeology* 34:484–497.

Kirch, P. V., and P. H. Rosendahl

1976 Early Anutan Settlement and the Position of Anuta in the Prehistory of the Southwest Pacific. In *Southeast Solomon Islands Cultural History: A Preliminary Survey*, edited by R. C. Green and M. Cresswell, pp. 225–244. Royal Society of New Zealand Bulletin 11. Royal Society of New Zealand, Wellington.

Kirch, P. V., D. R. Swindler, and C. G. Turner II

1989 Human Skeletal and Dental Remains from Lapita Sites (1600–500 BC) in the Mussau Islands, Melanesia. *American Journal of Physical Anthropology* 79:63–76.

Kirch, P. V., and D. E. Yen

1982 *Tikopia: The Prehistory and Ecology of a Polynesian Outlier*. Bernice P. Bishop Museum Bulletin 238. Bishop Museum Press, Honolulu, Hawaii.

Kobayashi, H.

1975 The Experimental Study of Bipolar Flakes. In *Lithic Technology: Making and Using Stone Tools*, edited by E. H. Swanson, pp. 115–127. Mouton Publishers, The Hague.

Kononenko, N.

2011 *Experimental and Archaeological Studies of Use-Wear and Residues on Obsidian Artefacts from Papua New Guinea*. Technical Reports of the Australian Museum Online 21. http://dx.doi.org/10.3853/j.1835-4211.21. 2011.1559.

2012 Middle and Late Holocene Skin-Working Tools in Melanesia: Tattooing and Scarification? *Archaeology in Oceania* 47:14–28.

Kononenko, N., R. Torrence, and P. Sheppard

2016 Detecting Early Tattooing in the Pacific Region Through Experimental Usewear and Residue Analyses of Obsidian Tools. *Journal of Archaeological Research, Reports* 8:147–163.

Lambrides, A. B. J., and M. I. Weisler

2015 Assessing Protocols for Identifying Pacific Island Archaeological Fish Remains: The Contribution of Vertebrae. *International Journal of Osteoarchaeology* 25:838–848.

2016 Ichthyoarchaeology: Implications for the Development of Prehistoric Fishing Studies and Global Sustainability. *Journal of Archaeological Research* 24:275–324.

Larson, G., T. Cucchi, M. Fujita, E. Matisoo-Smith, J. Robins, A. Anderson, B. Rolett, M. Spriggs, G. Dolman, T.-H. Kim, N. T. D. Thuy, E. Randi, M. Doherty, R. A. Due, R. Bollt, T. Djubiantono, B. Griffin, M. Intoh, E. Keane, P. Kirch, K.-T. Li, M. Morwood, L. M. Pedrina, P. J. Piper, R. J. Rabett, P. Shooter, G. Van den Bergh, E. West, S. Wickler, J. Yuan, A. Cooper, and K. Dobney

2007 Phylogeny and Ancient DNA of *Sus* Provides Insights into Neolithic Expansion in Island Southeast Asia and Oceania. *Proceedings of the National Academy of Sciences, U.S.A.* 104:4834–4839.

Lawlor, I.

1978 An Analysis of Chert and Obsidian Lithic Material from the Southeast Solomons Lapita Sites BS-SZ-8, BS-RF-2 and BS-RF-6. Manuscript on file, Department of Anthropology, University of Auckland, New Zealand.

Leach, B. F.

1986 A Method for the Analysis of Pacific Island Fish Bone Assemblages and Associated Database Management System. *Journal of Archaeological Science* 13:147–159.

Leach, B. F., and J. Davidson

1988 The Quest for the Rainbow Runner: Prehistoric Fishing on Kapingamarangi and Nukuoro Atolls, Micronesia. *Micronesica* 21:1–22.

2000 Fishing: A Neglected Aspect of Oceanic Economy. In *Australian Archaeologist: Collected Papers in Honour of Jim Allen*, edited by A. Anderson and T. Murray, pp. 412–426. Center for Archaeological Research and Department of Archaeology and Natural History, Australian National University, Canberra.

2001 The Use of Size-Frequency Diagrams to Characterize Prehistoric Fish Catches and to Assess Human Impacts on Inshore Fisheries. *International Journal of Osteoarchaeology* 11:150–162.

Leach, B. F., and H. Leach (editors)

1979 *Prehistoric Man in Palliser Bay*. National Museum of New Zealand Bulletin 21. Wellington, New Zealand.

Lebot, V., and J. Levesque

1989 The Origin and Distribution of Kava (*Piper methysticum* Forst. f., Piperaceae): A Phytochemical Approach. *Allertonia* 5:223–281.

Leenhouts, P. W.

1955 *The Genus* Canarium *in the Pacific*. Bernice P. Bishop Museum Bulletin 216. Bishop Museum Press, Honolulu, Hawaii.

Lepofsky, D.

1992 Arboriculture in the Mussau Islands, Bismarck Archipelago. *Economic Botany* 46:192–211.

Lepofsky, D., P. V. Kirch, and K. Lertzman

1998 Metric Analyses of Prehistoric Morphological Change in Cultivated Fruits and Nuts: An Example from Island Melanesia. *Journal of Archaeological Science* 25:1001–1014.

Lévi-Strauss, C.

1982 *The Way of the Masks*. Translated by Sylvia Modelski. University of Washington Press, Seattle.

Lilley, I.

1986 Prehistoric Exchange Across the Vitiaz Strait, Papua New Guinea. PhD dissertation, Department of Prehistory, Australian National University, Canberra.

Lindley, D.

1988 Early Cainozoic Stratigraphy and Structure of the Gazelle Peninsula, East New Britain: An Example of Extensional Tectonics in the New Britain Arc-Trench Complex. *Australian Journal of Earth Sciences* 35:231–244.

Lindstrom, A. J., K. D. Hill, and L. C. Stanberg

2009 The Genus *Cycas* (Cycadaceae) in Indonesia. *Telopia* 12:385–418.

Lipson, M., P. Skoglund, et al. (28 others)

2018 Population Turnover in Remote Oceania Shortly After Initial Settlement. *Current Biology* 28:1–9.

Loveridge, A.

1946 *Reptiles of the Pacific World*. MacMillan, New York.

Lowder, G. G., and I. Carmichael

1970 The Volcanoes and Caldera of Talasea, New Britain: Geology and Petrology. *Geological Society of America Bulletin* 81:17–38.

Lyman, R. L.

2008 *Quantitative Paleozoology*. Cambridge University Press, New York.

Malinowski, B.

1922 *Argonauts of the Western Pacific: An Account of Native Enterprise and Adventure in the Archipelagoes of Melanesian New Guinea*. George Routledge & Sons, London.

Marshall, T. C.

1964 *Fishes of the Great Barrier Reef.* Angus and Robertson, Sydney.

Martinez, F., and B. Taylor

1996 Backarc Spreading, Rifting, and Microplate Rotation Between Transform Faults in the Manus Basin. *Marine Geophysical Researches* 18:203–224.

Masse, W. B.

1986 A Millennium of Fishing in the Palau Islands, Micronesia. In *Traditional Fishing in the Pacific: Ethnographical and Archaeological Papers from the 15th Pacific Science Congress*, edited by A. Anderson, pp. 85–117. Pacific Anthropological Records 37. Bernice P. Bishop Museum, Honolulu, Hawaii.

1989 The Archaeology and Ecology of Fishing in the Belau Islands, Micronesia. PhD dissertation, Department of Anthropology, Southern Illinois University, Carbondale.

Masse, W. B., J. Liston, J. Carucci, and J. S. Athens

2006 Evaluating the Effects of Climate Change on Environment, Resource Depletion, and Culture in the Palau Islands Between AD 1200 and 1600. *Quaternary International* 151:106–132.

Masuda, H.

1975 *Coastal Fishes of Southern Japan.* Tokai University Press, Tokyo.

Matthews, P. J., and C. Gosden

1997 Plant Remains from Waterlogged Sites in the Arawe Islands, West New Britain Province, Papua New Guinea: Implications for the History of Plant Use and Domestication. *Economic Botany* 51:121–133.

May, P., and M. Tuckson

1982 *The Traditional Pottery of Papua New Guinea*. Bay Books, Sydney, Australia.

Mayr, E.

1997 *This Is Biology: The Science of the Living World*. Harvard University Press, Cambridge, Massachusetts.

McAlpine, J. R., and G. Keig, with R. Falls

1983 *Climate of Papua New Guinea*. Australian National University Press, Canberra.

McCoy, P. C.

1982 Manufacturing Technology. In *Tikopia: The Prehistory and Ecology of a Polynesian Outlier*, by P. V. Kirch and D. E. Yen, pp. 261–269. Bernice P. Bishop Museum Bulletin 238. Bishop Museum Press, Honolulu, Hawaii.

McCoy, P. C., and P. C. Cleghorn

1988 Archaeological Excavations on Santa Cruz (Nendo), Southeast Solomon Islands: Summary Report. *Archaeology in Oceania* 23:104–115.

McKern, W. C.

1929 *Archaeology of Tonga*. Bernice P. Bishop Museum Bulletin 60. Bishop Museum Press, Honolulu, Hawaii.

McKinnon, S.

1991 *From a Shattered Sun: Hierarchy, Gender, and Alliance in the Tanimbar Islands*. University of Wisconsin Press, Madison.

McLean, R. F.

1980 The Land–Sea Interface of Small Tropical Islands: Morphodynamics and Man. In *Population–Environment Relations in Tropical Islands: The Case of Eastern Fiji*, edited by H. Brookfield, pp. 125–130. MAB Technical Note No. 13. UNESCO, Paris.

Mead, S. M., L. Birks, H. Birks, and E. Shaw

1975 *The Lapita Pottery Style of Fiji and Its Associations*. Polynesian Society Memoir No. 38. The Polynesian Society, Wellington, New Zealand.

Merrill, E. D.

1945 *Plant Life of the Pacific World*. The MacMillan Co., New York.

Meyer, A. B.

1900 Speere von der Insel St. Matthias im Bismarck-Archipel. *Globus: Illustrierte Zeitschrift für Länder- und Völkerkunde* 78:178–179.

Meyer, O.

1909 Funde prähistorischer Töpferei und Steinmesser auf Vuatom, Bismarck Archipel. *Anthropos* 4:215–252, 1093–1095.

1910 Funde von Menschen- und Tierkochen, von prähistorischer Töpferei und Steinwerkzeugen auf Vuatom, Bismarck-Archipel. *Anthropos* 5:1160–1161.

Miller, L. J.

1997 Mollusk Exploitation and Paleoenvironmental Change in the Kone Region: A Reanalysis of the Site 13 Mollusk Assemblage. *Kroeber Anthropological Society Papers* 82:25–37.

Miyata, T., Y. Maeda, E. Matsumoto, Y. Matsushima, P. Rodda, A. Sugimura, and H. Kayanne

1990 Evidence for a Holocene High Sea-Level Stand, Vanua Levu, Fiji. *Quaternary Research* 33:352–359.

Montaggioni, L. F., and P. A. Pirazzoli

1984 The Significance of Exposed Coral Conglomerates from French Polynesia (Pacific Ocean) as Indicators of Recent Relative Sea-Level Changes. *Coral Reefs* 3:29–42.

Munro, I. S. R.

1967 *The Fishes of New Guinea*. Department of Agriculture, Stock and Fisheries, Port Moresby, Papua New Guinea.

Myers, R. F.

1989 *Micronesian Reef Fishes*. Coral Graphics, Guam.

Nagaoka, L.

1988 Lapita Subsistence: The Evidence of Non-Fish Archaeofaunal Remains. In *Archaeology of the Lapita Cultural Complex: A Critical Review*, edited by P. V. Kirch and T. L. Hunt, pp. 117–134. The Burke Museum, Seattle, Washington.

1994 Differential Recovery of Pacific Island Fish Remains: Evidence from the Moturakau Rockshelter, Aitutaki, Cook Islands. *Asian Perspectives* 33:1–17.

2005 Differential Recovery of Pacific Island Fish Remains. *Journal of Archaeological Science* 32:941–955.

Nelson, J. S., T. C. Grande, and M. V. H. Wilson

2016 *Fishes of the World*. 5th ed. John Wiley & Sons, Hoboken, New Jersey.

Nevermann, H.

1933 St. Matthias-Gruppe. In *Ergebnisse der Südsee-Expedition 1908–1910, Part II. Ethnographie: A. Melanesien, Band 2*, edited by G. Thilenius. Friederichsen, de Gruyter & Co., Hamburg.

NOAA (National Oceanic and Atmospheric Administration)

1987 *Tide Tables 1988: High and Low Water Predictions. Central and Western Pacific Ocean and Indian Ocean*. U. S. Department of Commerce, Riverdale, Maryland.

Nunn, P.

1990 Coastal Processes and Landforms of Fiji: Their Bearing on Holocene Sea-Level Changes in the South and West Pacific. *Journal of Coastal Research* 6:279–310.

2007 Echoes from a Distance: Research into the Lapita Occupation of the Rove Peninsula, Southwest Viti Levu, Fiji. *Oceanic Explorations 2007*:63.

Nunn, P. D., T. Ishimura, W. R. Dickinson, K. Katayama, F. Thomas, R. Kumar, S. Matararaba, J. Davidson, and T. Worthy

2007 The Lapita Occupation at Naitabale, Moturiki Island, Central Fiji. *Asian Perspectives* 46:96–132.

O'Connor, S., R. Ono, and C. Clarkson

2011 Pelagic Fishing at 42,000 Years Before the Present and the Maritime Skills of Modern Humans. *Science* 334:1117–1121.

Ono, R., and G. Clark

2010 A 2500-year Record of Marine Resource Use on Ulong Island, Republic of Palau. *International Journal of Osteoarchaeology* 22:637–654.

Ono, R., and M. Intoh

2011 Island of Pelagic Fishermen: Temporal Changes in Prehistoric Fishing on Fais, Micronesia. *Journal of Island and Coastal Archaeology* 6:155–286.

Orliac, C., and A. Plu

1988a Déterminations botaniques de bois et de charbons de bois provenant du site Lapita de Talepakemalai (Ile d'Eloaua, Groupe de Mussau, Archipel Bismark). Manuscript report on file, Oceanic Archaeology Laboratory, University of Hawai'i, Manoa.

1988b Utilization and Exploitation of Wood at the Talepakemalai Site: Results of SEM Identification of Preserved Wood from ECA. Manuscript report on file, Oceanic Archaeology Laboratory, University of Hawai'i, Manoa.

Page, R. W., and R. J. Ryburn

1977 K-Ar Ages and Geological Relations of Intrusive Rocks in New Britain. *Pacific Geology* 12:99–105.

Paijmans, K. (editor)

1976 *New Guinea Vegetation*. Australian National University Press, Canberra.

Palmer, J. B., E. Shaw, P. Dickinson, and M. Sykes

1968 Pottery Making in Sigatoka, Fiji. *Records of the Fiji Museum* 1(3):45–79.

Parham, J. W.

1972 *Plants of the Fiji Islands*. Government Printer, Suva, Fiji.

Parkinson, R.

1901 Die Einwohner der Insel St. Matthias (Bismarck-Archipel). *Globus: Illustrierte Zeitschrift für Länder- und Völkerkunde* 79:229–233, 256.

1905 St. Matthias und die Inseln Kerué und Tench. *Globus: Illustrierte Zeitschrift für Länder- und Völkerkunde* 88:69–72.

1907 *Dreißig Jahre in der Südsee: Land und Leute, Sitten und Gebräuche im Bismarckarchipel und auf den Deutschen Salomoninseln*. Strecker & Schröder, Stuttgart.

Parry, W. J., and R. L. Kelly

1987 Expedient Core Technology and Sedentism. In *The Organization of Core Technology*, edited by J. K. Johnson and C. A. Morrow, pp. 285–304. Westview Press, Boulder, Colorado.

Partlow, M. A.

2006 Sampling Fish Bones: A Consideration of the Importance of Screen Size and Disposal Context in the North Pacific. *Arctic Anthropology* 43:67–79.

Pawley, A., and R. C. Green

1984 The Proto-Oceanic Language Community. *The Journal of Pacific History* 19:123–146.

Peekel, P. G.

1984 *Flora of the Bismarck Archipelago for Naturalists*. Translated by E. E. Henty. Office of Forests, Lae, Papua New Guinea.

Petchy, F., and S. Ulm

2012 Marine Reservoir Variation in the Bismarcks Region: An Evaluation of Spatial and Temporal Change in ΔR and R over the Last 3000 Years. *Radiocarbon* 54:45–58.

Pirazzoli, P. A., and L. F. Montaggioni

1986 Late Holocene Sea-Level Changes in the Northwest Tuamotu Islands, French Polynesia. *Quaternary Research* 25:350–368.

1988 Holocene Sea-Level Changes in French Polynesia. *Paleogeography*, *Paleoclimatology, Paleoecology* 68:153–175.

Plog, F.

1977 Modeling Economic Exchange. In *Exchange Systems in Prehistory*, edited by T. K. Earle and J. E. Ericson, pp. 127–140. Academic Press, New York.

Poiner, I. R., and C. P. Catterall

1988 The Effects of Traditional Gathering on *Strombus luhuanus* Linne, 1758, Populations in Southern Papua New Guinea. *Oecologia* 76:191–199.

Posth, C., et al. (28 others)

2018 Language Continuity Despite Population Replacement in Remote Oceania. *Nature Ecology and Evolution* 2:731–740.

Poulsen, J.

1968 Archaeological Excavations on Tongatapu. In *Prehistoric Culture in Oceania*, edited by I. Yawata and Y. H. Sinoto, pp. 85–92. Bishop Museum Press, Honolulu, Hawaii.

1987 *Early Tongan Prehistory: The Lapita Period on Tongatapu and Its Relationships.* 2 vols. Terra Australis 12. Australian National University, Canberra.

Poutiers, J. M.

1998 Gastropods. In *FAO Species Identification Guide for Fishery Purposes: The Living Marine Resources of the Western Central Pacific*. Vol, 1, *Seaweeds, Corals, Bivalves, and Gastropods*, edited by K. E. Carpenter and V. H. Niem, pp. 263–648. United Nations Food and Agriculture Organization, Rome.

Reepmeyer, C., M. Spriggs, S. Bedford, and W. Ambrose

2010 Provenance and Technology of Lithic Artifacts from the Teouma Lapita Site, Vanuatu. *Asian Perspectives* 49:205–225.

Reimer, P. J., and 29 co-authors

2013 IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years Cal BP. *Radiocarbon* 55:1869–1887.

Reinman, F. M.

1967 *Fishing: An Aspect of Oceanic Economy*. Fieldiana: Anthropology Vol. 56(2). Field Museum of Natural History, Chicago.

Reitz, E. J., and E. S. Wing

1999 *Zooarchaeology*. Cambridge University Press, Cambridge, UK.

2008 *Zooarchaeology*. 2nd ed. Cambridge University Press, Cambridge, UK.

Reynolds, J. P.

1972 New Ireland District. In *Encyclopaedia of Papua New Guinea*, Vol. 2, edited by P. Ryan, pp. 847–859. Melbourne University Press, Melbourne, Australia.

Reynolds, M. A., and J. G. Best

1976 Summary of the 1953–57 Eruption of Tuluman Volcano, Papua New Guinea. In *Volcanism in Australia*, edited by R. W. Johnson, p. 287. Elsevier, Amsterdam.

Rieth, T. M., and J. S. Athens

2017 Late Holocene Human Expansion into Near and Remote Oceania: A Bayesian Model of the Chronologies of the Mariana Islands and Bismarck Archipelago. *Journal of Island and Coastal Archaeology* 14:5–16.

Rivers, W. H. R.

1914 *The History of Melanesian Society*. 2 vols. Cambridge University Press, Cambridge, UK.

Rodda, P.

1988 Visit to Western Samoa with HIPAC Team. In *Sea Level Change and Tectonics in the Middle Pacific: Report of the HIPAC Project in 1986 and 1987*, edited by N. Yonekura, pp. 85–90. Department of Geography, University of Tokyo.

Ross, M.

1988 *Proto Oceanic and the Austronesian Languages of Western Melanesia*. Pacific Linguistics, Series C-98. Australian National University, Canberra.

1989 Early Oceanic Linguistic Prehistory. *Journal of Pacific History* 24:135–149.

1995 Some Current Issues in Austronesian Linguistics. In *Comparative Austronesian Dictionary*, Part 1, edited by D. T. Tryon, pp. 45–120. Mouton de Gruyer, Berlin.

Ross, M., A. Pawley, and M. Osmond (editors)

2008 *The Lexicon of Proto Oceanic: The Culture and Environment of Ancestral Oceanic Society: 3. Plants*. Australian National University, Canberra.

2011 *The Lexicon of Proto Oceanic: The Culture and Environment of Ancestral Oceanic Society: 4. Animals*. Australian National University, Canberra.

Ross-Sheppard, C., C. Sand, J. Balenaivalu, and D. V. Burley

2013 Kutau/Bao Obsidian—Extending Its Eastern Distribution into the Fijian Northeast. *Journal of Pacific Archaeology* 4(2):79–83.

Rye, O. S.

1981 *Pottery Technology: Principles and Reconstruction*. Taraxacum, Washington, DC.

Sahlins, M.

1963 Poor Man, Rich Man, Big-Man, Chief: Political Types in Melanesia and Polynesia. *Comparative Studies in Society and History* 5:285–303.

Sand, C.

1996 *Le début du peuplement Austronésien de la Nouvelle-Calédonie: Données archéologiques récentes*. Les Cahiers de l'Archéologie en Nouvelle-Calédonie. Nouméa: Département Archéologie, Service des Musées et du Patrimoine de Nouvelle-Calédonie, Nouméa, New Caledonia.

1997 The Chronology of Lapita Ware in New Caledonia. *Antiquity* 71:539–547.

2007 Looking at the Big Motifs: A Typology of the Central Band Decorations of the Lapita Ceramic Tradition of New Caledonia (Southern Melanesia) and Preliminary Regional Comparisons. In *Oceanic Explorations: Lapita and Western Pacific Settlement*, edited by S. Bedford, C. Sand, and S. P. Connaughton, pp. 265–288. Australian National University, Canberra.

2010 *Lapita calédonien: Archéologie d'un premier peuplement insulaire océanien*. Société des Océanistes, Paris.

Sand, C., and P. V. Kirch

2002 *L'Expédition archéologique d'Edward W. Gifford et Richard Shutler, Jr. en Nouvelle-Calédonie au cours de l'année 1952. Edward W. Gifford and Richard Shutler Jr's Archaeological Expedition to New Caledonia in 1952.* Les Cahiers de l'Archéologie en Nouvelle-Calédonie Vol. 13. Service des Musées du Patrimoine de Nouvelle-Calédonie, Nouméa, New Caledonia.

Sasaki, K.

1989 Phylogeny of the Family Sciaenidae, with Notes on Its Zoogeography (Teleosti, Perciformes). *Memoirs of the Faculty of Fisheries, Hokkaido University* 361(1/2):1–137.

Scaglion, R.

1996 Chiefly Models in Papua New Guinea. *The Contemporary Pacific* 8:1–31.

Seeto, J., P. D. Nunn, and S. Sanjana

2012 Human-Mediated Prehistoric Marine Extinction in the Tropical Pacific? Understanding the Presence of *Hippopus hippopus* (Linn. 1758) in Ancient Shell Middens on the Rove Peninsula, Southwest Viti Levu Island, Fiji. *Geoarchaeology* 27:2–17.

Service, R. F.

1996 Rock Chemistry Traces Ancient Traders. *Science* 274:2012–2013.

Shackley, M. L.

1975 *Archaeological Sediments*. Wiley and Sons, New York.

Sharp, N.

1988 Style and Substance: A Reconsideration of the Lapita Decorative System. In *Archaeology of the Lapita Cultural Complex: A Critical Review*, edited by P. V. Kirch and T. L. Hunt, pp. 61–82. Thomas Burke Memorial Washington State Museum Research Report No. 5. The Burke Museum, Seattle, Washington.

Shepard, A. O.

1965 *Ceramics for the Archaeologist*. Carnegie Institution of Washington, Washington, DC.

Shepard, F. P.

1963 Thirty-Five Thousand Years of Sea Level. In *Essays in Marine Geology in Honor of K. O. Emery, University of Southern California*, edited by T. Clements. Los Angeles: University of California Press, Los Angeles.

Sheppard, P. J.

1993 Lapita Lithics: Trade/Exchange and Technology. A View from the Reefs/Santa Cruz. *Archaeology in Oceania* 28:121–137.

2010 Lapita Stone Tool Technology. In *Lapita: Ancêtres océaniens/Oceanic Ancestors*, edited by C. Sand, S. Bedford, and C. Chambonniere, pp. 240–250. Somogy, Paris.

Sheppard, P. J., S. Chiu, and R. Walter

2015 Re-Dating Lapita Movement into Remote Oceania. *Journal of Pacific Archaeology* 6:26–36.

Sheppard, P. J., and R. C. Green

1991 Spatial Analysis of the Nenumbo (SE-RF-2) Lapita Site, Solomon Islands. *Archaeology in Oceania* 26:89–101.

Sheppard, P., B. Trichereau, and C. Milicich

2010 Pacific Obsidian Sourcing by Portable XRF. *Archaeology in Oceania* 45:21–30.

Shott, M.

1989 Bipolar Industries: Ethnographic Evidence and Archaeological Implications. *North American Archaeologist* 10:1–24.

Siméoni, P., and V. Lebot

2014 *Buveurs de Kava*. Editions Géo-Consulte, Port Vila, Vanuatu.

Skoglund, P., et al. (30 others)

2016 Genomic Insights into the Peopling of the Southwest Pacific. *Nature* 538:510–513.

Smith, I. E. M., and R. W. Johnson

1981 Contrasting Rhyolite Suites in the Late Cenozoic of Papua New Guinea. *Journal of Geophysical Research* 86:10257–10372.

Solheim, W. G., II

1964 *The Archaeology of the Central Philippines*. Bureau of Printing, Manila, Philippines.

Specht, J.

1968 Prehistoric and Modern Pottery Industries of Buka Island, T. P. N. G. PhD dissertation, Department of Prehistory, Australian National University, Canberra.

1972 The Pottery Industry of Buka Island, T.P.N.G. *Archaeology and Physical Anthropology in Oceania* 7:125–144.

1981 Obsidian Sources at Talasea, West New Britain, Papua New Guinea. *Journal of the Polynesian Society* 90:337–356.

1985 Crabs as Disturbance Factors in Tropical Archaeological Sites. *Australian Archaeology* 12:13–15.

1991 Kreslo: A Lapita Pottery Site in Southwest New Britain, Papua New Guinea. In *Report of the Lapita Homeland Project*, edited by J. Allen and C. Gosden, pp. 189–204. Occasional Papers in Prehistory No. 20. Department of Prehistory, Australian National University, Canberra.

2002 Obsidian, Colonising and Exchange. In *Fifty Years in the Field: Essays in Honour and Celebration of Richard Shutler Jr's Archaeological Career*, edited by S. Bedford, C. Sand, and D. Burley, pp. 37–49. New Zealand Archaeological Association, Monograph 25. New Zealand Archaeological Association, Auckland.

2007 Small Islands in the Big Picture. In *Oceanic Explorations: Lapita and Western Pacific Settlement*, edited by S. Bedford, C. Sand, and S. P. Connaughton, pp. 51–70. Terra Australis 26. Australian National University, Canberra.

Specht, J., T. Denham, J. Goff, and J. E. Terrell

2014 Deconstructing the Lapita Cultural Complex in the Bismarck Archipelago. *Journal of Archaeological Research* 22:89–140.

Specht, J., and C. Gosden

1997 Dating Lapita Pottery in the Bismarck Archipelago, Papua New Guinea. *Asian Perspectives* 36:175–199.

2019 New Dates for the Makekur (FOH) Lapita Pottery Site, Arawe Islands, New Britain, Papua New Guinea. In *Debating Lapita: Distribution, Chronology, Society and Subsistence*, edited by S. Bedford and M. Spriggs, pp. 169–202. Terra Australis 52. Australian National University, Canberra.

Specht, J., and J. D. Hollis

1982 A New Obsidian Source in West New Britain, Papua New Guinea. *Mankind* 13(5):424–427.

Specht, J., R. Fullagar, R. Torrence, and N. Baker

1988 Prehistoric Obsidian Exchange in Melanesia: A Perspective from the Talasea Sources. *Australian Archaeology* 27:3–16.

Spennemann, D. H. R.

1987 Availability of Prehistoric Shellfish Resources on Prehistoric Tongatapu, Tonga: Effects of Human Predation and Changing Environment. *Archaeology in Oceania* 22:81–96.

Spriggs, M. J. T.

1984 The Lapita Cultural Complex: Origins, Distribution, Contemporaries and Successors. *Journal of Pacific History* 19:202–223.

1990a Dating Lapita: Another View. In *Lapita Design, Form and Composition*, edited by M. Spriggs, pp. 6–27. Occasional Papers in Prehistory No. 19. Department of Prehistory, Australian National University, Canberra.

1990b The Changing Face of Lapita: Transformation of a Design. In *Lapita Design, Form and Composition*, edited by M. Spriggs, pp. 83–122. Occasional Papers in Prehistory No. 19. Department of Prehistory, Australian National University, Canberra.

1991 Nissan, the Island in the Middle: Summary Report on Excavations at the North End of the Solomons and the South End of the Bismarcks. In *Results of the Lapita Homeland Project*, edited by J. Allen and C. Gosden, pp. 222–243. Occasional Papers in Prehistory No. 20. Department of Prehistory, Australian National University, Canberra.

1993a. How Much of the Lapita Design System Represents the Human Face? In *Artistic Heritage in a Changing Pacific*, edited by P. J. C. Dark and R. G. Rose, pp. 7–14. University of Hawaii Press, Honolulu.

1993b Island Melanesia: The Last 10,000 Years. In *Sahul in Review: Pleistocene Archaeology in Australia, New Guinea, and Island Melanesia*, edited by M. A. Smith, M. Spriggs, and B. Fankhauser, pp. 187–205. Occasional Papers in Prehistory No. 24. Department of Prehistory, Australian National University, Canberra.

1997 *The Island Melanesians*. Blackwell Publishers, Oxford, UK.

2019 The Hat Makes the Man: Masks, Headdresses, and Skullcaps in Lapita Iconography. In *Debating Lapita: Distribution, Chronology, Society and Subsistence*, edited by S. Bedford and M. Spriggs, pp. 257–273. Terra Australis 52. Australian National University, Canberra.

Spriggs, M. J. T., and D. Reich

2019 An Ancient DNA Pacific Journey: A Case Study of Collaboration Between Archaeologists and Geneticists. *World Archaeology* 51:620–629.

Steadman, D. W., and P. V. Kirch

1998 Biogeography and Prehistoric Exploitation of Birds in the Mussau Islands, Bismarck Archipelago, Papua New Guinea. *Emu* 98:13–22.

Stein, J. K.

1985 Interpreting Sediments in Cultural Settings. In *Archaeological Sediments in Context*, edited by J. K. Stein and W. R. Farrand, pp. 5–20. Center for the Study of Early Man, University of Maine, Orono.

1987 Deposits for Archaeologists. *Advances in Archaeological Theory and Method* 11:337–396.

Stewart, W. D., and M. J. Sandy

1986 *Cenozoic Stratigraphy and Structure of New Ireland and Djual Island, New Ireland Province, Papua New Guinea*. Geological Survey of Papua New Guinea, Report No. 86/12. Department of Minerals and Energy, Port Moresby, Papua New Guinea.

1988 Geology of New Ireland and Djaul Islands, Northeastern Papua New Guinea. In *Geology and Offshore Resources of Pacific Island Arcs—New Ireland and Manus Region, Papua New Guinea*, edited by M. S. Marlow, S. V. Dadisman, and N. F. Exon, pp. 13–30. Circum-Pacific Council for Energy and Mineral Resources Vol. 9. Circum-Pacific Council for Energy and Mineral Resources, Houston.

Stoddart, D. R.

1992 Biogeography of the Tropical Pacific. *Pacific Science* 46:276–293.

Stuiver, M., and T. F. Braziunas

1993 Modelling Atmospheric ^{14}C Influences and ^{14}C Ages of Marine Samples to 10,000 BC. *Radiocarbon* 35:137–189.

Stuiver, M., G. W. Pearson, and T. Braziunas

1986 Radiocarbon Age Calibration of Marine Samples back to 9000 Cal Yr BP. *Radiocarbon* 28(2B):980–1021.

Suggs, R. C.

1961 *The Archaeology of Nuku Hiva, Marquesas Islands, French Polynesia.* Anthropological Papers of the American Museum of Natural History, Volume 49, Part 1. American Museum of Natural History, New York.

Summerhayes, G. R.

2000a *Lapita Interaction*. Terra Australis 15. Australian National University, Canberra.

2000b Recent Archaeological Investigations in the Bismarck Archipelago, Anir–New Ireland Province, Papua New Guinea. *Indo-Pacific Prehistory Association Bulletin* 19:167–174.

2001a Lapita in the Far West: Recent Developments. *Archaeology in Oceania* 36:53–63.

2001b Defining the Chronology of Lapita in the Bismarck Archipelago. In *The Archaeology of Lapita Dispersal in Oceania*, edited by G. R. Clark, A. J. Anderson, and T. Vunidilo, pp. 25–38. Terra Australis 17. Australian National University, Canberra.

2003 The Rocky Road: The Selection and Transport of Admiralties Obsidian to Lapita Communities. *Australian Archaeology* 57:135–142.

2004 The Nature of Prehistoric Obsidian Importation to Anir and the Development of a 3,000-Year-Old Regional Picture of Obsidian Exchange Within the Bismarck Archipelago, Papua New Guinea. *Records of the Australian Museum Supplement* 29:145–156.

2007a The Rise and Transformations of Lapita in the Bismarck Archipelago. In *From Southeast Asia to the Pacific: Archaeological Perspectives on the Austronesian Expansion and the Lapita Cultural Complex*, edited by S. Chiu and C. Sand, pp. 141–169. Academia Sinica, Taipei, Taiwan.

2007b Island Melanesian Pasts: A View from Archaeology. In *Genes, Language, and Culture History in the Southwest Pacific*, edited by J. S. Friedlaender, pp. 10–35. Oxford University Press, Oxford, UK.

2009 Obsidian Network Patterns in Melanesia: Sources, Characterization and Distribution. *Bulletin of the Indo-Pacific Prehistory Association* 29:109–123.

2010 The Emergence of the Lapita Cultural Complex in the Bismarck Archipelago. In *Lapita: Oceanic Ancestors*, edited by C. Sand and S. Bedford, pp. 92–101. Musée du Quai Branly, Paris.

Summerhayes, G. R., and J. Allen

1993 The Transport of Mopir Obsidian to Late Pleistocene New Ireland. *Archaeology in Oceania* 28:144–148.

Summerhayes, G. R., J. R. Bird, R. Fullagar, C. Gosden, J. Specht, and R. Torrence

1998 Application of PIXE-PIGME to Archaeological Analysis of Changing Patterns of Obsidian Use in West New Britain, Papua New Guinea. In *Advances in Obsidian Glass Studies*, edited by S. Shackley, pp. 129–158. Plenum Press, New York.

Summerhayes, G. R., C. Gosden, R. Fullagar, J. Specht, R. Torrence, J. R. Bird, N. Shahgholi, and A. Katasaros

1993 West New Britain Obsidian: Production and Consumption Patterns. In *Archaeometry: Current Australian Research*, edited by B. L. Fankhauser and J. R. Bird, pp. 57–68. Occasional Papers in Prehistory No. 22. Australian National University, Canberra.

Summerhayes, G. R., and M. Hotchkis

1992 Recent Advances in Melanesian Obsidian Sourcing: Results of the 1990 and 1991 PIXE/PIGME Analyses. In *Poterie Lapita et peuplement: Actes du Colloque LAPITA*, edited by J.-C. Galipaud, pp. 127–134. ORSTOM, Nouméa, New Caledonia.

Summerhayes, G. R., J. Kennedy, E. Matisoo-Smith, H. Mandui, W. Ambrose, C. Allen, C. Reepmeyer, R. Torrence, and F. Wadra

2014 Lepong: A New Obsidian Source in the Admiralty Islands, Papua New Guinea. *Geoarchaeology* 29:238–248.

Summerhayes, G. R., L. Matisoo-Smith, H. Mandui, J. Allen, J. Specht, N. Hogg, and S. McPherson

2010 Tamuarawai (EQS): An Early Lapita Site on Emirau, New Ireland, PNG. *Journal of Pacific Archaeology* 1:62–75.

Summerhayes, G. R., and I. Scales

2005 New Lapita Pottery Finds from Kolombangara, Western Solomon Islands. *Archaeology in Oceania* 40:14–20.

Summerhayes, G. R., K. Szabó, A. Fairbairn, M. Horrocks, S. McPherson, and A. Crowther

2019 Early Lapita Subsistence: The Evidence from Kamgot, Anir Islands, New Ireland Province, Papua New Guinea. In *Debating Lapita: Distribution, Chronology, Society and Subsistence*, edited by S. Bedford and M. Spriggs, pp. 379–402. Terra Australis 52. Australian National University, Canberra.

Swadling, P.

1976 Changes Induced by Human Exploitation in Prehistoric Shellfish Populations. *Mankind Quarterly* 11:11–18.

1977a Central Province Shellfish Resources and Their Utilization in the Prehistoric Past of PNG. *Veliger* 19:293–302.

1977b Depletion of Shellfish in the Traditional Gathering Beds of Pari. In *The Melanesian Environment*, edited by J. H. Winslow, pp 182–187. Australian National University Press, Canberra.

1986 Lapita Shellfishing: Evidence from Sites in the Reef Santa Cruz Group, Southeast Solomon Islands. In *Traditional Fishing in the Pacific*, edited by A. Anderson, pp. 137–148. Pacific Anthropological Records 37. Bernice P. Bishop Museum, Honolulu, Hawaii.

2017 Analysis of Shellfish Excavated from Square N21/ii. In *Excavations on Motupore Island*, Vol. 2, edited by J. Allen, pp. 451–499. University of Otago Working Papers in Anthropology No. 4 (Vol. 2). Department of Anthropology and Archaeology, University of Otago, Dunedin, New Zealand.

Swindler, D.

[1990] Typescript report on human teeth from site ECA. On file, Oceanic Archaeology Laboratory archives, University of Hawaiʻi, Manoa.

Szabó, K.

2005 Technique and Practice: Shell-Working in the Western Pacific and Island Southeast Asia. PhD dissertation, Department of Archaeology and Natural History, Australian National University, Canberra.

2009 Molluscan Remains from Fiji. In *The Early Prehistory of Fiji*, edited by G. Clark and A. Anderson, pp. 183–214. Terra Australis 31. Australian National University, Canberra.

2010 Shell Artefacts and Shell-Working Within the Lapita Cultural Complex. *Journal of Pacific Archaeology* 1(2):1–13.

Tate, G.

1951 The Rodents of Australia and New Guinea. *American Museum of Natural History Bulletin* 97:189–430.

Taylor, R. E.

1987 *Radiocarbon Dating: An Archaeological Perspective*. Academic Press, New York.

Tcherkezoff, S.

2008 *Polynésie-Mélanésie, l'invention française des "races" et des régions de l'Océanie (XVIe–XXe siecles)*. Au Vent des Îles, Papeete, Tahiti.

Terrell, J.

1986 *Prehistory in the Pacific Islands*. Cambridge University Press, Cambridge, UK.

1989 Commentary: What Lapita Is and What Lapita Isn't. *Antiquity* 63:623.

2018 Understanding Lapita as History. In *The Oxford Handbook of Prehistoric Oceania*, edited by E. E. Cochrane and T. L. Hunt, pp. 112–132. Oxford University Press, Oxford, UK.

Thilenius, G.

1927 *Ergebnisse der Südsee-Expedition 1908–1910*. Vol. I, *Allgemeines*. L. Friederichsen & Co., Hamburg, Germany.

Thomas, N.

1989 The Force of Ethnology: Origins and Significance of the Melanesia/Polynesia Division. *Current Anthropology* 30:27–41.

Thomson, J.-A. R., and J. P. White

2000 Localism of Lapita Pottery in the Bismarck Archipelago. In *Australian Archaeologist: Collected Papers in Honor of Jim Allen*, edited by A. Anderson and T. Murray, pp. 308–323. Coombs Academic Publishing (Australian National University), Canberra.

Titcomb, M.

1952 *Native Use of Fish in Hawaii*. Polynesian Society Memoir 29. The Polynesian Society, Wellington, New Zealand.

Torrence, R.

1992 What Is Lapita About Obsidian? A View from the Talasea Sources. In *Poterie Lapita et peuplement: Actes du Colloque Lapita, Nouméa, Nouvelle Calédonie*, edited by J. C. Galipaud, pp. 111–126. ORSTOM, Nouméa, New Caledonia.

1993 Ethnoarchaeology, Museum Collections and Prehistoric Exchange: Obsidian-Tipped Artifacts from the Admiralty Islands. *World Archaeology* 24:467–481.

2002 What Makes a Disaster? A Long-Term View of Volcanic Eruptions and Human Responses in Papua New Guinea. In *Natural Disasters and Cultural Change*, edited by R. Torrence and J. Grattan, pp. 308–328. Routledge, London.

2004 Now You See It, Now You Don't: Changing Obsidian Source Use in the Willaumez Peninsula, Papua, New Guinea. In *Explaining Social Change: Studies in Honour of Colin Renfrew*, edited by J. Cherry, C. Scarre, and S. Shennan, pp. 115–125. McDonald Institute for Archaeological Research, Cambridge, UK.

Torrence, R., N. Kononenko, P. Sheppard, M. S. Allen, S. Bedford, P. V. Kirch, and M. Spriggs

2018 Tattooing Tools and the Lapita Cultural Complex. *Archaeology in Oceania* 53:58–73.

Torrence, R., C. Pavlides, P. Jackson, and J. Webb

2000 Volcanic Disasters and Cultural Discontinuities in Holocene Time, in West New Britain, Papua New Guinea. *Geological Society, London, Special Publications* 171(1):225–244.

Torrence, R., J. Specht, R. Fullagar, and R. Bird

1992 *From Pleistocene to Present: Obsidian Sources in West New Britain, Papua New Guinea*. Records of the Australian Museum, Supplement 15. The Australian Museum, Sydney.

Torrence, R., J. Specht, R. Fullagar, and G. Summerhayes

1996 Which Obsidian Is Worth It? A View from the West New Britain Sources. In *Oceanic Culture History: Essays in Honour of Roger Green*, edited by J. Davidson, G. Irwin, F. Leach, A. Pawley, and D. Brown, pp. 211–224. New Zealand Archaeological Association, Dunedin, New Zealand.

Torrence, R., and G. R. Summerhayes

1997 Sociality and the Short Distance Trader: Intra-Regional Obsidian Exchange in the Willaumez Region, Papua New Guinea. *Archaeology in Oceania* 32:74–84.

Torrence, R., and K. L. Victor

1995 The Relativity of Density. *Archaeology in Oceania* 30:121–131.

Tracey, J. I., Jr., D. P. Abbott, and T. Arnow

1961 *Natural History of Ifaluk Atoll: Physical Environment*. Bernice P. Bishop Museum Bulletin 222. Bishop Museum Press, Honolulu, Hawaii.

Tromp, M.

2016 Lapita Plants, People and Pigs. PhD dissertation, Department of Anatomy, University of Otago, Dunedin, New Zealand.

Valentin, F., F. Detroit, M. J. T. Spriggs, and S. Bedford

2016 Early Lapita Skeletons from Vanuatu Show Polynesian Craniofacial Shape: Implications for Remote Oceanic Settlement and Lapita Origins. *Proceedings of the National Academy of Sciences, U.S.A.* 113:292–297.

Valentin, F., M. Spriggs, S. Bedford, and H. Buckley

2011 Vanuatu Mortuary Practices over Three Millennia: Lapita to the Early European Contact Period. *Journal of Pacific Archaeology* 2(2):49–65.

van Balgooy, M. M. J.

1971 Plant Geography of the Pacific, as Based on the Distribution of Phanerogam Genera. *Blumea*, Supplement 6.

Vanderwal, R. L.

1978 Exchange in Prehistoric Coastal Papua. *Mankind* 11:416–426.

Van Heekeren, H. R.

1972 *The Stone Age of Indonesia*. Verhandelingen van het Koninklijk Instituut voor Taal-, Land- en Volkenkunde 61. Koninklijk Instituut voor Taal-, Land- en Volkenkunde, The Hague, Netherlands.

van Steenis, C. G. G. J.

1950 The Delimitation of Malaysia and Its Main Plant Geographical Divisions. In *Flora Malesiana*, Vol. I, edited by C. G. G. J. van Steenis, pp. lxx–lxxv. Rijksherbarium, Leiden, Holland.

Von Kotzebue, O.

1967 *A Voyage of Discovery into the South Sea and Beering's Straits*. Biblioteca Australiana No. 19, Facsimile reprint. Israel Press, Amsterdam.

Wallace, D. A., R. W. Johnson, B. W. Chappell, R. J. Arculus, M. R. Perfit, and I. H. Crick

1983 Cainozoic Volcanism of the Tabar, Lihir, Tanga, and Feni Islands, Papua New Guinea: Geology, Whole-Rock Analyses, and Rock-Forming Mineral Compositions. *Australian Bureau of Mineral Resources, Geology, and Geophysics Report* 243:1–62 [BMR Microform MF197].

Walter, R.

1989 Lapita Fishing Strategies: A Review of the Archaeological and Linguistic Evidence. *Pacific Studies* 31:127–149.

Walter, R., and P. Sheppard

2017 *Archaeology of the Solomon Islands*. University of Hawai'i Press, Honolulu.

Waterson, R.

1990 *The Living House: An Anthropology of Architecture in South-East Asia*. Oxford University Press, Singapore.

1993 Houses and the Built Environment in Island Southeast Asia: Tracing Some Shared Themes in the Uses of Space. In *Inside Austronesian Houses: Perspectives on Domestic Designs for Living*, edited by J. J. Fox, pp. 220–225. Australian National University, Canberra.

1995 Houses and Hierarchies in Island Southeast Asia. In *About the House: Lévi-Strauss and Beyond*, edited by J. Carsten and S. Hugh-Jones, pp. 47–68. Cambridge University Press, Cambridge, UK.

Weisler, M. I.

2001 Lapita Rockshelters of Eloaua and Mussau Islands (Sites EHM, EHN, EKO, EKP, and EKQ). In *Lapita and Its Transformations in Near Oceania: Archaeological Investigations in the Mussau Islands, Papua New Guinea, 1985–1988*, edited by P. V. Kirch, pp. 146–161. Archaeological Research Facility Contribution No. 59. University of California, Berkeley.

Wheeler, A., and A. Jones

1989 *Fishes.* Cambridge University Press, Cambridge, UK.

White, J. P.

1996 Rocks in the Head: Thinking About the Distribution of Obsidian in Near Oceania. In *Oceanic Culture History: Essays in Honour of Roger Green*, edited by J. Davidson, G. Irwin, F. Leach, A. Pawley, and D. Brown, pp. 199–209. New Zealand Journal of Archaeology, Dunedin.

White, J. P., J. Allen, and J. Specht

1988 Peopling the Pacific: The Lapita Homeland Project. *Australian Natural History* 22:410–416.

White, J. P., and J. E. Downie

1980 Excavations at Lesu, New Ireland. *Asian Perspectives* 23:193–220.

White, J. P., and M. Harris

1997 Changing Sources: Early Lapita Period Obsidian in the Bismarck Archipelago. *Archaeology in Oceania* 32:97–107.

White, T. E.

1953 A Method of Calculating the Dietary Percentages of Various Food Animals Utilized by Aboriginal Peoples. *American Antiquity* 18:396–398.

Whitmore, N. (editor)

2015 *A Rapid Biodiversity Survey of Papua New Guinea's Manus and Mussau Islands*. Wildlife Conservation Society Papua New Guinea Program, Goroka, Papua New Guinea.

Wickler, S.

1995 Twenty-Nine Thousand Years on Buka: Long-Term Cultural Change in the Northern Solomon Islands. PhD dissertation, Department of Anthropology, University of Hawai'i (Manoa), Honolulu.

Wiens, H. J.

1962 *Atoll Environment and Ecology*. Yale University Press, New Haven, Connecticut.

Wolff, T.

1966 The *Noona Dan* Expedition 1961–62: General Report and Lists of Stations. *Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening I København* 29.

Wright, A., and A. H. Richards

1985 A Multispecies Fishery Associated with Coral Reefs in the Tigak Islands, Papua New Guinea. *Asian Marine Biology* 2:69–84.

Wu, P.

2016 What Happened at the End of Lapita: Lapita to Post-Lapita Pottery Transition in West New Britain, Papua New Guinea. PhD dissertation, Department of Anthropology, University of Otago, Dunedin, New Zealand.

Yen, D. E.

1971 The Development of Agriculture in Oceania. In *Studies in Oceanic Culture History*, Vol. 2, edited by R. C. Green and M. Kelly, pp. 1–12. Pacific Anthropological Records 12. Bishop Museum, Honolulu, Hawaii.

1973 The Origins of Oceanic Agriculture. *Archaeology and Physical Anthropology in Oceania* 8:68–85.

1974 Arboriculture in the Subsistence of Santa Cruz, Solomon Islands. *Economic Botany* 28:247–284.

1982 The Southeast Solomons Cultural History Programme. *Bulletin of the Indo-Pacific Prehistory Association* 3:52–66.

1985 Wild Plants and Domestication in the Pacific Islands. In *Recent Advances in Indo-Pacific Prehistory*, edited by V. N. Misra and P. Bellwood, pp. 315–326. Oxford and IBH Publishing Co., New Delhi.

1991 Polynesian Cultigens and Cultivars: The Questions of Origin. In *Islands, Plants, and Polynesians*, edited by P. A. Cox and S. A. Banack, pp. 67–98. Dioscorides Press, Portland, Oregon.

1996 Melanesian Arboriculture: Historical Perspectives with an Emphasis on the Genus *Canarium*. In *South Pacific Indigenous Nuts*, edited by M. L. Stevens, R. M. Bourke, and B. R. Evans, pp. 36–44. Proceedings of a Workshop Held from 31 October to 4 November 1994 at Port Vila, Vanuatu. ACIAR Proceedings No. 69. Australian Center for International Agricultural Research, Canberra.

Yonekura, N., T. Ishii, Y. Saito, Y. Maeda, Y. Matsushima, E. Matsumoto, and H. Kayanne

1988 Holocene Fringing Reefs and Sea-Level Change in Mangaia Island, Southern Cook Islands. *Paleogeography, Paleoclimatology, Paleoecology* 68:177–188.

Yuncker, T. G.

1959 *Plants of Tonga*. Bernice P. Bishop Museum Bulletin 220. Bishop Museum Press, Honolulu, Hawaii.

Ziegler, A. C.

1973 *Inference from Prehistoric Faunal Remains*. Addison-Wesley Module in Anthropology No. 43. Addison-Wesley Publishing, Reading, Massachusetts.

Zohar, I., and M. Belmaker

2005 Size Does Matter: Methodological Comments on Sieve Size and Species Richness in Fishbone Assemblages. *Journal of Archaeological Science* 32:635–641.

Zuffa, G. G.

1979 Hybrid Arenites: Their Composition and Classification. *Journal of Sedimentary Petrology* 50:21–29.

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TALEPAKEMALAI

Lapita and Its Transformations in the Mussau Islands of Near Oceania

The Lapita Cultural Complex—first uncovered in the mid-twentieth century as a widespread archaeological complex spanning both Melanesia and Western Polynesia—has subsequently become recognized as of fundamental importance to Oceanic prehistory. Notable for its highly distinctive, elaborate, dentate-stamped pottery, Lapita sites date to between 3500-2700 BP, spanning the geographic range from the Bismarck Archipelago to Tonga and Samoa. The Lapita culture has been interpreted as the archaeological manifestation of a diaspora of Austronesian-speaking people (specifically of Proto-Oceanic language) who rapidly expanded from Near Oceania (the New Guinea-Bismarcks region) into Remote Oceania, where no humans had previously ventured. Lapita is thus a foundational culture throughout much of the southwestern Pacific, ancestral to much of the later, ethnographically-attested cultural diversity of the region.

Talepakemalai is a single integrated volume in which all of the results of the Mussau Project, including more recent analyses of chronology, obsidian, ceramics, and faunal remains, are brought together. It thus presents the definitive final report on the excavation not only of Talepakemalai, but also of all Lapita and post-Lapita sites investigated during the Mussau Project.

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Front: Small anthropomorphic artifact from Area B at Talepakemalai, made of cetacean bone.
Photograph by Patrick Vinton Kirch.

Above: The 1986 Talepakemalai field team at the conclusion of Area B excavations.
Photograph by Patrick Vinton Kirch.

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