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PREHISTORIC HAWAIIAN OCCUPATION IN THE ANAHULU VALLEY, O'AHU ISLAND: EXCAVATIONS IN THREE INLAND ROCKSHELTERS

Patrick V. Kirch
Editor

With Contributions by

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Patrick V. Kirch, and Gail Murakami

ARCHAEOLOGICAL RESEARCH FACILITY

DEPARTMENT OF ANTHROPOLOGY
UNIVERSITY OF CALIFORNIA
AT BERKELEY

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PREFACE

The rockshelter excavations reported herein were carried out in 1982 as part of a coordinated, ethnohistoric-archaeological study of the Anahulu Valley, O'ahu Island. The project, officially titled "The Archaeology of Ethnohistory: The Historical Transformation of Hawaiian Society and Economy," was jointly directed by the author and Professor Marshall Sahlins, and was funded under Grant BNS 82-05621 from the National Science Foundation. The project was sponsored by the Department of Anthropology, Bernice P. Bishop Museum, Honolulu.

Permission to work in the Anahulu Valley was granted by the Bishop Estate, by Castle and Cooke, Ltd., and by the Waialua Agricultural Co.

For assistance in the field during the rockshelter excavations, I thank Jane Allen, Melinda Allen, Sara Collins, Jim Landrum, Holly McEldowney, Art Saxe, Matthew Spriggs, Ken Shun, and Marshall Weisler, and the students of the 1982 University of Hawaii archaeological field school.

Various individuals have assisted since 1982 in the analysis of materials from these sites, and in the preparation of this report. In particular, I am grateful to Melinda Allen, Laura Carter, Carl Christensen, Sara Collins, Peter Gilpin, Terry Hunt, Eric Komori, Gail Murakami, and George Quimby. A special acknowledgement is due Christine Kleinke and Elzelina Callis for their patient word processing and formatting of the text of this volume.

Patrick V. Kirch
January 1989

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CHAPTER ONE

INTRODUCTION

by Patrick V. Kirch

As in many parts of the world, rockshelters have been a favored site type for archaeological studies in the Hawaiian Islands. J.F.G. Stokes' pioneering excavations in 1913 on Kaho'olawe Island (Kirch 1985:12) penetrated the deposits of a fisherman's shelter rich in well-preserved organic materials. In 1950, when Hawaiian archaeology was rejuvenated by K. P. Emory, the Kuli'ou'ou Shelter on O'ahu Island provided the setting (Emory and Sinoto 1961). Over the past three and one-half decades, more than 50 rockshelters have been excavated or tested, on every major island (see, as examples, Bonk 1954; Chapman and Kirch 1979; Emory and Sinoto 1961; Kirch 1979b; McCoy 1977; Soehren 1966). However, almost all of these sites are situated within the coastal zone, less than 1 km from the shoreline. Indeed, many of these shelters were selected for excavation because they would predictably yield fishing gear, especially fishhooks, so important for Hawaiian relative chronology (Emory, Bonk, and Sinoto 1959). Only the small shelter sites within the Mauna Kea adz quarry, at 3,500 m on Hawai'i Island, are exceptions to this pattern (McCoy 1977).

This monograph presents the results of excavations in three rockshelter sites located in a wholly different environmental setting: an interior valley locale some 6 km from the coast, on the island of O'ahu. Excavations in the Anahulu Valley rockshelters thus provide an important test case for the putative general Hawaiian pattern of early coastal settlement, followed by later "inland expansion" of populations (Hommon 1976, 1986; Kirch 1985:296-7). In the stratigraphic sequences of the three rockshelters reported herein, it is possible to track the initial stages of exploitation of interior valley resources, followed by more intensive utilization and permanent occupation immediately prior to European contact.

THE ANAHULU VALLEY PROJECT

The 1982 Anahulu Valley Project, organized jointly by the author and Marshall Sahlins (University of Chicago), is the shortened designation for a research endeavor entitled "The Archaeology of Ethnohistory: The Historical Transformation of Hawaiian Society and Economy" (National Science Foundation Grant No. BNS 82-05621). The Project built upon extensive ethnohistorical research on the early Hawaiian Kingdom, carried out by Sahlins from 1971 to 1976, and on a pilot archaeological study in the Anahulu Valley by Kirch in 1974 and 1976 (Kirch 1979a). The aim of the 1982 Project was an inter-disciplinary archaeological and ethnohistorical investigation of socio-political organization, economy, land use, and settlement pattern in the Anahulu Valley, situated on northwest O'ahu Island (fig. 1.1). As a land unit *(ahupua'a)* within the political district of Waialua, Anahulu had come under the control of several important high chiefs of the early Hawaiian Kingdom from A.D. 1804 and into the mid-nineteenth century. The consequent wealth of archival and ethnohistoric material relating to Anahulu was matched by an undisturbed archaeological landscape in the middle and

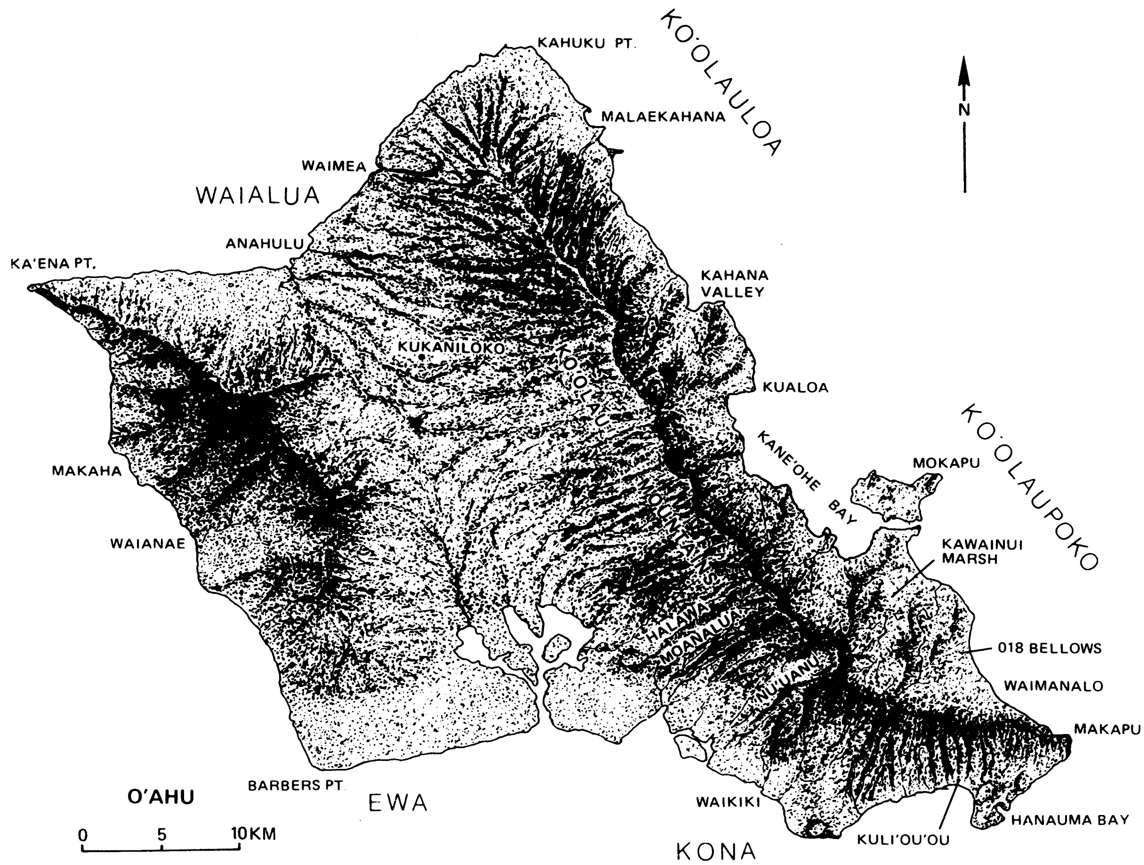


Figure 1.1. O'ahu Island, showing the location of Waialua District and the Anahulu Valley (after Kirch 1985, fig. 86).

upper reaches of the valley. Thus, the expectation was that the transformation of indigenous Hawaiian society and economy in the early decades following European contact and during the formation of the Hawaiian Kingdom, might be elucidated through the analysis of this particular valley system (Kirch, in press).

The 1982 fieldwork in Anahulu Valley concentrated on three main types of archaeological site: (1) stone-faced pondfield irrigation systems constructed on alluvial terraces in the valley bottom; (2) a series of open habitation sites on the colluvial slopes; and (3) three rockshelters with occupation deposits, in the middle valley. The first two site types proved to date almost wholly to the nineteenth century, and to reflect a phase of permanent occupation and intensive agricultural utilization of the interior Anahulu Valley following the conquest and occupation of O'ahu by the forces of Kamehameha I in 1804. The rockshelters, in contrast, yielded a sequence of prehistoric use extending back to the thirteenth century A.D., with only limited occupation in the very early historic period.

While the Anahulu rockshelter sites are thus of considerable interest for Hawaiian prehistory, they bear less directly on the principal aim of the Anahulu Valley Project, namely the analysis of historic-period transformation of Hawaiian economy and society. Nonetheless, because the shelters yielded significant archaeological materials, and provided some of the few examples of truly *interior* valley rockshelter sites in the entire archipelago, it was important that the results of our excavations in these sites be presented in full. Hence, the decision to publish this monograph on the rockshelter excavations, separately from the combined report on our ethnohistorical and archaeological study of the valley from 1804 to the later nineteenth century (Sahlins and Kirch, in prep.).

ROCKSHELTER SITES OF THE ANAHULU VALLEY

The geomorphological characteristics of Hawaiian valleys vary substantially depending upon their position on either windward or leeward slopes of the volcanic mountain ranges. Windward valleys, subject to heavy rainfall and consequent sheet erosion, mass wasting, and rapid chemical weathering of rock, are typically amphitheatre-headed, with U-shaped profiles (Wentworth 1928; MacDonald and Abbot 1970:172-9). Leeward valleys, especially in their lower elevations farther from the heavy rainfall zone at the mountain crest, tend to be more linear, narrow, and deeply incised, with streamflow the main erosive agent. This is the case with Anahulu and other valleys (e.g., Waimea, Opaeula, Helemano) that incise the leeward, arid southwesterly slopes of the Ko'olau Mountain range on O'ahu Island. Consequently, for the first 6 km inland from the coast, the valley walls consist largely of vertical cliffs (cutting through alternating flows of aa and pahoehoe lava) and talus scree slopes. (Farther inland than 6 km, the rainfall gradient becomes sufficiently steep to change the erosional regime, and the valley profile becomes more U-shaped, lacking cliffs.) These cliffs provide an ideal geological setting for rockshelters, which were formed where the stream undercut massive aa lava formations by eroding the less resistant underlying clinker layers. Many of these stream-cut notches are now stranded well above the present stream level due to continued downcutting of the Anahulu Stream.

The first rockshelter to be archaeologically investigated in the Anahulu Valley was Site OA-D6-14* (originally designated Site O6), a small shelter at the base of a vertical cliff on the north side of the valley. Site D6-14 was excavated in the late 1950s by an amateur, Mr. A. Andersen, with advice from Dr. Kenneth P. Emory of the Bishop Museum. The site evidently spanned both the prehistoric and early historic periods, although no radiocarbon dates were ever obtained. A brief note on the site was published by Kirch (1979a:61-2) based on Andersen's field notes in the Bishop Museum.

With the commencement of a pilot archaeological study in the Anahulu Valley in 1974 (Kirch 1979a), reconnaissance surveys were made along the valley walls for additional rockshelters that might contain well stratified occupation deposits. Five such shelters were recorded (D6-52, -56, -57, -58, and -60) (Kirch 1979a:59-60), and Site D6-52 was selected for investigation. This shelter lies just above the stream flats (irrigated for taro cultivation during the historic period) on the north side of the valley, about 4 km inland. The 1974 test excavations showed that the site was well stratified, yielding the first occupation sequence for the middle Anahulu Valley. Consequently, additional excavations were carried out in 1976, with a total area of 6.21 m^2 being exposed in the two field seasons (fig. 1.2).

Radiocarbon dates on samples of charcoal and ash from two hearths in Site D6-52 yielded ages of 185 ± 80 and 325 ± 80 B.P. The deposits yielded a range of faunal and carbonized floral materials, as well as 153 portable artifacts. Analyses of these materials are presented in detail in Kirch (1979a:32-50). The evidence from the D6-52 rockshelter excavation was interpreted as follows:

> The late prehistoric utilization of middle Anahulu Valley was probably of a transient nature, as a resource zone or area exploited by a permanent, coastal-dwelling population. Rock-shelters such as that at Keae or Site O6 served as temporary bases—occupied for a few days or perhaps weeks at a time—for local groups practicing shifting cultivation, collecting forest materials such as firewood or cordage fibers, catching birds, or collecting freshwater shell-fish and shrimp from the stream (1979a:51-2).

RESEARCH DESIGN

With the decision in 1982 to expand the Anahulu pilot research into a major coordinated ethnohistoric-archaeological program, it was clear that further excavations in mid-valley rockshelters would be essential to test the model outlined above. Our initial plans called for the excavation of two sites, D6-58 and D6-60, both large overhang shelters on north and south sides of the valley 5-6 km inland from the coast. After work had commenced at these sites, a third, smaller shelter (D6-36) was discovered not far from Site D6-58, and was included in the excavation program.

The 1982 rockshelter excavations comprised one facet of a larger research program focussed on the historical transformation of indigenous Hawaiian society and economy (see above). Within this research framework, the rockshelters were regarded as the most likely site class to yield materials extending back prior to the European contact period, thus providing the evidential basis for a prehistoric occupation sequence from the middle valley. Understanding the patterns of *prehistoric* occupation and utilization of the valley was

*The site numbering system used in this monograph is that of the Bernice P. Bishop Museum. The prefix OA- refers to O'ahu Island, and for brevity has been dropped from the numbers henceforth. D refers to the district of Waialua, and 6 to the *ahupua'a* or land unit of Kawailoa. The final number is the individual site designation within the *ahupua'a* unit.

Figure 1.2. 1976 excavation in the main occupation floor in Site D6-52, a rockshelter in the Keae area of Anahulu Valley.

obviously essential if the rapid and intense changes of the early European-contact period were to be isolated. At the commencement of fieldwork in 1982, it was unclear whether the middle and upper portions of the Anahulu Valley had been permanently occupied in prehistory, or whether the extensive taro pondfield irrigation systems of the valley flats had been in use prior to European contact. The results of four months of excavations, not only in the three rockshelters, but also in nine open habitation sites, and several irrigation systems, were to show that the irrigation systems and open, permanent residential complexes were developments of the early contact period (Kirch, in press; Sahlins and Kirch, in prep.). Thus, it is indeed the rockshelters that hold the key to understanding the prehistoric period in the interior portions of the Anahulu Valley.

Given the overall research framework of the 1982 Anahulu Valley Project, the rockshelter excavations were oriented primarily at obtaining a temporal sequence of occupation. Our field strategy thus focussed on vertical, stratigraphic exposures in several shelters, rather than extensive horizontal excavations of shelter floors. However, in Site D6-60 we did open up an area of 18 m^2 in an effort to gain some understanding of the horizontal distributions of features, artifacts, and faunal materials.

At the time our excavations were undertaken, there was increasing awareness that prehistoric Polynesian occupation of the Hawaiian Islands had resulted in significant environmental changes to this formerly isolated, and vulnerable island ecosystem (Kirch 1982). Along with several other Hawaiian archaeological projects at this time (e.g., Clark and Kirch 1983; Schilt 1984), considerable emphasis was placed on recovering a full range of sedimentological, faunal, and floral materials from the rockshelters, with the aim of reconstructing the local sequence of ecological changes precipitated by prehistoric human use of the Anahulu Valley. In excavation procedure, this objective was reflected in the use of fine screening (both 1/8 and 1/4 inch mesh sieves) of all deposits, and in the use of column samples for extraction of minute seeds and land snails. As the various chapters in this monograph attest, considerable effort was expended on the laboratory analysis of sediments, non-marine molluscs, charcoal, botanical remains, and vertebrate and invertebrate faunal assemblages, in addition to artifactual materials. In many respects, these analytical efforts were pioneering, and our results at times reflect the limitations of inadequate reference collections (as with the charcoal identification project, see chapter 7), or unanticipated problems of sample size (as in the analysis of flotation samples of seeds, see chapter 6). Nonetheless, the results reported in the various contributions to this volume reveal the potential of carefully controlled rockshelter excavations to yield a wealth of information not only on Hawaiian cultural prehistory, but on biogeographic and ecological change as well.

The research design for the investigation of the Anahulu rockshelters was thus oriented by four major objectives: (1) To establish a chronology for the prehistoric utilization and occupation of the middle valley region, based on radiocarbon dating. (2) To test the model derived from the 1974-76 excavation at rockshelter Site D6-52, that the shelters were temporary occupations, part of a pattern of low-intensity exploitation of the interior valley during the prehistoric period. (3) To determine whether the occupation sequences of any of the shelters exhibited a shift from temporary to permanent use in the late prehistoric or early historic periods, that might correspond with a more intensive exploitation of the upper valley. Objectives 2 and 3 required the acquisition of stratigraphically-controlled assemblages of artifacts and faunal materials, as well as of non-portable cultural features. (4) To track the sequence of environmental conditions in the vicinity of the rockshelters throughout the period of their human utilization, as reflected in the rockshelter sediments, terrestrial molluscs, archaeobotanical materials, and charcoal.

ENVIRONMENTAL CONTEXT OF THE MIDDLE ANAHULU VALLEY

The three rockshelter sites reported in this monograph are located in what we have termed "middle" Anahulu Valley, a distance of approximately 6 km from the coast (fig. 1.3). In this stretch, the valley floor is only about 150 km wide, flanked on either side by steep talus slopes and vertical cliffs. The valley floor has an elevation of between 98-110 m above sea level, while the adjacent tablelands above the cliffs are about 215 m above sea level. The cliffs, into the bases of which the rockshelters are cut, expose sections through the basaltic lavas of the Ko'olau Volcanic Series, of Pliocene age (Stearns and Vaksvik 1935).

The Anahulu Stream meanders across the valley, dividing the floor into a series of alluvial flats or terraces, alternatively to the south or north of the stream. These alluvial terraces were the focus of intensive pondfield irrigation of taro *(Colocasia esculenta)* in the early historic period. Prior to terracing for pondfields, the alluvial flats would have been ideal environments for shifting cultivation. The soils on these terraces consist of varying facies of the Kawaihapai Soil Series, well-drained mollisols (Foote et al. 1972:63).

The valley has a steep rainfall gradient (Rosenau, Lubke, and Nakahara 1971:D7-13, fig. 6), with the area in which the rockshelter sites are located receiving approximately 1,250 mm annually. The Anahulu headwaters are inundated with as much as 7,500 mm annually, ensuring permanent streamflow even in the lower elevation, more arid parts of the valley. Since the beginning of this century, however, much of this streamflow has been diverted out of the valley to the adjacent tablelands for sugar cane irrigation. Thus today the Anahulu Stream in the vicinity of the rockshelter sites exhibits intermittent flow. Prehistorically, however, there is no doubt that the Anahulu Stream flowed permanently throughout the length of the valley.

The flora and vegetation patterns of the middle Anahulu Valley reflect several centuries of human-induced ecological change, beginning with prehistoric exploitation and continuing in the historic period with ranching and plantation agriculture. The flora of the valley is dominated by exotic introductions, with only limited numbers of indigenous or endemic species that hint at the pre-human phytogeography. The middle valley falls within Zone C of Ripperton and Hosaka's (1942) classification, with the valley slopes and side walls dominated by the exotics *Leucaena leucocephala*, *Schinus terebinthifolius*, and *Lantana camara*. (This is also comparable to the "Guava zone" of Hosaka 1937.) *Psidium guayava* is also common on the lower slopes and alluvial flats. The alluvial flats are shaded by stands of large *Mangifera indica*, although *Eugenia cuminii* is also common in places. Among the few indigenous-endemic species found on the valley walls are isolated *Acacia koa* and *Canthium odoratum* trees, and shrubs of *Styphelia tameiameiae*, and on the talus slopes, *Erythrina sandwicensis*.

There are a number of feral cultigens in the middle valley, which have evidently naturalized following their

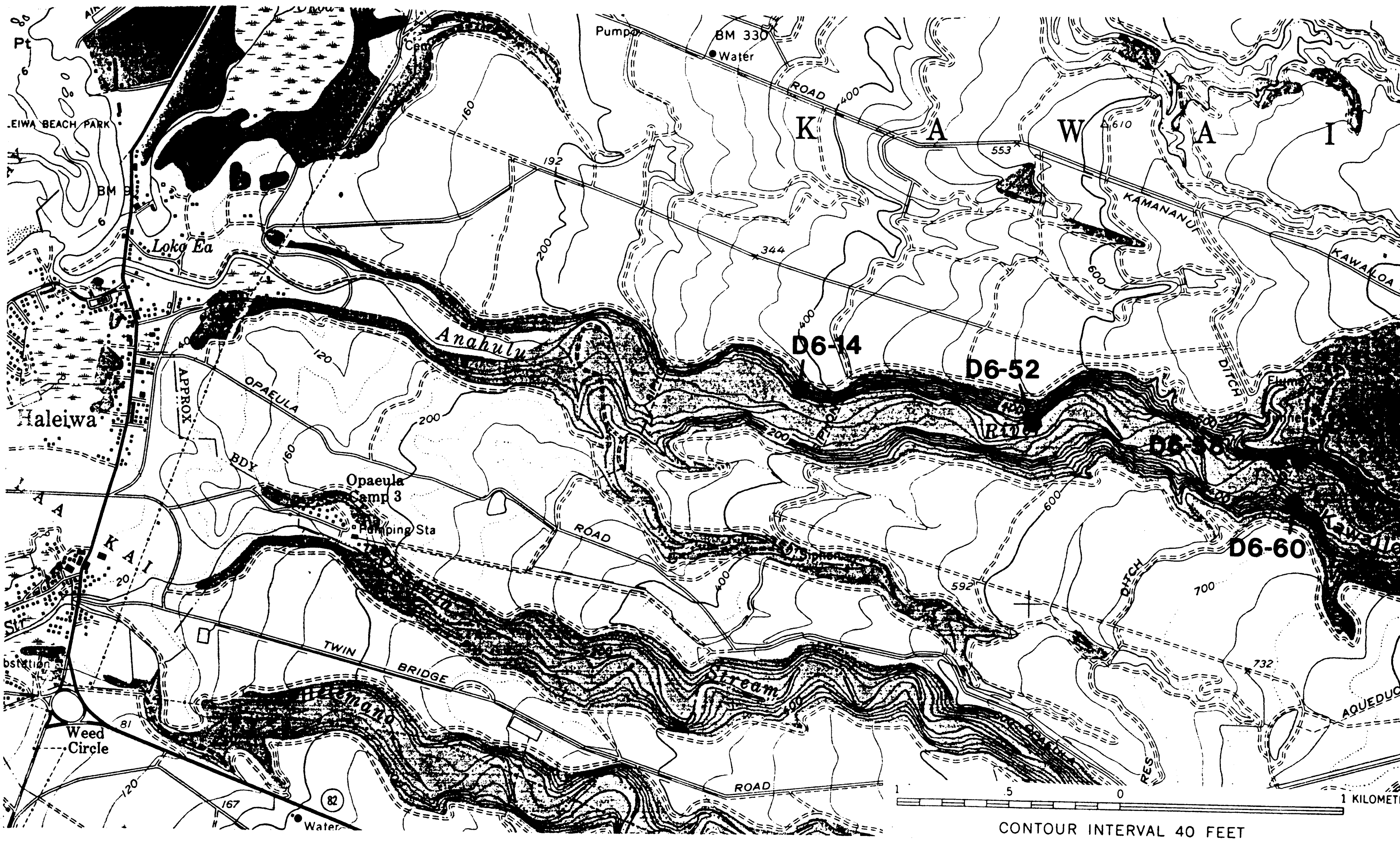


Figure 1.3. Topographic map of the lower and middle Anahulu Valley, showing the locations of principal rockshelter sites (map adapted from U.S. Geological Survey 1:24,000 sheet).

introduction during the period of Polynesian utilization of the middle valley. Among these are the breadfruit *(Artocarpus altilis)*, of which scattered trees are found at the base of the talus slopes, the ti plant *(Cordyline fruticosa)* which is common on the lower slopes and alluvial flats, the bitter yam *(Dioscorea bulbifera)* found on the colluvial slopes, and *noni (Morinda citrifolia)* which grows commonly on the alluvial flats.

The fauna of the valley has also changed radically in historic times. Native land birds, such as the honeycreepers, are now either extinct or confined to the highest portions of the Ko'olau Range, well inland of the rockshelter zone. The same is true of most of the endemic land snails, such as the brightly-colored *Achatinella* spp. tree snails, which are currently threatened with extinction. The native goboid fishes *(Chonophorus* spp.) and shrimp, along with the edible freshwater snail *(Neritina granosa)*, that formerly would have been common in the Anahulu Stream have been virtually eliminated by streamflow alteration and pollution (especially by fertilizers and insecticides) from plantation agriculture. The valley's fauna is dominated by exotic introductions, including a number of land birds (mynahs, rice birds, house finches, etc.), and mongoose.

REFERENCES CITED

Bonk, W.J. 1954. "Archaeological Excavations on West Molokai," M.A. Thesis, University of Hawaii.

Chapman, P.S., and P.V. Kirch. 1979. *Archaeological Excavations at Seven Sites, Southeast Maui, Hawaiian Islands*. Dept. of Anthropology Report 79-1. B.P. Bishop Museum. Honolulu.

Clark, J., and P.V. Kirch, eds. 1983. *Archaeological Investigations in the Mudlane-Waimea-Kawaihae Road Coridor, Island of Hawaii: An Interdisciplinary Study of an Environmental Transect*. Dept. of Anthropology Report 83-1. B.P. Bishop Museum. Honolulu.

Emory, K.P., W.J. Bonk, and Y.H. Sinoto. 1959. *Hawaiian Archaeology: Fishhooks*. B.P. Bishop Museum Special Publication 47. Honolulu.

Emory, K.P., and Y.H. Sinoto. 1961. *Hawaiian Archaeology: Oahu Excavations*. B.P. Bishop Museum Special Publication 49. Honolulu.

Foote, D.E. et al. 1972. *Soil Survey of the Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii*. U.S. Dept. Agriculture, Soil Conservation Service. Government Printing Office. Washington.

Hommon, R.J. 1976. "The Formation of Primitive States in Pre-Contact Hawaii." Ph.D. Dissertation, Univ. of Arizona. (University Microfilms.)

_____. 1986. Social evolution in ancient Hawaii. In P.V. Kirch, ed., *Island Societies: Archaeological Approaches to Evolution and Transformation*, pp. 55-68. Cambridge University Press.

Hosaka, E.Y. 1937. Ecological and floristic studies in Kipapa Gulch, Oahu. *B.P. Bishop Museum Occasional Papers* 13(17):175-232. Honolulu.

Kirch, P.V. 1979a. *Late Prehistoric and Early Historic Settlement-Subsistence Systems in the Anahulu Valley, O'ahu*. Dept. of Anthropology Report 79-2. B.P. Bishop Museum, Honolulu.

_____. 1979b. *Marine Exploitation in Prehistoric Hawai'i: Archaeological Excavations at Kalahuipua'a, Hawai'i Island*. Pacific Anthropological Records 29. Dept. of Anthropology, B.P. Bishop Museum. Honolulu.

_____. 1982. The impact of the prehistoric Polynesians on the Hawaiian ecosystem. *Pacific Science* 36(1):1-14.

_____. 1985. *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory*. University of Hawaii Press. Honolulu.

_____. in press. Production, intensification and the early Hawaiian kingdom. In D.E. Yen, ed., *Pacific Production Systems*. Australian National University.

MacDonald, G.A., and A.T. Abbot. 1970. *Volcanoes in the Sea: The Geology of Hawaii*. University of Hawaii Press. Honolulu.

McCoy, P.C. 1977. The Mauna Kea Adze Quarry Project: a summary of the 1975 field investigations. *Journal of the Polynesian Society* 86(2):223-44.

Ripperton, J.C., and E.Y. Hosaka. 1942. *Vegetation Zones of Hawaii*. Hawaii Agricultural Experiment Station Bulletin 89. Honolulu.

Rosenau, J.C., E. Lubke, and R. Nakahara. 1971. *Water Resources of North-Central Oahu, Hawaii*. Geological Survey Water-Supply Paper 1899-D. Government Printing Office. Washington.

Sahlins, M., and P.V. Kirch. in prep. *Anahulu: The Archaeology of History in the Early Sandwich Islands Kingdom*.

Schilt, A. 1984. *Subsistence and Conflict in Kona, Hawaii*. Dept. of Anthropology Report 84-1. B.P. Bishop Museum. Honolulu.

Soehren, L.J. 1966. "Hawaii Excavations, 1965." Typescript in Dept. of Anthropology, B.P. Bishop Museum. Honolulu.

Stearns, H.T., and K.N. Vaksvik. 1935. *Geology and Ground-Water Resources of the Island of Oahu, Hawaii*. Bulletin 1, Division of Hydrography, Territory of Hawaii. Honolulu.

Wentworth, C.K. 1928. Principles of stream erosion in Hawaii. *Journal of Geology* 36:385-410.

CHAPTER TWO

THE ROCKSHELTER EXCAVATIONS

by Patrick V. Kirch

ALTHOUGH THE PARTICULAR STRATEGIES of sampling design varied for the three rockshelters, excavation procedures were the same in all cases. All sites were first mapped at a scale of 1:50 with plane table and telescopic alidade. Surface artifacts were plotted and collected at this time. A metric grid was then established over the site surface, with the grid oriented to the long axis of the shelter. Trowels and brushes were used exclusively in excavation. Natural stratigraphic boundaries served as the basis for excavation control, although within homogenous strata finer control was exercized through the use of 5 cm arbitrary levels. In this manner we were able to combine the advantages of both natural and arbitrary excavation methods. Features (such as hearths and ovens) were excavated as individual units, and their contents bagged separately. Depth control was maintained both by measurement below surface and by taking below-datum instrument elevations. All excavated sediment was passed through nested sieves with mesh sizes of 1/4 and 1/8 inch. All artifacts, macroscopic floral remains (including charcoal fragments), faunal materials (both vertebrate and invertebrate), and any evident non-local lithic materials (including waterworn pebbles) were collected from these sieves for laboratory analysis. In addition, the contents of some features were bagged whole for later flotation of plant materials in the laboratory (see chapter 6). Following the completion of excavation, several continuous column samples were taken from cleaned profiles in Sites D6-36 and -60 (because of stratigraphic disturbances, no continuous columns were removed from Site D6-58). These column samples provided materials for detailed laboratory studies of sediment, archaeobotanical remains including charcoal, and of non-marine molluscs, as reported in chapters 3, 5, 6, and 7.

During the excavation of each unit, standard grid record sheets were maintained showing horizontal plans (1:10 scale) for each 5-cm increment or natural stratigraphic boundary; all artifacts recovered *in situ* were plotted on these sheets. Features were recorded both on the grid sheets, and with a separate feature recording form. After excavation, cleaned profiles were drawn at a scale of 1:10 and described in terms of color, texture, structure, boundary, and other physical characteristics. Photographic records maintained during excavation include 35 mm color slides and black-and-white negatives, and selected 120 black-and-white roll film negatives.

KUOLULO ROCKSHELTER (Site OA-D6-60)

Kuolulo rockshelter is situated on the south, or Wai'anae, side of the Anahulu Valley, at an elevation of 97 m above sea level. The shelter lies within the indigenous Hawaiian land unit, or *'ili*, of Ke'eke'e and, more specifically, within the *kuleana* or ancestral estate of Kuolulo (Land Commission Award 4308-1). We have given the name of this mid-nineteenth century Hawaiian cultivator and principal resident of 'Ili Ke'eke'e to Site D6-60.

Figure 2.1. View of Site D6-60, Kuolulo Shelter, from the east.

The shelter consists of a large "notch" in the precipitous cliff at the southern end of one of the valley's alluvial benches (fig. 2.1). The shelter was formed at a time when the Anahulu Stream was higher than at present (probably during the late Pleistocene), and hydraulically eroded a less resistent stratum of aa lava clinker (about 2-3 m thick) sandwiched between denser strata of flow basalt. As seen in figure 2.1, the dense basalt forms a jagged overhang rising 20-30 m above the shelter floor. Above the shelter, the valley wall is very steep, ascending rapidly in a series of cliffs and scree slopes to the edge of the tablelands at 209 m above sea level. Kuolulo shelter sits about 5 m higher than the level of the adjacent alluvial bench, and is separated from the latter by a gentle talus slope. The alluvial bench would have provided excellent terrain for indigenous gardening, although unlike other alluvial terraces in the valley, it was not modified for pondfield irrigation of taro.

The present vegetation in the vicinity of Kuolulo rockshelter is almost wholly exotic. Several banyan trees *(Ficus* sp.) have implanted themselves in the overhanging cliff, and their aerial roots cascade down the dripline (fig. 2.1). The talus slope in front of the shelter is shaded by Java plum trees *(Eugenia jambos),* with a ground cover of *honohono* grass. The steep valley wall above the shelter is dominated by Christmas Berry *(Schinus terebinthifolius), koa haole (Leucaena leucocephala),* and lantana *(Lantana camara).* A feral remnant of indigenous Hawaiian cultivation existing on the alluvial bench near the shelter is clumps of the ti plant *(Cordyline fruticosa),* the large roots of which provided a source of sugar for the prehistoric Hawaiians.

Kuolulo shelter (fig. 2.2) has a main floor area under the drip line of about 25 m long and 12 m deep, with a usable dry floor area of approximately 300 m^2. The overhanging ceiling of dense basalt is restrictive only at the very rear of the shelter, where it declines in height to about 2 m; elsewhere it is 4 or more meters high. Although protected from the elements, the shelter is airy and well lighted. When the valley was more open, shelter occupants would have had a clear view out over the adjacent alluvial bench to the Anahulu Stream, and across to the north side of the valley.

In 1982 when we commenced work at the site, there were no obvious signs of recent disturbance, and various surface features and artifacts appeared to be *in situ.* One feature, a small crypt (fig. 2.3), had been constructed against the shelter wall east of the main occupation floor. This crypt consists of a semi-circular wall of basalt cobbles (.3-.8 m high) held in place with a reddish clay "mortar." The crypt had been opened at some time in the past, and was empty. Similar features elsewhere in the valley are known to contain human burials and we presume that such was the original function of this structure as well. The eastern boundary of the main floor area of the shelter is defined by a low wall of basalt cobbles and boulders (fig. 2.4), two to three courses high (.4-.7 m), which runs from the back of the shelter, across the floor, and down the talus slope to the alluvial bench. This wall is not substantial enough to have kept pigs or other animals out of the shelter. It may have served as a symbolic boundary of the secular activity space of the shelter, as distinct from the burial crypt area to the east (for further discussion of the semiotic value of east-west spatial relationships on Hawaiian sites, see Weisler and Kirch 1985).

As seen in the plan map (fig. 2.2) and in figure 2.5, the main shelter floor displayed a number of surface structures and features. A large roof-fall block of dense basalt at the front of the shelter (behind A. Saxe in the photo, fig. 2.5) had been modified with a grinding surface on its flat top. The circular grinding area was probably used for sharpening the bevels of stone adzes or other artifacts. Immediately south of the grinding-stone boulder is a small, earth-filled terrace, defined by a cobble retaining wall on the west, and by the base of a second retaining wall on the south. Referred to henceforth as the "outer terrace," this area measures about 4 by 2 m. (The Nikon survey level in fig. 2.5 is set up on this outer terrace.) The innermost part of the shelter was leveled by the construction of another terrace (the "inner terrace"), defined on the north by a 6.5 m long retaining wall that incorporates a large roof-fall boulder. Much of our excavation effort was directed toward these two terraces and their sub-floor deposits. The eastern portion of the main occupation area is not marked by terraces or other structures.

While the terrace retaining walls were constructed largely of angular basalt cobbles derived from the shelter overhang, there were also seven large waterworn, stream cobbles on the shelter floor (see fig. 2.2). These had been purposely carried to the site from the Anahulu Stream, possibly for use as seats or as anvils. Lying on the dirt floor in the eastern part of the shelter were four massive wooden timbers, sawn and notched (fig. 2.6), of unknown function. These timbers certainly date to the historic period, and may have been associated with the construction by Waialua Plantation, in the early twentieth century, of a large irrigation syphon immediately west of the rockshelter. A variety of smaller artifacts were also found scattered over the site surface in 1982, and these were plotted and collected prior to excavation (fig. 2.2). Indigenous artifacts included basalt and volcanic glass flakes, a grooved pebble sinker, a drilled dog tooth pendant, a basalt adze preform, and a polished adz flake. Historic period artifacts included bottle glass fragments, ceramic fragments, and a gun flint.

Excavation Strategy

Following mapping and establishment of the metric grid, excavation commenced in the P-trench (fig. 2.7), which bissected the retaining wall of the inner terrace, thus providing a stratigraphic section through the terrace fill, and north toward the drip line. We then expanded the excavation of the inner terrace area (fig. 2.8), which proved to have a relatively shallow depth of cultural deposit (ranging from 5-25 cm). Some 8 m^2 of the inner terrace were excavated, revealing several small hearth features. Attention was then directed to the outer terrace, which was sampled by excavating the M-trench through the retaining wall of the inner terrace, and out across the outer terrace to abut the large rock-fall boulder. The M-trench thus provided a second stratigraphic profile, through both the inner and outer terraces.

While most of our efforts were directed at the western half of the main occupation area, with its two structural terraces, we also tested the eastern half. Unit I25 was excavated in the approximate mid-point of the shelter, toward the rear wall. This unit revealed a very shallow, and nearly sterile, deposit overlying bedrock. A second unit, D20, was then excavated in the center of the flat occupation floor in the eastern half of the shelter. This unit revealed a deep cultural deposit, extending to 80 cm below surface. While it would have been desirable to expand our sample of these deep deposits, we were restricted by project time constraints. Future archaeological work at Kuolulo Shelter should be directed at the eastern half of the site, to expose what is probably a sizeable area of well-stratified cultural material dating to as old as the fifteenth century A.D.

A total of 18 m^2 was excavated at Kuolulo Shelter, with an approximate total volume of 4.5 m^3 of cultural deposit.

Physical Stratigraphy

The physical stratigraphy of the shelter deposits differed substantially between the western and eastern portions of the main occupation area. The western area, with the two structural terraces, was characterized by relatively shallow, homogeneous cultural deposits overlying bedrock or pre-occupation clays. The stratigraphy in this area was best exposed along the M- and P-trench profiles, described in detail below. The eastern area of the shelter contains a deep deposit, exposed only in the D20 test unit, also described below. Stratigraphic sections were drawn and described in the field, at which time column samples of sediment were also taken for laboratory analysis. The results of the laboratory studies are presented in chapter 3.

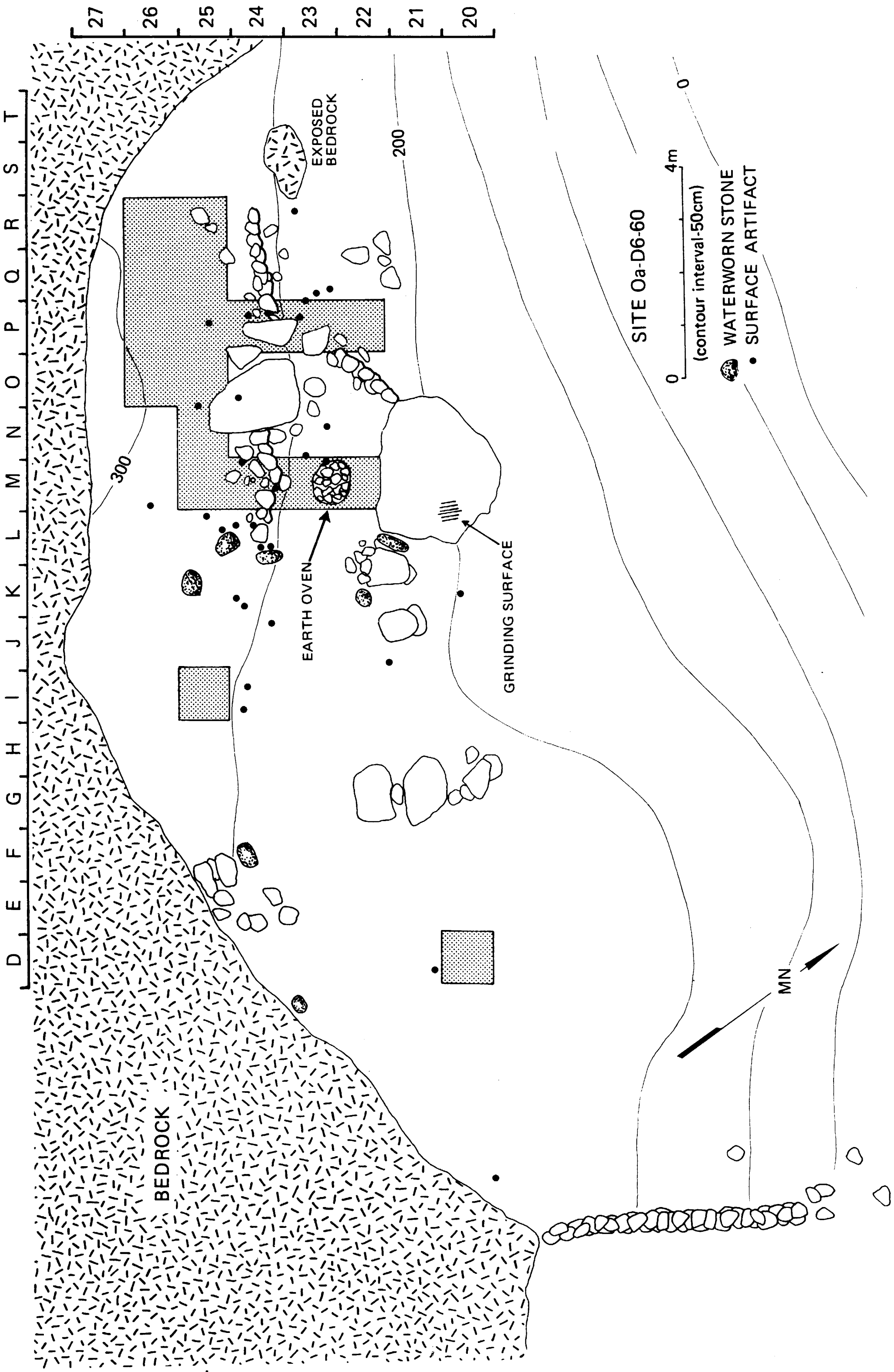


Figure 2.2A. Plan of Site D6-60, showing areas excavated in 1982.

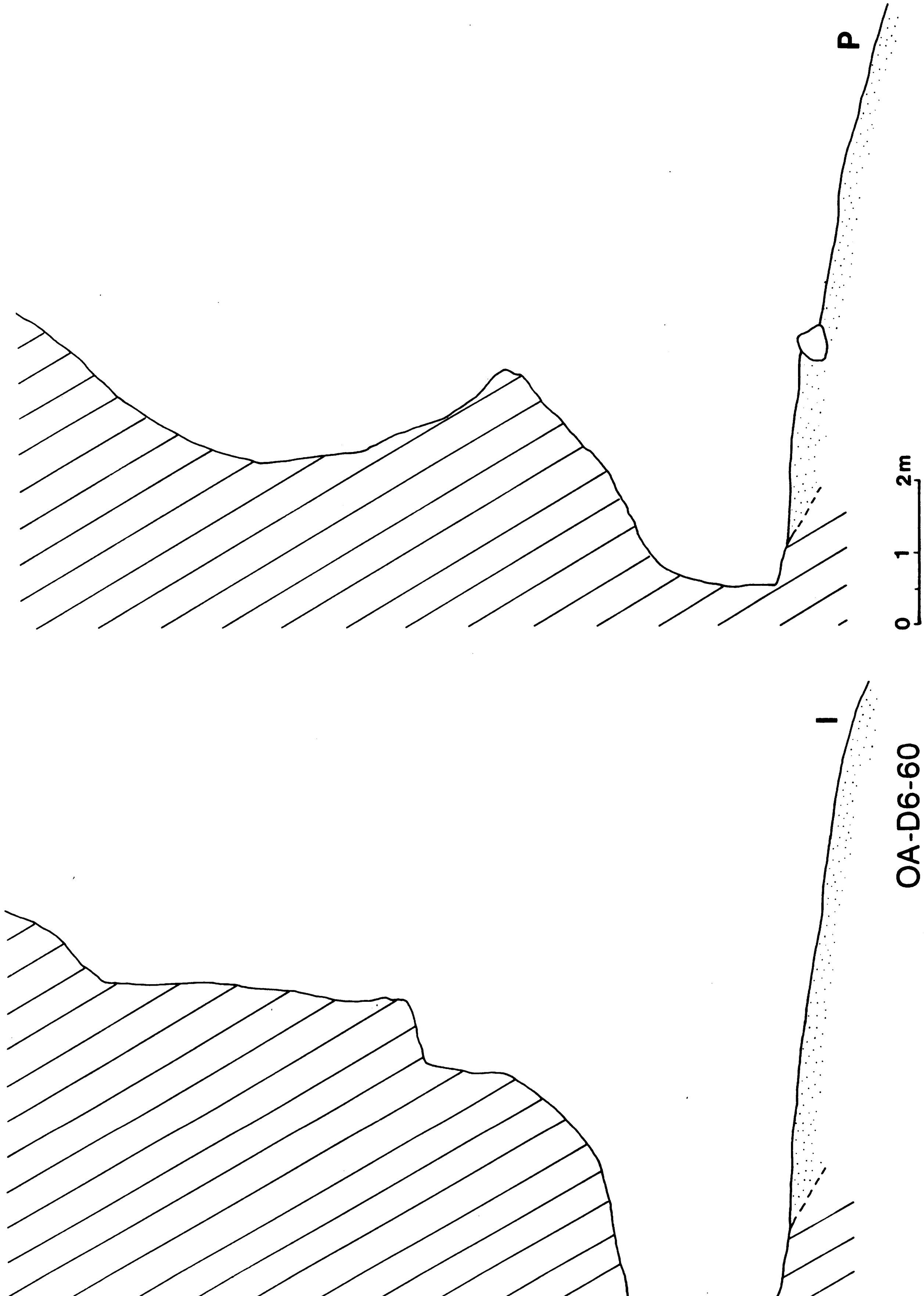


Figure 2.2B. Profiles through Site D6-60, along the I- and P-grid lines.

Figure 2.3. Stone crypt located east of the main occupation area at Site D6-60; view from the west.

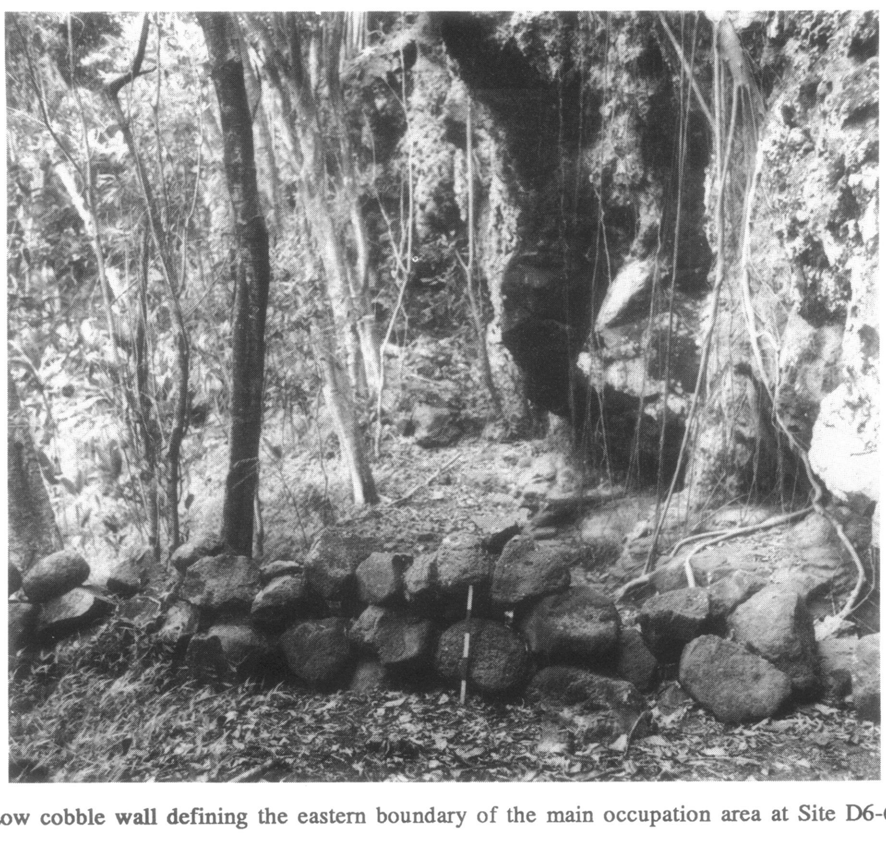


Figure 2.4. Low cobble wall defining the eastern boundary of the main occupation area at Site D6-60.

Figure 2.5. View from the east of the main occupation floor of Site D6-60; the Nikon level is situated on the outer terrace.

Figure 2.6. Sawn and notched wooden timbers on the floor of Site D6-60.

Figure 2.7. Commencement of excavation in the inner terrace area of Site D6-60. The cobble retaining wall of the inner terrace is clearly visible on the left.

Figure 2.8. The inner terrace of Site D6-60 after completion of excavations.

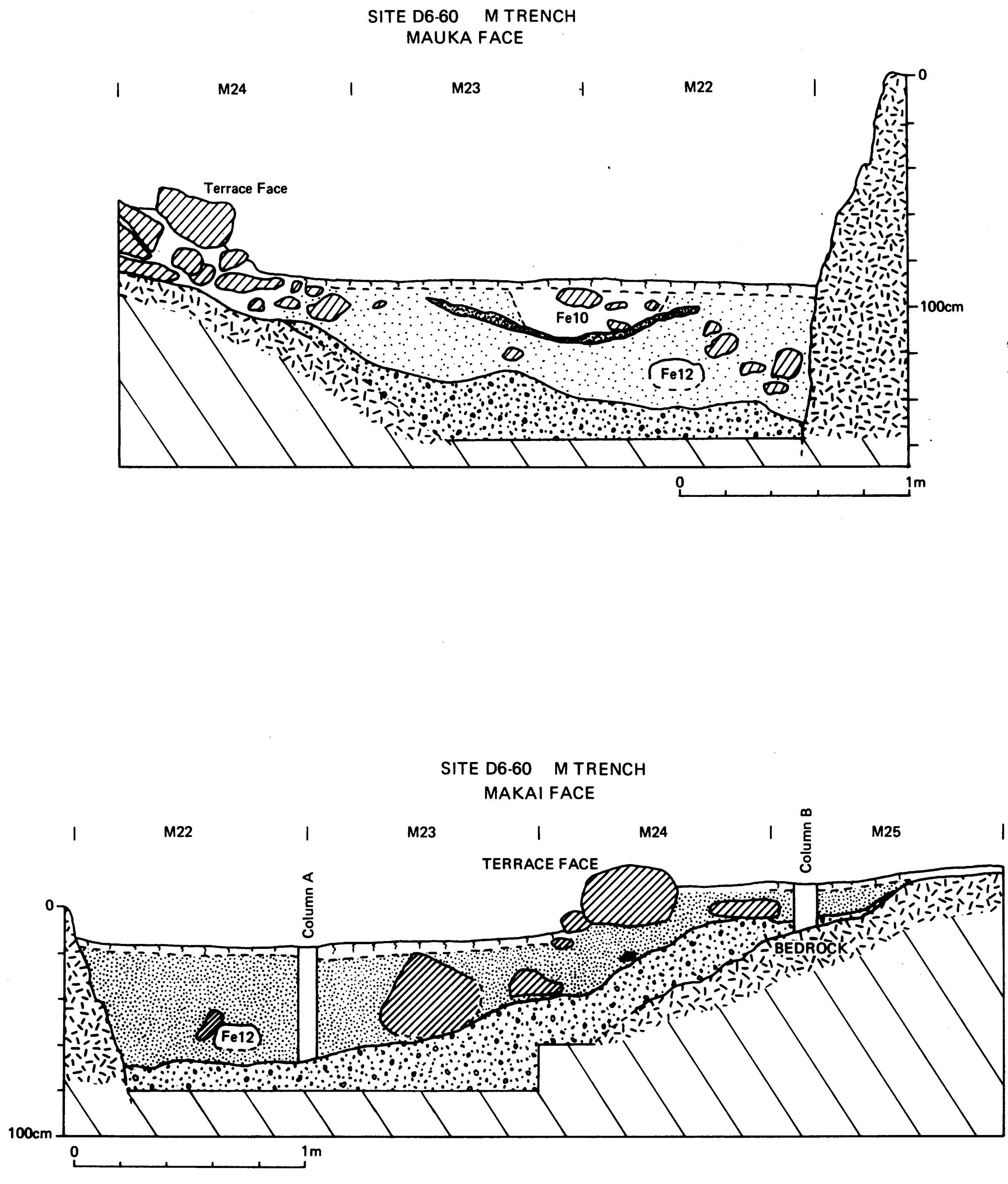


Figure 2.9. Stratigraphic sections of the M-Trench in Site D6-60.

The M-Trench Profile. The east and west faces of the M-trench exposed parallel sections bissecting the low cobble retaining wall of the inner terrace, as well as the cultural deposits of both the inner and outer terraces. These sections are shown in figure 2.9, and a view of the west face of the M-trench is provided in figure 2.10. The deposits were comprised of three strata: *Layer I,* a dark reddish brown (5 YR 3/2-3) deposit 4-6 cm thick, representing a post-occupational buildup of sediment (derived from roof decomposition and aeolian materials) and organic litter. The boundary between Layer I and II was abrupt, grading over a 1 cm zone. *Layer II,* a dark brown to very dark grayish brown (7.5 YR 3/2 to 10 YR 3/2) cultural deposit, largely homogeneous from top to bottom. The deposit had a very fine granular structure, largely unaggregated, with a soft consistence when dry. Fine gray ash appeared to be a significant constituent of the deposit, as well as larger charcoal fragments, with individual pieces of charcoal ranging up to 1-1.5 cm in diameter. The presence of ash and charcoal was doubtless related to the large earth oven (Feature 10) occupying the center of the outer terrace (see below). The basal boundary of Layer II was abrupt, grading into Layer III over no more than 1 cm. *Layer III,* a dark red (2.5 YR 3/6), culturally-sterile deposit, with very fine granular structure. At the Layer II/III interface we noted a high frequency of large (woody) charcoal fragments, many of which appeared to have been pressed down into the top of Layer III. This phenomenon was suggestive of an initial clearance of woody vegetation at the site by burning, immediately prior to human occupation.

The P-Trench Profile. The east and west faces of the P-trench are shown in figure 2.11. Throughout the length of this trench, the cultural deposit was identical to Layer II in the M-trench, described above. In the upper terrace (south of the retaining wall), the cultural deposit rested directly on the bedrock of the shelter floor. North of the retaining wall, the bedrock itself is capped by a deposit of sterile, dark red gravelly mud, identical to Layer III described in the M-trench. At the interface of the cultural deposit and this sterile gravelly mud, we noted the presence of numerous large charcoal flecks (as in the M-trench), and also several examples of the large, endemic arboreal snail *Achatinella (A.)* cf. *decora.* As described further in chapter 5, the presence of this species strongly suggests that the shelter was covered in an endemic forest association immediately prior to human occupation, and that the first occupants of the site cleared this vegetation by burning.

Figure 2.10. View of the west face of the M-Trench in Site D6-60, after the completion of excavations. The trench bissected the cobble retaining wall of the inner terrace.

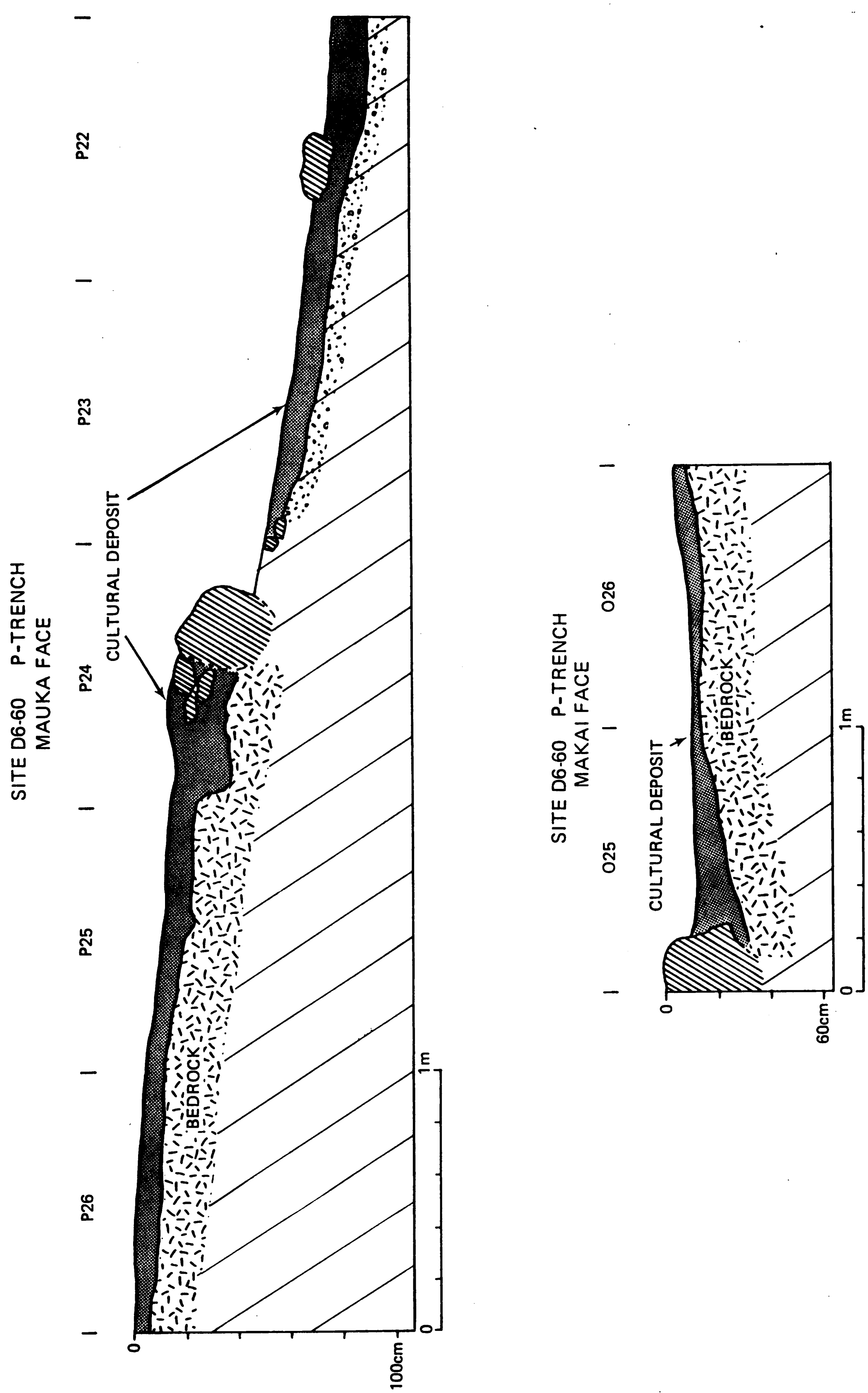


Figure 2.11. Stratigraphic sections of the P-Trench in Site D6-60.

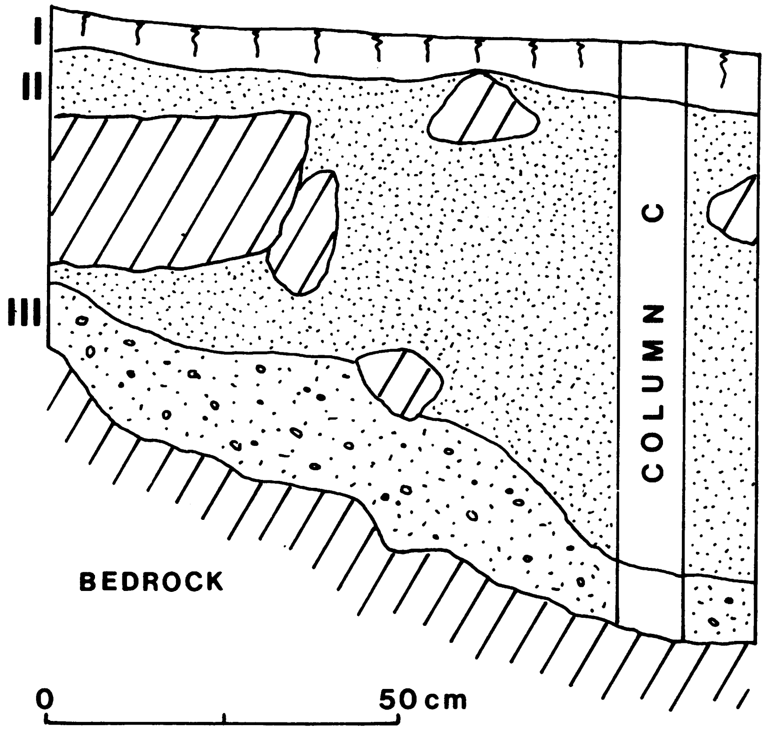


Figure 2.12. Stratigraphic section of the west face of Unit D20, Site D6-60.

The Unit D20 Profile. The west face of Unit D20 is shown in figure 2.12, which also indicates the position of Column C, utilized for geoarchaeological analysis, and for extraction of landsnail, charcoal, and seed samples (see chapters 3, 5, 6, and 7). Three depositional units are represented in the profile: *Layer I,* a dark-reddish brown (5 YR 3/2-4) deposit which accumulated after abandonment of the site; *Layer II,* a thick dark brown to very dark grayish brown (7.5 YR 3/2 to 10 YR 3/2) cultural deposit with substantial quantities of charcoal, relatively homogeneous throughout the section; and *Layer III,* a basal deposit of dark reddish brown (5 YR 3/3-4) sediment with some angular gravel, presumably derived from roof fall. Layer III rested directly upon the bedrock floor of the shelter. A detailed sedimentological analysis of this stratigraphic section is provided in chapter 3 (see table 3.3).

Cultural Content and Features

The excavations at D6-60 yielded a total of 1,636 indigenous Hawaiian artifacts, of which 1,407 (or 86%) are small flakes and cores of volcanic glass. Of particular interest in this assemblage are five small fishhooks and three line sinkers, 10 hammerstones, and 52 small cone-shell beads. The upper cultural deposits also yielded artifacts of Euro-American manufacture. These portable artifacts are described in detail in chapter 8. The site also produced an array of vertebrate and invertebrate faunal materials, analyzed in chapter 4.

Eleven discrete features were recognized during the excavation. These are listed and described in table 2.1. Ten of the features consisted of small hearths, characterized by shallow, basin-shaped concentrations of white ash and charcoal. Significantly, none of these features was stone-lined, or showed other signs of permanent use. Rather, each hearth feature appeared to represent a single burning event. The most interesting of these hearths was Fe 3, situated in Unit Q26, which contained the partial cranium, and a mandible, of a Polynesian dog *(Canis familiaris),* as well as burned endocarp fragments of candlenut *(Aleurites moluccana)* and marine shell (fig. 2.13).

Of particular note is the large earth-oven feature (Fe 10) situated in the middle of the outer terrace. The plan and stratigraphic section of this feature are shown in figure 2.14, while figures 2.15 and 2.16 show the oven during excavation, before and after sectioning. This feature is a typical indigenous Hawaiian earth oven, and was filled with angular, fire-altered volcanic oven stones.

A rather unusual feature (Fe 12) was exposed in the M-trench after the removal of the Fe 10 oven (fig. 2.17). This was an embankment or ridge of hard-packed

TABLE 2.1

FEATURES IN KUOLULO ROCKSHELTER

FEATURE NO.	UNIT	DEPTH BELOW SURFACE (cm)	TYPE	DESCRIPTION
1	P26-27	2-8	Hearth	Small hearth, measuring 19 by 14 cm in plan view, maximum depth 6 cm. Roughly oval in outline. Consisted of white ash with some included charcoal, and contained burned bone and marine shell.
2	P25	10-17	Hearth	Small hearth, measuring 15 by 30 cm, maximum depth 7 cm. Consisted of white ash with some charcoal flecking.
3	Q26	7-10	Hearth	Small, oval hearth, measuring 20 by 30 cm, maximum depth 3 cm. The hearth lay just above the contact between the cultural deposit and bedrock. Consisted of a lens-like concentration of "greasy" charcoal and ash, containing burned *Aleurites* endocarp, a dog cranium and mandible, burned shell, volcanic glass flake, and coral abrader.
4	D20	23-29	Hearth	Small hearth only partially exposed in D20 excavation. Consisted of charcoal and ash overlying oxidized soil.
5	D20	21-29	Hearth	Small circular hearth, approximately 20 cm in diameter, maximum depth 8 cm. Consisted of charcoal and ash with burned bone, burned *Aleurites* endocarp, and burned marine shell.
6			(no. not assigned)	
7	D20	26-35	Hearth	Small concentration of charcoal and ash, measuring 20 by 25 cm, with maximum depth of 9 cm.
8	D20	0-30	Hearth	Only a portion of this feature was exposed in D20; most apparently lies in adjacent Unit D19.
9	N25-24	8-25	Hearth	Small, circular hearth about 20 cm in diameter, maximum depth 17 cm. Consisted of white ash and charcoal.
10	M22-23	4-39	Earth Oven	Large, circular earth oven, approximately 1 m in diameter, maximum depth 35 cm. The oven was filled with vesicular, angular, fire-altered volcanic stones. The base of the oven was marked by a 3-4 cm thick deposit of white ash, and charcoal in pockets.
11	M22	9-17	Hearth	Basin-shaped hearth about 40 cm in diameter, maximum depth 8 cm. Consisted of white ash with some charcoal flecks. About 8 fire-altered volcanic stones were also included in the feature.
12	M22	32-44	Clay Ridge	Hard-packed ridge or embankment of clay running perpendicularly across trench near base of cultural deposit

Figure 2.13. Feature 3 hearth in Unit Q26, on the inner terrace of Site D6-60, containing a dog mandible.

clay, running perpendicularly across the trench at a depth of 32-44 cm. The ridge appeared to have been an artificial construction, but its full extent could not be determined, and its function remains unknown.

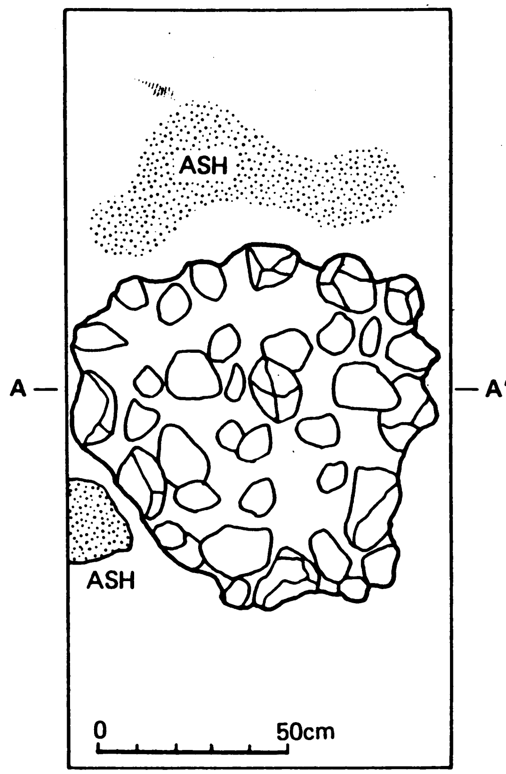
The horizontal exposure of 16 m^2 in the western part of the rockshelter, behind the inner terrace and across the outer terrace, provides a picture of the distribution of major classes of cultural material. Figure 2.18 depicts the frequencies of vertebrate faunal remains, marine molluscan fauna, charcoal, and the endocarp remains of candlenut *(Aleurites moluccana)* by excavation unit. Shell and bone midden are most densely concentrated in the fill of the inner and outer terraces. Charcoal fragments are heavily concentrated in Units M22-M23, reflecting the presence of the large earth oven in the outer terrace (Fe 10). Endocarp fragments of candlenut *(Aleurites)* are heavily concentrated on the inner terrace, suggesting that candlenut lamps were most frequently used in that part of the site.

The Depositional and Occupation Sequence

Three radiocarbon age determinations from Kuolulo shelter are discussed in full at the end of this chapter. Briefly, the oldest determination, of 460 ± 70 B.P., from 65-70 cm below surface in Unit D20, establishes the initial human use of the shelter in the fifteenth century A.D. The earliest use of the site appears to have been confined to the eastern portion of the main floor area, and was thus sampled only in the D20 unit. A charcoal sample from the contact between the cultural deposit and sterile base in Unit M23 yielded a conventional ^{14}C age of 190 ± 60 B.P. This result was closely matched by a charcoal sample from the same stratigraphic situation in Unit Q26, which yielded a conventional age of 180 ± 80 B.P. Thus the construction of the inner and outer terraces (which stratigraphically overlie these two charcoal samples), must date to sometime in the seventeenth to eighteenth centuries. The site continued to be utilized into the early historic period, based on the presence of exotic, Euro-American artifacts in the upper 15 cm of deposit.

KE'EKE'E NUI ROCKSHELTER (Site OA-D6-58)

Site D6-58 lies at an elevation of 85 m above sea level, on the northern, or Ko'olau, side of the Anahulu Stream. As with D6-60, this shelter is situated within the traditional Hawaiian land section, or *'ili,* of Ke'eke'e. We therefore dubbed the site Ke'eke'e Nui rockshelter, or "big" Ke'eke'e (in contrast to the smaller shelter, D6-36, which we named Ke'eke'e Iki rockshelter, or "little" Ke'eke'e). Site D6-58 is located just outside the mapped



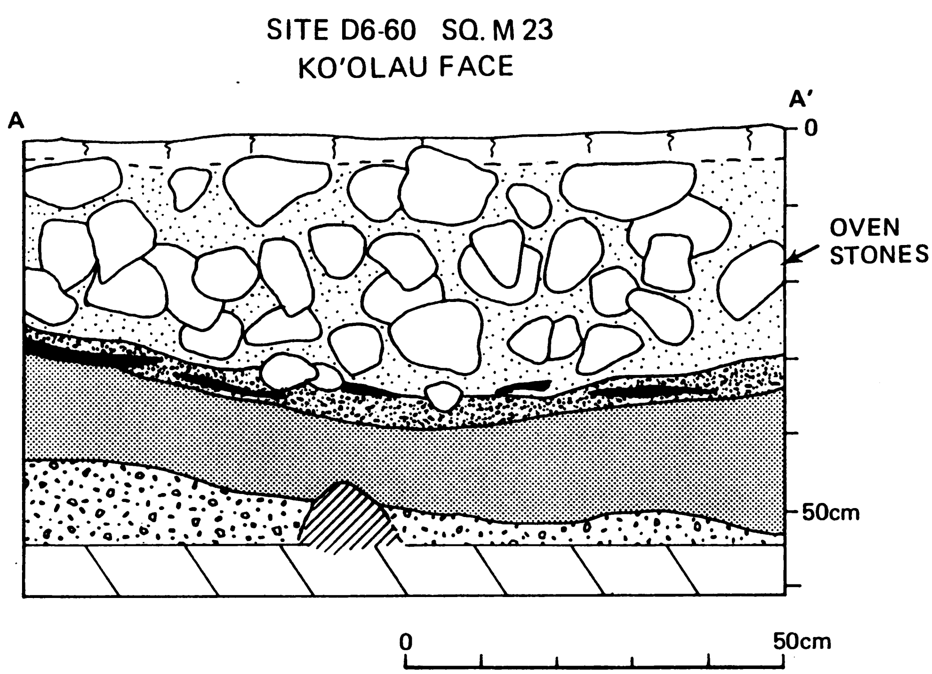


Figure 2.14. Plan and stratigraphic section of Feature 10, a large earth oven in the outer terrace of Site D6-60.

Figure 2.15. Feature 10 earth oven in Site D6-60 during excavation.

Figure 2.16. Feature 10 earth oven in Site D6-60 after sectioning.

Figure 2.17. The M-Trench in Site D6-60 after completion of excavations; view to the north. The ridge of hard-packed clay (Feature 12) can be seen at the far end of the trench, near the base of the large rockfall boulder.

boundary of Land Commission Award 4308-2, claimed by the native cultivator Kuolulo, in 1848.

As with Kuolulo shelter, the Ke'eke'e Nui site was formed when the stream level was higher than at present and differentially eroded a stratum of less-resistent aa clinker alternating between beds of dense flow basalt. Thus the roof of the shelter is formed by a massive cliff of dense basalt. Unlike Kuolulo rockshelter, however, Ke'eke'e Nui rockshelter lies very close to the stream, where the latter forms a sharp bend just downstream against a sheer rock cliff. The occupation floor of Ke'eke'e Nui shelter is only 2.5-5 m above the normal stream level, and the lowest parts of the shelter floor are thus subject to occasional flooding when the stream level rises (see fig. 2.19). (The highest flood level that had occured within the year or two prior to excavation

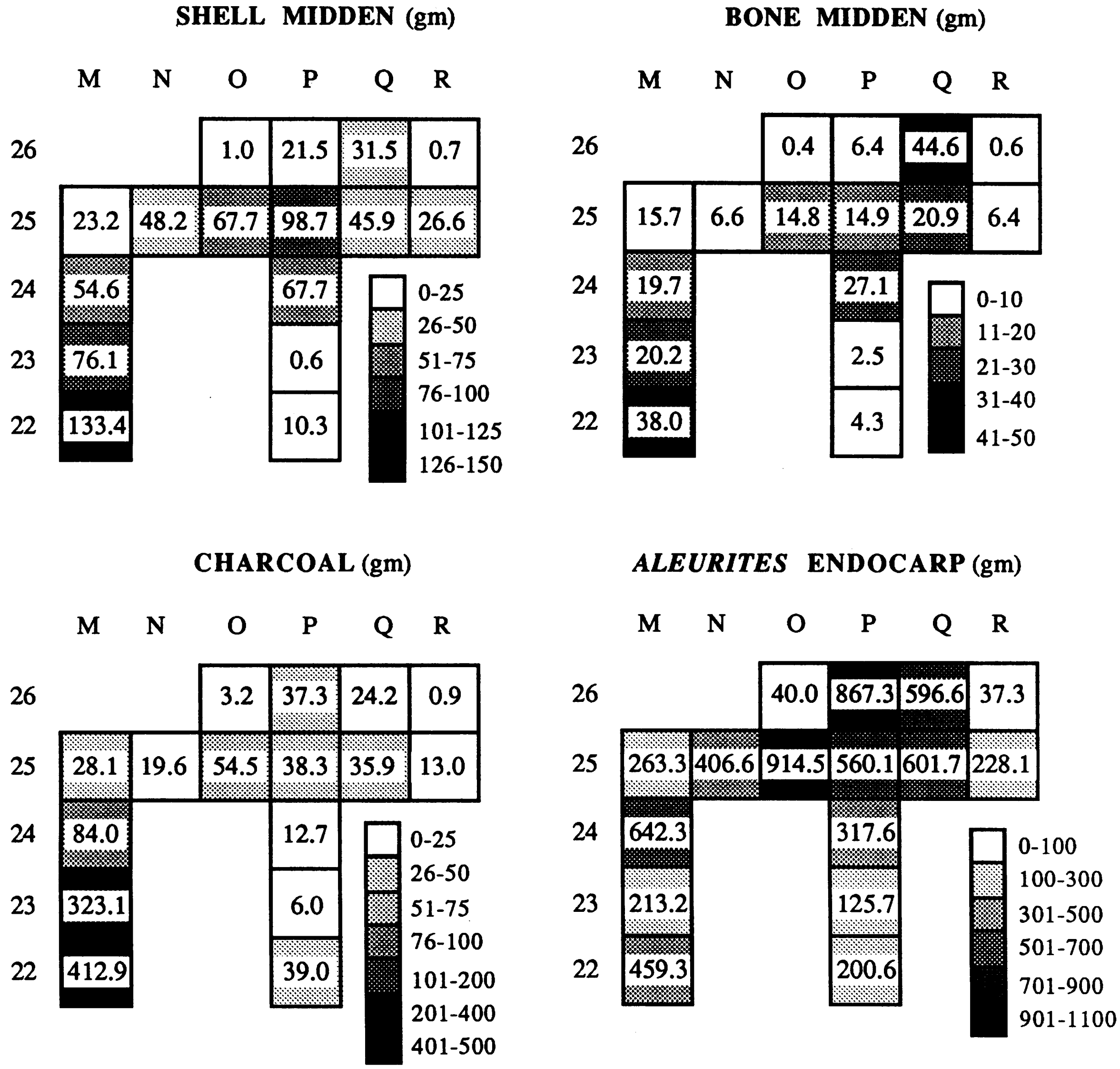


Figure 2.18. Frequencies of shell and bone midden, charcoal, and candlenut *(Aleurites)* endocarp in the western area of Site D6-60.

was marked by a "strandline" of vegetation debris, 2.85 m above the normal streamflow level.) Upstream from the site (east) is an alluvial terrace or bench, which in the early nineteenth century was intensively cultivated in taro *(Colocasia esculenta)* and other crops (see Sahlins and Kirch, in prep.). The small rockshelter, Site D6-36, is situated in the same cliff as Ke'eke'e Nui rockshelter, a short distance to the east (up-valley).

The vegetation surrounding Ke'eke'e Nui rockshelter is almost wholly exotic, dominated by Java plum *(Eugenia jambos)*, mango *(Mangifera indica)*, and banyan *(Ficus* sp.), the roots of the latter forming a cascadse down the rockshelter dripline. A large cycad palm *(Cycas* sp.) grows just outside the shelter at the downstream end.

Ke'eke'e Nui rockshelter has a floor area 22 m long, and ranging from 3 to 6.5 m deep, with an approximate usable floor area under the dripline of 88 m^2. Movement in the rear portion of the shelter is restricted due to a low roof, which drops to 1 m or less in height. However, the outer 2-3 m under the dripline has a higher ceiling. The large banyan and mango trees that shade the shelter make for a rather gloomy aspect today, but when the shelter was clear of vegetation, it would have commanded a view southward across the valley, toward the Wai'anae valley wall. The proximity to the

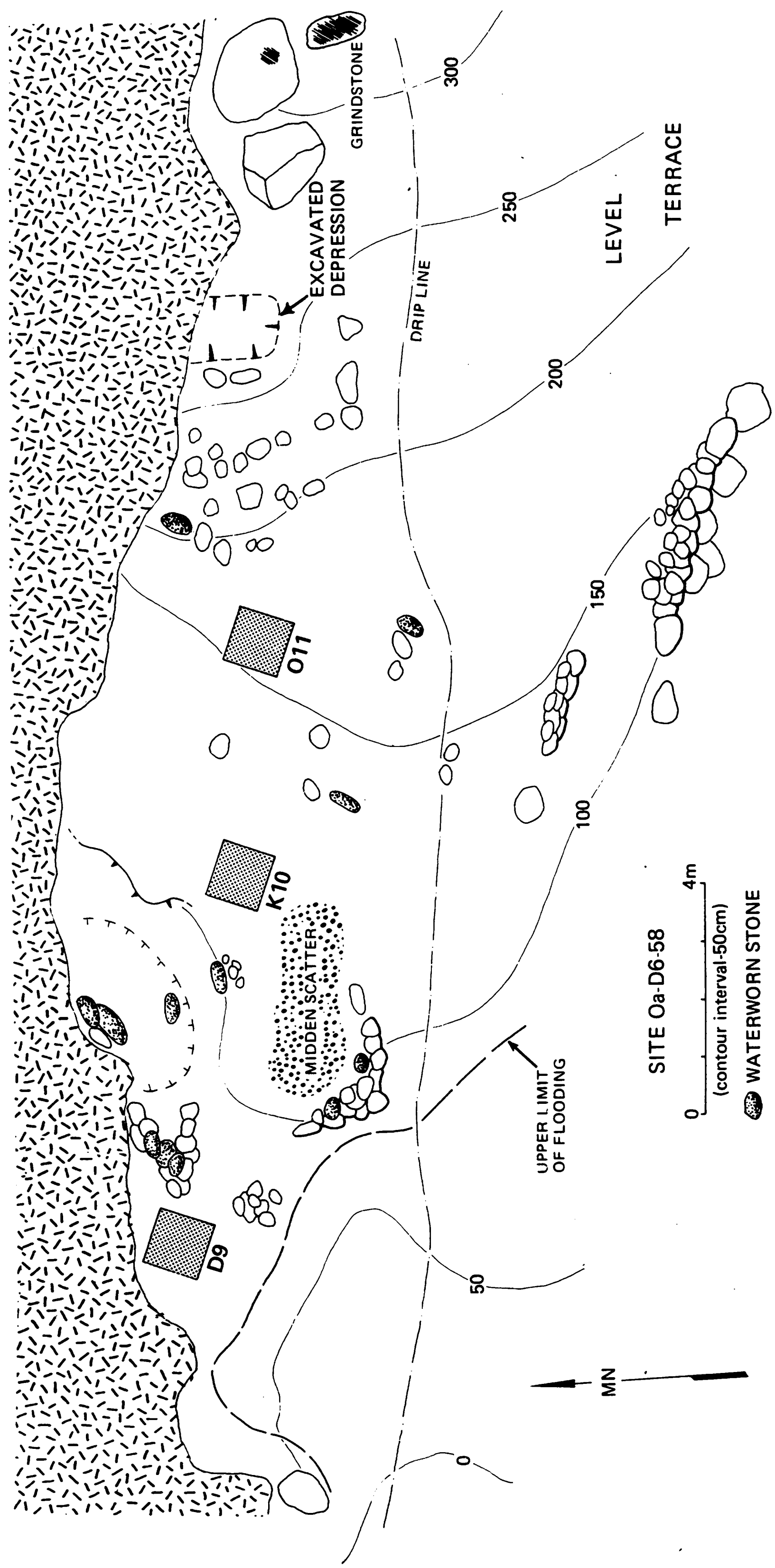


Figure 2.19. Plan of Site D6-58, showing surface features and the location of units excavated in 1982.

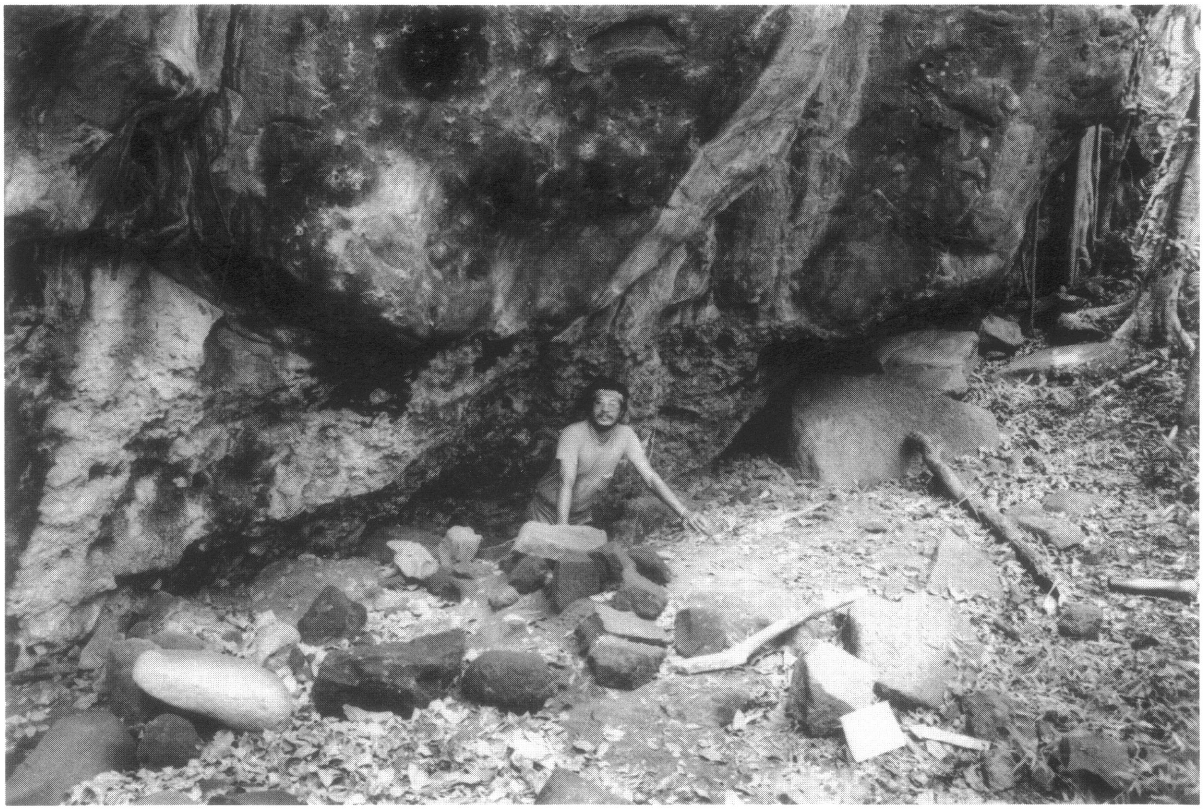


Figure 2.20. Ken Shun standing in the disturbed stone crypt in the eastern portion of Site D6-58.

stream, a permanent source of fresh water, would certainly have been an asset.

Unfortunately, Ke'eke'e Nui rockshelter had been disturbed in several respects prior to our excavation there. Earlier in this century, a cattle fence had been erected across the valley, with one end running directly into the middle of the shelter. Two large wooden fence posts were still standing in the shelter floor. More recently, the shelter had been the temporary home of a "hippie" recluse, who left behind a scatter of debris, including newspapers (dating to 1971), a rotting mattress, candles, a rusted lawn chair, and other paraphenalia. This most recent occupant of the site had shoveled out a depression in the rear of the shelter, presumably to increase the ceiling height; in the process, the integrity of some of the inner shelter deposits was damaged. The eastern portion of the shelter was further disturbed, where a rock crypt had been opened by means of a crude excavation (fig. 2.20), possibly by the "hippie" occupant. (We know from conversations with pig hunters and hikers resident in the Anahulu area that this particular "hippie," who lived in the valley for a year or so, opened and disturbed a number of burial caves.)

Despite such disturbance, much of the shelter was in surprisingly good condition when we commenced work, with several surface features relating to the prehistoric occupation of the site. Near the western end of the floor area, just inside the dripline, was an L-shaped terrace facing of angular basalt cobbles, 2-3 courses high. On top of this terrace the cultural deposit had been exposed by water dripping from the ceiling, and several artifacts were collected in this area. The crypt in the eastern portion of the site, disturbed probably in 1971, has already been mentioned. At the extreme eastern end of the shelter is a large rockfall boulder with a grinding surface. South of this is a second, smaller boulder, the entire upper face of which (.5 x 1 m) had been smoothed by grinding, probably of basalt adzes. Outside of the dripline are two additional basalt cobble terrace facings, the highest standing 90 cm. These retain a roughly terraced area south of the crypt and grinding slabs. In addition to these features, a number of large waterworn, stream cobbles were distributed over the site surface. These had presumably been carried to the site for use as seats or anvils.

Excavation Strategy

As Site D6-58 was the last rockshelter to be investigated during the 1982 Anahulu Project, only a few days could be devoted to its sampling. Our experience with Kuolulo shelter had shown that different portions of an occupation floor might have substantially different depositional sequences. Therefore, at Ke'eke'e Nui we decided to space our test units so as to sample several areas, while carefully avoiding parts of the site that had been recently disturbed. We completed the excavation of three 1-m^2 units, designated D9, K10, and O11 on our grid. While these provided a reasonable sample of the internal stratigraphy of the site, they of course provide no details on continuous horizontal activity areas. As will be described below, Ke'eke'e rockshelter provides a well-stratified sequence spanning some 500-600 years, with much potential for elucidating the occupation history of the middle Anahulu Valley. We estimate that at least 80 m^2 of undisturbed cultural deposits are present (both inside and outside the dripline) in the site. Thus, Ke'eke'e rockshelter clearly merits a major excavation effort, especially one focused on the horizontal exposure of activity surfaces.

A total of 3 m^2 was excavated, with a combined volume of approximately 2.0 m^3 of cultural deposit.

Physical Stratigraphy

Site D6-58 presents a rather complex stratigraphic situation, especially owing to the number of features and disturbances in the excavated test units. The stratigraphy of each unit is described below (see chapter 3 for laboratory analysis of sediments).

Test Unit O11. The stratigraphy of O11 was difficult to interpret due to the presence of an earth oven, several hearths, and a number of rodent burrows that obscured relationships among the main deposits. It was possible, however, to recognize two main cultural deposits, especially in the north face of the unit. The upper cultural deposit, from about 5-35 cm below surface, was dark grayish brown (10 YR 4/2), with a gravelly texture, and very ashy. The lower cultural deposit, from about 35-65 cm, was reddish brown (5 YR 5/3-4), more silty in texture, and contained much less ash and charcoal flecking than the upper cultural deposit. The stratigraphic boundary between the upper and lower cultural deposits was gradational over about 1 cm, but clearly distinguishable. The Feature 9 ash lens covered the base of the unit, and directly overlay the sterile alluvial sand.

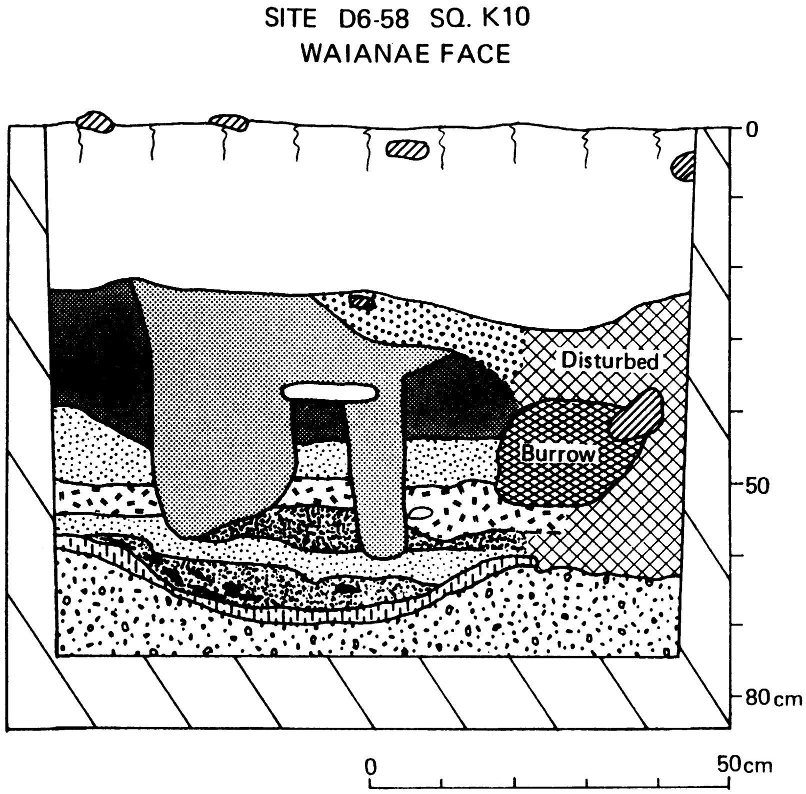
Test Unit K10. The stratigraphic situation in K10 was highly complex, as illustrated in the profiles of the north and south faces (fig. 2.21).

The individual stratigraphic components visible in the north face were: (1) upper cultural deposit, dark grayish brown (10 YR 4/2), ashy, with charcoal flecking throughout, and considerable small waterworn stream gravel (1-7 mm size class): (2) white ash (5 YR 8/1) with charcoal flecking; (3) grayish midden deposit very similar to 1; (4) thin lens of white ash (5 YR 8/1); (5) large pit with brown fill (5 YR 5/2); (6) lens of white ash (5 YR 8/1); (7) dusky red (10 YR 3/3-4), oxidized alluvium; and (8) basal deposit of reddish brown (5 YR 4/4) sandy alluvium.

In the south face, the visible components in the section were: (1) upper cultural deposit, dark grayish brown with significant quantities of charcoal flecking; (2) gray-brown pit fill, with mottled flecks of white ash, charcoal, and shell midden; (3) lower cultural deposit, reddish brown (5 YR 5/3-4), with substantially less ash and charcoal than 1; (4) compact white ash with charcoal; (5) reddish-brown silt loam with charcoal; (6) gray ash with charcoal; (7) compact, white ash with charcoal; (8) base of the Feature 5 earth oven, gray ash with charcoal concentrations; (9) thin lens of dark red, oxidized alluvium underlying the Feature 5 oven; and (10) sterile sandy alluvium. The sequence of strata 4-9 are all associated with the Feature 5 earth oven.

Despite the complexities of these sections, it was clear that the two main cultural deposits recognized in Unit O11 were also present in K10.The upper cultural deposit in both units was characterized by a more gravelly texture, and by the presence of substantial quantities of ash and charcoal. The lower cultural deposit contained much less ash and charcoal, as reflected in its reddish brown, rather than dark grayish brown color. In the field, we noted that these differences probably mark a change in the behavioral activities taking place in the rockshelter when these sediments were being deposited. Clearly, there must have been an increase in the number of fires (both for hearths and earth ovens) lit in the shelter during the later period of occupation. The possibility was also raised that the upper cultural deposit marks an increased intensity of occupation on the site, perhaps a shift from intermittent to permanent utilization.

Test Unit D9. The stratigraphy of this test unit differed substantially from that of Units O11 and K10, due primarily to its lower elevation (the surface of D9 is 25 cm below the surface of K10, and 80 cm below the surface of O11), and susceptibility to flooding from the nearby Anahulu Stream. The stratigraphic section is shown in figure 2.22, and the identified strata are as follows: (1) alluvial sand, brown (7.5 YR 5/4), representing a flood deposit; (2) alluvial silt, brown, also a flood deposit; (3) crumbly deposit of reddish brown (5 YR 4/4) sand, containing some cultural material; (4) alluvial silt, sterile (7.5 YR 5/4), representing a flood event; (5) thin cultural deposit identical to 3; (6) dark reddish brown (5 YR 3/4) midden deposit; (7) dark brown (7.5 YR 3/2) midden deposit; (8) basal, sterile, reddish brown (5 YR 4/4) alluvial sand. It is not possible, without further excavation, to



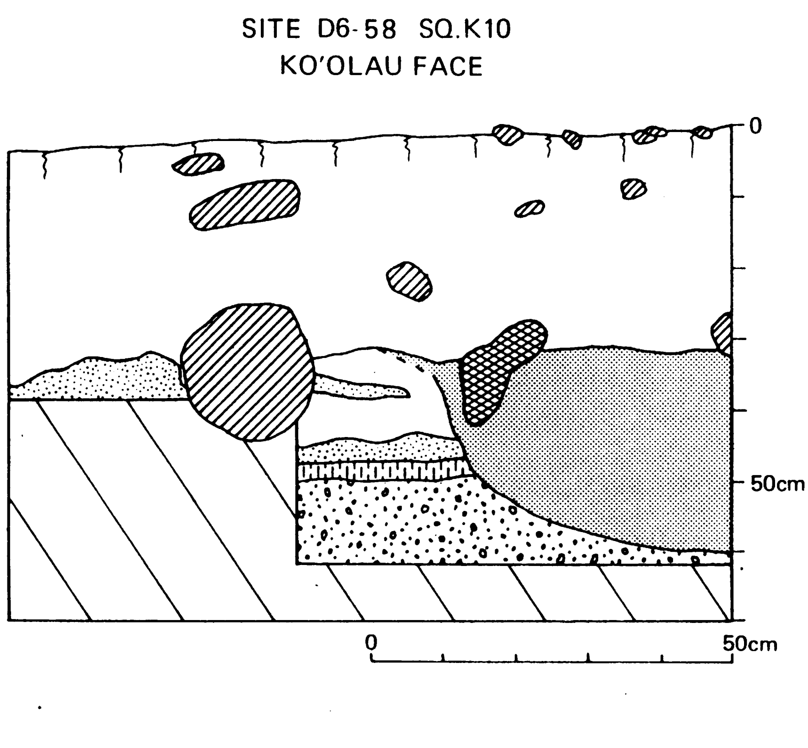


Figure 2.21. Stratigraphic sections of Unit K10, Site D6-58.

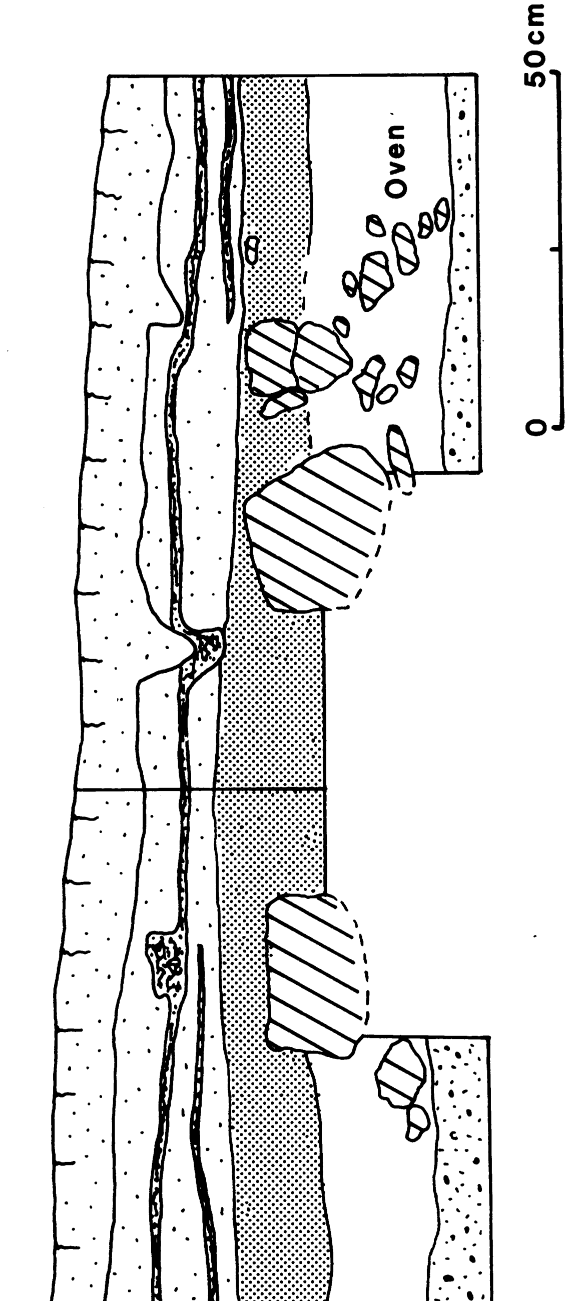


Figure 2.22. Stratigraphic section of Unit D9, Site D6-58.

correlate either the lower midden deposits, or the thin upper lenses containing cultural materials, with the sections in K10 or O11.

Cultural Content and Features

Site D6-58 yielded a collection of 478 portable artifacts of indigenous Hawaiian manufacture, of which 336 consist of flakes and cores of volcanic glass. Of particular note are four fishhooks, a basalt adz, a gaming stone, and a tattooing needle. The presence of these and other artifact classes in the upper cultural deposit provide additional evidence of a shift from temporary to permanent occupation of this shelter. These artifacts are analyzed in full in chapter 8. The site also yielded artifacts of Euro-American manufacture. Vertebrate and invertebrate faunal assemblages are analyzed in chapter 4.

Ten features were recognized during excavation, as enumerated in table 2.2. Unit K10 contained five features, one of which is a large earth oven visible in the stratigraphic section (fig. 2.21). Unit O11 had four features, including an earth oven. Unit D9 also contained an earth oven, although this was only partly exposed in the excavated area. All other features were small, scoop-type hearths or ash lenses.

The Depositional and Occupation Sequence

The base of the depositional sequence in all excavation units consists of a stream-deposited alluvial sand, evidently derived from a flood-stage of the Anahulu Stream. No charcoal flecking was noted in this alluvial deposit, which might be taken as evidence that there was no significant burning in the Anahulu drainage basin prior to the occupation of Ke'eke'e Nui shelter. (Alluvial deposits in the valley which have been dated to the period of human occupation generally contain significant quantities of macroscopic charcoal flecking, derived from burning within the catchment area.) In Unit O11, the alluvial sand is directly overlain by Feature 9, a 6 cm thick ash deposit extending beyond the confines of the 1-m^2 unit. This deposit probably represents burning of vegetation debris on the floor of the shelter immediately prior to human utilization, and subsequent accumulation of midden deposits. Feature 9 yielded a conventional ^{14}C age of 600 ± 110 B.P., calibrated to A.D. 1280-1430, with all intercepts on the calibration curve falling in the mid-fourteenth century A.D. This radiocarbon age thus provides an estimate of the initial human use of the site in approximately the fourteenth century.

Both units O11 and K10 revealed differentiated lower and upper occupation deposits, as described above. The lower deposit is characterized by a sediment with substantially less charcoal and ash than the upper cultural deposit. The densities of both vertebrate and invertebrate faunal materials are also significantly higher in the upper cultural deposit (see chapter 4, tables 4.4 and 4.7). Although our excavated sample of the total occupation area in this site is limited, the stratigraphy suggests a major change in the use and behavioral activities at the site, between earlier and later phases. Tentatively, I suggest that this change was from an earlier pattern of infrequent, temporary occupations in the rockshelter, to a later pattern of more frequent, intensive, and possibly permanent residence. This occupation sequence will be discussed in further detail in chapter 9.

The large earth oven in Unit K10, Feature 5, yielded a conventional ^{14}C age of 280 ± B.P., calibrated to A.D. 1516-1599 and 1617-1659 at one standard deviation (the two ranges reflect fluctuations in the calibration curve at this time interval). Although the base of Feature 5 lies on the sterile alluvium, the oven was cut from near the base of the upper cultural deposit. Thus the change in site occupation reflected in the interface between lower and upper cultural deposits can be dated to approximately the sixteenth-seventeenth centuries.

A third ^{14}C age was obtained from an oven (Feature 10) in Unit D9: less than 90 years B.P. at one standard deviation, or less than 180 B.P. at two standard deviations (and therefore not calibrated). Stratigraphically, the oven is related to stratum 6 (see fig. 2.22) and contains only indigenous artifacts. The oven is overlain by the sequence of alluvial flood deposits, and two thin occupation lenses (strata 3 and 5), the latter two containing artifacts of Euro-American origin (glass beads, gun flints, and glass sherds). Thus, Feature 9 probably dates to the end of the eighteenth or first few years of the nineteenth century (consistent with the date range of two standard deviations), prior to the regular introduction of imported artifacts to the Anahulu Valley (see Sahlins and Kirch, in prep.).

KE'EKE'E IKI ROCKSHELTER
(Site OA-D6-36)

Ke'eke'e Iki rockshelter is located not more than 100 m east of Ke'eke'e Nui shelter, in the same cliff formation on the northern side of the valley. Access between the two shelters is easy along the base of the steep cliff into which both sites are cut. Because the Anahulu Stream meanders southwards from D6-58, the stream is 100-150 m south of Ke'eke'e Iki shelter. In other respects, the immediate environments of both sites are very similar.

TABLE 2.2

FEATURES IN KE'EKE'E NUI ROCKSHELTER

FEATURE NO.	UNIT	DEPTH BELOW SURFACE (cm)	TYPE	DESCRIPTION
1	K10	17-28	Hearth	Small, scoop hearth measuring 13 by 30 cm, maximum depth 11 cm. Consisted of white ash and charcoal.
2	K10	30-35	Ash lens	Thin lens-like deposit of ash with some charcoal, 3-5 cm thick; 25 by 100 cm in plan view.
3	K10	40-45	Hearth	Basin-shaped hearth measuring 40 by 55 cm, maximum depth 5 cm. Consisted of compact white ash with some charcoal flecking, and burned *Aleurites* endocarp.
4	K10	40-43	Ash lens	Small, lens-shaped deposit of white ash with charcoal flecks, underlain by red (burned, oxidized) soil. Irregular shape, with maximum diameter of 30 cm, depth of 3 cm.
5	K10	55-68	Earth Oven	Large earth oven, measuring > 1 m in diameter (not fully exposed in test unit). Basin-shaped, with base resting on sterile alluvium. Contained 14 fist-sized, fire-altered volcanic stones. At base of feature is a 3-4 cm thick deposit of grey ash with charcoal. Underlying alluvium a dark red color (oxidized).
6	O11	10-24	Earth Oven	Earth oven measuring 50 by 60 cm, maximum depth 14 cm. Contained 83 small fire-altered volcanic stones, dog and fish bone, marine shell, charcoal, and ash.
7	O11	30-41	Hearth	Small, scoop hearth measuring 20 by 40 cm, maximum depth 14 cm. Contained charcoal and ash, with some burned bone and shell.
8	O11	45-55	Hearth	Hearth measuring 12 by 31 cm, maximum depth 10 cm. Contained ash, charcoal, and marine shell.
9	O11	74-80	Ash Deposit	Lens-like deposit of ash and charcoal, 6 cm thick, extending over entire base of O11 test unit. Ash lies directly over sterile alluvium.
10	D9	43-58	Earth Oven	Earth oven only partially exposed in excavated unit; maximum depth 15 cm. Contained 37 fist-sized, fire-altered vesicular, volcanic stones. Orange-colored ash lined the base and rim of the oven. Considerable charcoal flecking between oven stones. Some carbonized *Aleurites* endocarps were present, as well as 3 fragments of a flat, spongy material that may have been *Lagenaria* gourd.

Figure 2.23. View of Ke'eke'e Iki rockshelter, Site D6-36.

As with the other shelter sites, Ke'eke'e Iki consists of a stream-eroded notch in the cliff face (fig. 2.23). This site, however, is considerably smaller than those described above. The main occupation floor measures 12 m long, with a width of between 2.5 to 5.5 m, and a total floor area of slightly less than 50 m^2 (fig. 2.25A). As it is shallow, the shelter is quite light and airy, and the roof is constricting only in the rear 1-2 m of the floor area (fig. 2.25B).

The main occupation floor is nearly level, and is retained by a low terrace facing of angular volcanic cobbles that more-or-less coincides with the shelter dripline. The western boundary of the occupation area is defined by several large rockfall boulders over which a low, crude stone wall had been constructed. At the eastern end of the occupation floor, a semicircular stone crypt had been constructed against the rear wall of the shelter. The crypt appeared to have been opened at some time in the past, and was empty. As with the crypt structures situated at the eastern ends of Kuolulo and Ke'eke'e Nui shelters, this structure may formerly have contained a burial. South of the occupation area, and outside of the shelter dripline is a large rockfall from the cliff high above the site.

Aside from the disturbance to the crypt, Ke'eke'e Iki shelter was in very good, undisturbed condition in 1982. A hammerstone lay on the surface of the occupation floor about 1.5 m behind the terrace facing. Several large waterworn stream cobbles were also situated within the occupation area.

Excavation Strategy

The main objectives at D6-36 were to sample the occupation floor between the terrace facing and the rear of the shelter, and to obtain a continuous stratigraphic profile which would provide a temporal sequence for the site. To meet these objectives most efficiently, we excavated a 5-m long trench along the K-line of our grid, running from the rear shelter wall out to the terrace facing (fig. 2.24). This trench yielded a reasonable sample of the occupation deposits within the dripline area, and stratigraphic profiles along both the west and east sides of the trench were recorded. The cultural deposits proved to be relatively shallow in the interior of the shelter, and were deepest immediately behind the terrace retaining wall, where excavation reached 95 cm below surface. In all, a total volume of 1.95 m^3 was excavated.

Physical Stratigraphy

The stratigraphy of Ke'eke'e shelter is uncomplicated, consisting of a single, undifferentiated,

Figure 2.24. View of Site D6-36 from the west, showing the excavated trench bissecting the main occupation floor and extending out to the terrace retaining wall.

cultural occupation deposit overlying and retained by the artifically constructed stone terrace. In the rear portion of the shelter, the cultural deposit directly overlies bedrock. The profile of the western face of the K-trench is diagrammed in fig. 2.26 and a view of the trench showing this face is also given in fig. 2.27. The uppermost 5 cm consisted largely of culturally-sterile aeolian sediment mixed with organic debris which had accumulated after the abandonment of the shelter. Below this the occupation deposit was a dark brown (7.5 YR 3/2), ashy midden. At about 30-35 cm below surface, the deposit graded into a dark grayish brown (10 YR 4/2) sediment with more angular gravel, representing terrace fill. A 50-cm deep sediment column was taken from the eastern face of Unit K18.

Cultural Content and Features

Site D6-36 yielded a collection of 274 portable artifacts of indigenous Hawaiian manufacture, of which 213 (78%) consist of flakes and cores of volcanic glass. The site also yielded artifacts of Euro-American manufacture. These artifacts are analyzed in chapter 8. The assemblages of vertebrate and invertebrate faunal materials are analyzed in chapter 4.

Six features were revealed during the excavation of the K-trench, as enumerated and described in table 2.3. Five of these were hearths or charcoal and ash lenses, and one (Fe 4) was a small earth-oven. The Feature 4 oven yielded a radiocarbon sample (see below).

The Depositional and Occupation Sequence

The human use of Ke'eke'e Iki rockshelter began with the construction of a 2-3 course high terrace facing running along the shelter's dripline, and with concomitant leveling of the main occupation area by filling in the area behind the retaining wall with stones and rubble. Occupation then commenced on the roughly leveled surface, leading to the accumulation over time of up to 35 cm of cultural midden deposit. A radiocarbon sample from the Feature 4 oven yielded a conventional age of 240 ± 50 B.P., and probably dates the initial use of the site immediately following construction of the terrace. This ^{14}C age may be calibrated to either the mid-seventeenth or mid-to-late eighteenth centuries A.D. (due to fluctuations in the calibration curve for this time interval, Stuiver and Becker 1986). The use of Ke'eke'e Iki shelter is thus quite late, corresponding to the final one or two centuries of Hawaiian prehistory.

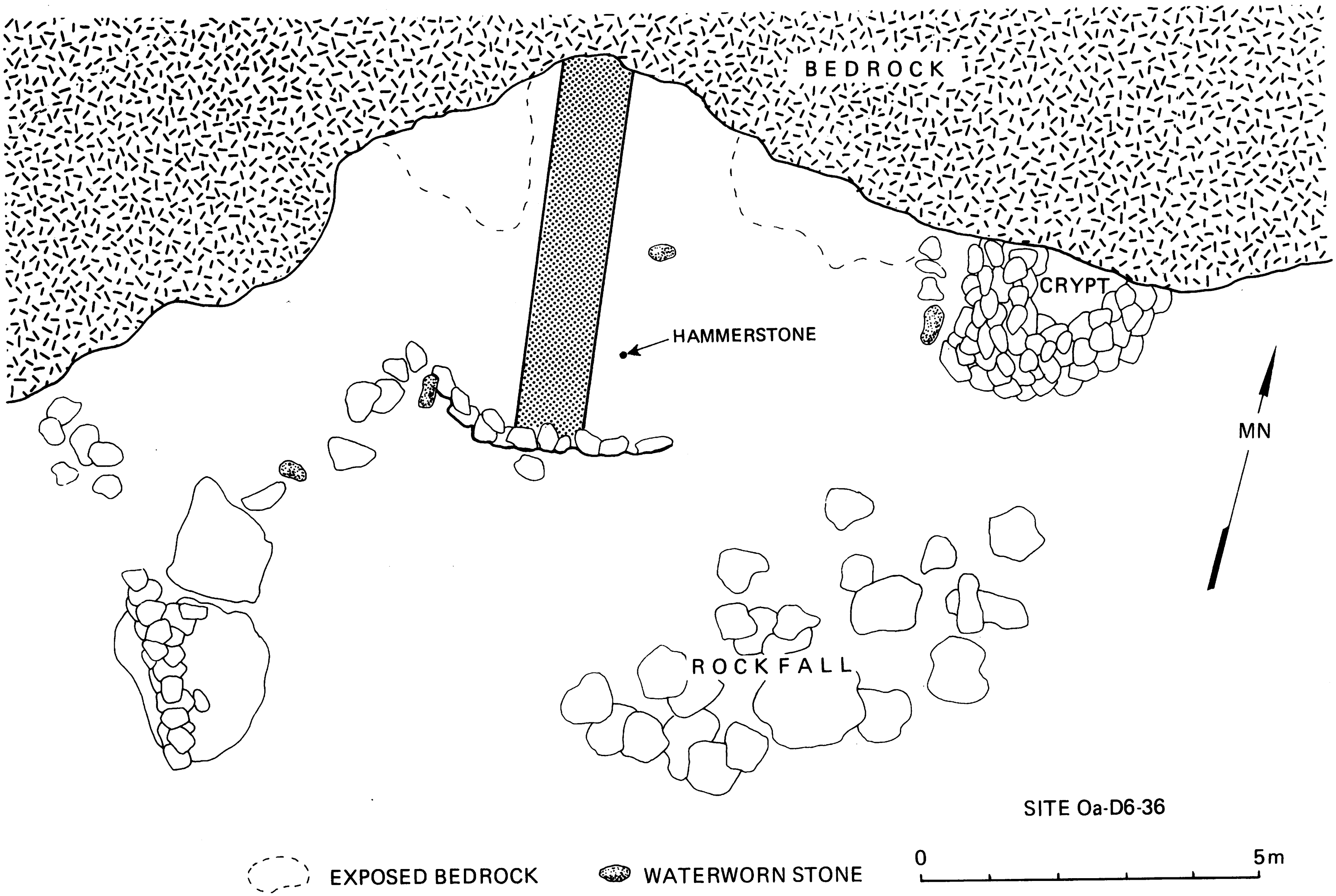


Figure 2.25A. Plan of Site D6-36, showing the locations of surface features and of the trench excavated in 1982.

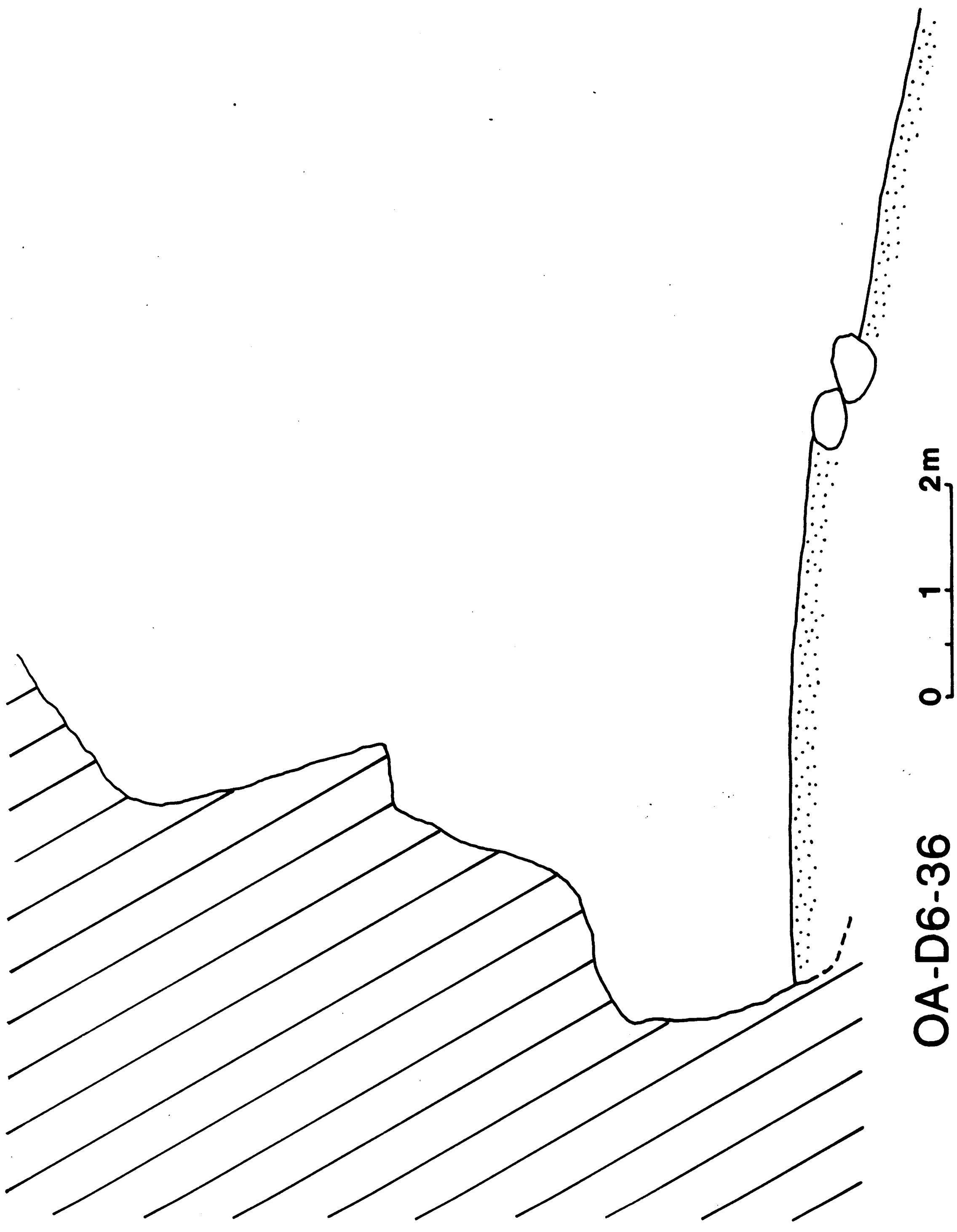


Figure 2.25B. Profile through Site D6-36 rockshelter.

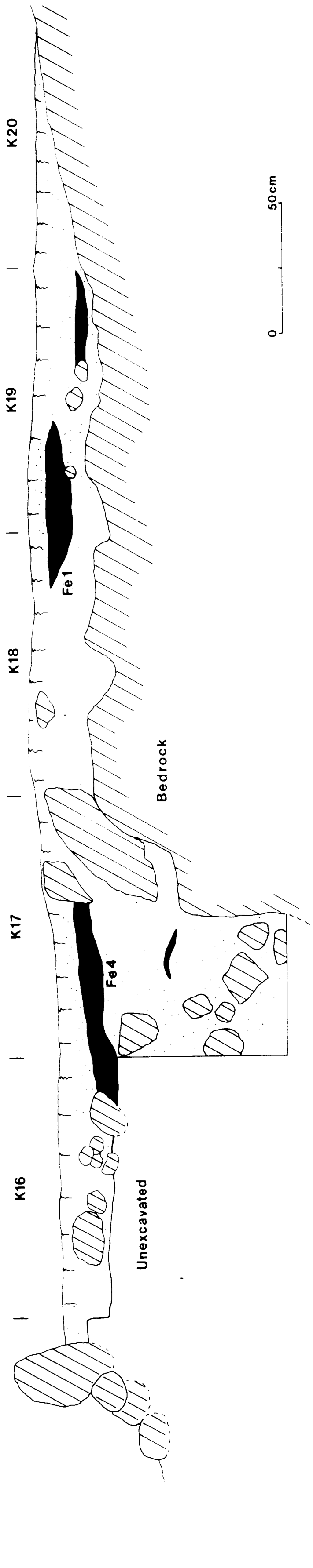


Figure 2.26. Stratigraphic section of the west face of the K-Trench in Site D6-36.

TABLE 2.3

FEATURES IN KE'EKE'E IKI ROCKSHELTER

FEATURE NO.	UNIT	DEPTH BELOW SURFACE (cm)	TYPE	DESCRIPTION
1	K18-19	6-3	Hearth	Scoop hearth measuring 55 by 73 cm, containing charcoal and ash, some fire-cracked volcanic stone, carbonized *Aleurites* endocarps, marine shell and bone.
2	K19	19-22	Ash lens	Small lens-like concentration of white ash with wood charcoal measuring 20 by 30 cm, maximum depth 3 cm.
3	K19-20	18-20	Ash lens	Thin lens of white ash and charcoal, resting on bedrock. Measured 30 x 50 cm, 2 cm deep.
4	K19	25-40	Earth Oven	Basin-shaped earth oven (60 by 65 cm, 15 cm deep) filled with fire-cracked, fist-sized volcanic stones. Large pieces of wood charcoal were dispersed between the oven stones, and a lens-shaped concentration of white ash lined the bottom of the feature.
5	K16	10-29	Hearth	Concentration of charcoal and ash (19 cm deep).
6	K17	25-36	Hearth	Small concentration of charcoal and ash, measuring 26 x 40 cm, maximum depth 11 cm.

The occupation period for Ke'eke'e Iki shelter probably corresponds roughly with the "upper cultural deposit" in nearby Ke'eke'e Nui shelter.

RADIOCARBON CHRONOLOGY OF THE ROCKSHELTERS

Seven samples were submitted for radiocarbon age determinations, three each from Sites D6-60 and -58, and one from Site D6-36, as enumerated in table 2.4. All samples consisted of wood charcoal, with the addition of carbonized candlenut *(Aleurites moluccana)* endocarp fragments in the case of five samples. All determinations were made by the Beta Analytic, Inc. laboratory, using the liquid scintillation spectrometer method. All samples were first hand picked for elimination of rootlets, then given an extensive hot acid pretreatment to eliminate any contamination by carbonates. Samples were rinsed to neutrality and submitted to hot alkali solution to extract humic acids, followed by another acid treatment, and final rising to neutrality. All benzene syntheses and subsequent radioactivity measurements proceeded normally (M. Tamers, pers. comm., Sept. 10 and Nov. 8, 1982).

Table 2.4 provides data on ^{13}C, and on the "conventional ^{14}C age" B.P. (Stuiver and Polach 1977) for all samples. The calibrated A.D. ages shown in the right-hand column of table 2.4 are based on the terrestrial curve of Stuiver and Becker (1986), and were determined using a revised FORTRAN microcomputer program ("CALIB") provided to the author by M. Stuiver and P. Reimer (cf. Stuiver and Reimer 1986). The calibrated age ranges provided are those obtained from the intercepts of the calibration curve ("Method A"), at one standard deviation.

TABLE 2.4

RADIOCARBON AGE DETERMINATIONS FROM ANAHULU VALLEY ROCKSHELTER SITES

LAB NO.	SITE	PROVENIENCE	MATERIAL	^{13}C	CONVENTIONAL ^{14}C AGE B.P.	CALIBRATED AGE A.D. (1 s.d.)*
B-5169	D6-60	Unit D20, 65-70 cm	Wood charcoal	–24.57	460 ± 70	1412-1465
B-5170	D6-60	Unit M23, 40-45 cm	Wood charcoal	–25.27	190 ± 60	1650-1690, 1724-1810
B-5168	D6-60	Unit Q26, Fe 3, 7-20 cm	Wood charcoal, *Aleurites* endocarp	–24.37	180 ± 80	1647-1712, 1716-1886
B-5613	D6-58	Unit O11, Fe 9, 7-10 cm	Wood charcoal, *Aleurites* endocarp	–24.78	600 ± 110	1280-1430
B-5172	D6-58	Unit K10, Fe 5, 55-68 cm	Wood charcoal, *Aleurites* endocarp	–21.62	280 ± 60	1516-1699, 1617-1659
B-5612	D6-58	Unit D9, Fe 10, 43-58 cm	Wood charcoal, *Aleurites* endocarp	–22.37	<90	—
B-5609	D6-36	Unit K19, Fe 4, 25-40 cm	Wood charcoal, *Aleurites* endocarp	–23.53	240 ± 50	1639-1668, 1751-1758, 1776-1797

* Method A of Stuiver and Becker at one standard deviation.

Figure 2.27. View of the K-Trench in Site D6-36 after completion of excavations.

The stratigraphic positions of all samples, and their interpretations in reference to individual site depositional sequences, have been discussed above. As a group, the entire suite of samples indicates that Ke'eke'e Nui rockshelter was probably the first to be utilized by prehistoric Hawaiians, in about the fourteenth century A.D. Kuolulo rockshelter was in use by the mid-fifteenth century A.D. The smaller Ke'eke'e Iki shelter was not in use until about the mid-seventeenth (or possibly eighteenth) century, when the nearby Ke'eke'e Nui shelter was becoming more intensively occupied.

In terms of the archipelago-wide cultural sequence established by Kirch (1985:298-308), these sites were first utilized in the middle of the Expansion Period, a time of major expansion of settlements into leeward areas, and into more ecologically 'marginal' situations (see also Hommon 1976, 1986). Occupation of the Anahulu shelters continued into the Proto-Historic Period (A.D. 1650-1795), during which time these sites may have become more intensively used, even on a permanent basis. Based on their artifact assemblages all shelters appear to have been abandoned as occupation loci early in the Historic Period.

REFERENCES CITED

Hommon, R.J. 1976. "The Formation of Primitive States in Pre-Contact Hawaii." Ph.D. Dissertation, Univ. of Arizona. (University Microfilms.)

_____. 1986. Social evolution in ancient Hawaii. In P.V. Kirch, ed., *Island Societies: Archaeological Approaches to Evolution and Transformation*, pp. 55-68. Cambridge University Press.

Kirch, P.V. 1985. *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory*. University of Hawaii Press. Honolulu.

Sahlins, M., and P.V. Kirch. in prep. *Anahulu: The Archaeology of History in the Early Sandwich Islands Kingdom.*

Stuiver, M., and B. Becker. 1986. High-precision decadal calibration of the radiocarbon time scale, A.D. 1950-2500 B.C. *Radiocarbon* 28(2B):863-910.

Stuiver, M., and H.A. Polach. 1977. Reporting of ^{14}C Data. *Radiocarbon* 19:355-63.

Stuiver, M., and P.J. Reimer. 1986. A computer program for radiocarbon age calibration. *Radiocarbon* 28(2B):1022-30.

Weisler, M., and P.V. Kirch. 1985. The structure of settlement space at Kawela, Molokai. *New Zealand Journal of Archaeology* 7:129-58.

CHAPTER THREE

A GEOARCHAEOLOGICAL ANALYSIS OF SEDIMENTS FROM THE ANAHULU VALLEY ROCKSHELTERS

by Terry L. Hunt

THE PRIMARY GOAL OF GEOARCHAEOLOGICAL research in Anahulu Valley rockshelter sites is to describe and examine the sedimentary matrix of the sites in order to infer the history of deposition (see Stein and Farrand 1985; Stein 1987). Stein (1985, 1987) has recently discussed general principles of sedimentation as a useful structure for studying archaeological deposits. General principles are based on a "life history" concept where a sediment has (1) a source, (2) a transport history, (3) an environment of deposition, and (4) undergoes post depositional alterations. These principles are used here to interpret the sedimentary matrix and its relation to artifactual and paleoecological data from the rockshelters (see table 3.1, adapted from Stein and Rapp 1985:144).

ANALYTIC METHODS

During the course of excavations, 1 to 2 kg of sediment were systematically sampled from exposed stratigraphic profiles in at least one location from each site (see chapter 2). This sampling strategy not only included multiple samples of most stratigraphic units, it also enabled various differences within the major strata to be analyzed. An external control sample was also taken so that sediment characteristics between natural and archaeological deposits could be compared (Stein 1985). In the laboratory, sediment samples were allowed to air dry (in the bags from the field). Small sub-samples were taken from the air-dried field samples for various analyses. These sub-samples, ranging from as little as 5 grams up to ca. 40 grams, were made using a Jones sample splitter, thus assuring a non-biased selection of the particles present in the larger samples. A basic goal was one of conservative use of the field samples—thus reserving much of the sediment for analyses not performed in this project or for any necessary re-analysis.

Particle Size Analysis

Sub-samples for particle size analysis generally require a portion of 20 to 40 grams, depending on the size classes present (Folk 1965). All of the sub-samples for particle size analysis were pretreated to remove organic matter (Folk 1965:17). Prior to pretreatment, the sub-sample was inspected with a low power binocular microscope for materials such as plant macrofossils, landsnails, and artifacts that might be chemically or mechanically damaged or destroyed. Pretreatment for removal of organic matter assures the break up of organically consolidated particles and removal of recent organic (e.g., leaf fragments, etc.) as well as chemical precipitates. The practical effect of pretreatment for organic matter is to keep clay minerals in dispersion and to preclude analytic measurement of debris not thought to relate directly to depositional or post-depositional processes.

Jackson (1969) has described the method for removal of organic matter. However, sodium hypochlorite ($NaOCl$) was used as a much less expensive alternative to hydrogen peroxide, and it has proven just as effective with less danger of violent

TABLE 3.1

A MODEL FOR GEOARCHAEOLOGICAL RESEARCH IN ANAHULU VALLEY

Principles of Sedimentation	Geological Interpretation[1]	Attributes of Sediment	Analyses Used in Anahulu Study[2]
1) Source	defing areas from which sediment derives; weathering processes	textural and mineral maturity; uniformity/ composition; mineralogy	texture, including grain size distributions; point counts; microartifact counts
2) Transport Mechanism	water, wind, and gravity as agents	texture (size distributions and grain morphology and surface structure); structure of the deposit	texture, especially grain size distribution; artifacts (micro- to non-portable)
3) Environment of Deposition	sites of deposition after transport, e.g., valley floors, caves, dunes, etc.	texture and structure; geomorphic expressions of the unit	texture (and stratigraphic context)
4) Post-Depositional Alterations	lithification; pedogenesis; family of turbations	measuring the additions, removals, transfers, and transformations within soil using chemical and physical analyses	pH; organic matter and carbonate analysis; color; texture

[1] Adapted from Stein and Rapp (1985:144); they add archaeological interpretations primarily by adding humans as agents in the life history of a sediment.

[2] Analyses relating directly to one phase of life history or attributes of a sediment overlap and have important bearing on other aspects of a sediment.

reaction (see Briner 1963; Anderson 1961; Lavkulich and Wiens 1970). Commercial Chlorox liquid bleach (NaOCL) was adjusted to a pH of 9.5 by adding a small (variable) amount of hydrochloric acid (HCl). This procedure is necessary, as a high alkaline solution may attack clay particles (Jackson 1969:37). All of the Anahulu particle size sub-samples received the same basic treatment (following Jackson 1969).

Subsequent to pretreatment for removal of organic matter, the sediments were inspected under a low power binocular microscope in order to ascertain the presence of any remaining organically bound aggregates. This examination revealed a range of fine sand to coarse silt size aggregates comprised of clay and bound by free iron oxides. Such pedogenic aggregation of particles would bias measures of particle size distributions in the direction of large phi classes. As Kunze (1965:574) points out, iron-containing samples are difficult to properly disperse without removal of iron oxides. Thus, a second pretreatment for free iron oxide removal was undertaken on all Anahulu rockshelter samples using the sodium dithionite-citrate procedure (Kunze 1965:575-76 and references therein).

Following the pretreatment for removal of organic matter and free iron oxides, samples were thoroughly rinsed using distilled water and then oven dried (under 100° C). The dry sediment was then added to flasks with 150 mls of $(NaPO_3)_6$ and mechanically shaken vigorously for five minutes after which it was left to stand for a minimum of 24 hours to assure that no flocculation would occur. The sample was then wet screened (4 phi screen), separating sand from the finer fraction. The course fraction was dried and sieved into phi intervals for measurement (grams to nearest .0001) using an electronic balance. The fine fraction was added to a dispersing agent and analyzed using the pipette method (phi intervals are sampled based on differential settling times and measured to .0001 grams; see Sternberg and Creager 1961 for a comparison with hydrometer method). Statistics for particle size distributions were calculated and classified after Folk (1974) using a computer program written specifically for this purpose. These distributions were plotted as frequency curves and as cumulative curves (Reineck and Singh 1980:132-34). Such statistics in conjunction with other data form the basis of interpreting "the energy of the depositing medium and the energy of the basin of deposition" (Reineck and Singh 1980:132). In other words, particle size informs on the transport mechanism(s) and environment of deposition as determined by available source material. The particle size distributions for the Anahulu rockshelter sites are given below and interpreted in terms of this general sedimentological model (Folk 1965; Folk and Ward 1957; Visher 1969).

Grain Shape and Surface Texture

The shape (roundness, sphericity) of sedimentary particles ideally records distinguishing features of origin, transport agent, and depositional history (Shackley 1975). These features are recorded under magnification and can be assigned to ordinal level classes on visual criteria (e.g., Powers 1953). Estimation of grain shape or rounding has proven quite successful, particularly in the long temporal sequences of French and African rockshelters (e.g., Farrand 1975). Anahulu samples (prepared with grains of 4 phi class) were examined for patterns of grain rounding under varying magnification (40-800X) on the scanning electron microscope (SEM) (see Gillieson 1983).

Organic Matter and Carbonate Analysis

The loss-on-ignition method is a means to estimate the percentage of organic matter and carbonates of a sediment sample (Stein 1984). The theory of the ignition loss method is that when a dried powdered sample is heated, organic matter will begin to ignite at 200°C and completely burn off when the temperature reaches 550°C. Calcium carbonate ($CaCO_2$) evolves into carbon dioxide at 800°C and is completed at approximately 850°C (Stein 1984). Thus, to measure organic matter and carbonate percentages, the weight difference of an oven dried sample (ca. 5 grams) before and after a 550°C and a 1000°C burn is measured to the nearest .0001 grams. The method used here is described in more detail by Dean (1974) and by Stein (1984), who also discusses applications in archaeology. The Anahulu samples were analyzed for organic matter and carbonate percentages to describe and document patterns of potential cultural and natural additions and pedogenic transfers within and across strata of the rockshelter deposits.

pH Analysis

The acidity, neutrality, or alkalinity of sediment is measured in pH levels. Measurements of pH in the Anahulu samples were made on an automatic Altex 70 pH meter. A minimum of three readings was taken once the sample stabilized (20 ml sediment with 20 ml distilled water), with the pH value calculated as an average. This common method yields data on the chemistry of a depositional matrix and can be used to assess factors of preservation (e.g., Gordon and Buikstra 1981). For the Anahulu samples, pH data were recorded in order to assess any potential of differential preservation and to relate pH to other pedogenic factors.

Color

Sediment color, recorded using the standardized Munsell system, provides information on source (primary coloration) and/or may reflect diagenetic causes such as biochemical alterations (Shackley 1981). The color of Anahulu samples was recorded as air dried and moist under laboratory conditions and is included primarily for descriptive purposes.

Microartifact Analysis

A method designed to determine quantitatively the percentage of various minerals present in a rock (Galehouse 1971) has recently been extended to estimate the quantity of "microartifacts" in archaeological sediments (Fladmark 1982; Stein 1987). This simple method involves mounting grains of individual phi classes (generally sand-sized classes) on glass slides, then identifying and counting all grains within a particular sized area (e.g., one square centimeter; see Galehouse 1971 for variations in method). Samples from the Kuolulo Rockshelter (Column C) were examined (the 1 phi class) for microartifacts (e.g., lithic microdebitage), including bone, shell, and charcoal fragments, with a minimum of 300 grains counted. From these counts, the frequencies of various classes of material can be estimated. These data potentially offer an independent line of evidence for kinds of human activity associated with the Anahulu rockshelters.

RESULTS AND INTERPRETATION

Site D6-60, Column A

Column A was taken from the central area of the Kuolulo rockshelter, Units M22/M23. The column comprises 11 samples taken at 5 cm intervals with the column reaching a maximal depth of 55 cm below the

TABLE 3.2

ANALYTIC DATA FOR COLUMN A (SITE D6-60)

Sample Depth (cm)	Mean Grain Size (phi)	s.d.	Organic Matter %	Carbonates %	pH	Color Dry	Color Moist
0-5	3.70	5.20	18.02	10.32	8.18	5YR 3/3	5YR 2/2
5-10	5.49	5.25	15.12	12.61	8.20	5YR 3/2	5YR 2/1
10-15	5.49	4.98	16.52	13.05	8.39	5YR 3/2	5YR 2/1
15-20	4.24	5.15	11.25	17.42	8.45	10YR 3/2	5YR 2/1
20-25	5.10	5.31	13.60	14.35	8.58	10YR 3/2	5YR 2/1
25-30	5.76	5.05	13.50	13.21	8.52	10YR 3/2	5YR 2/1
30-35	3.39	4.43	15.29	14.43	8.55	10YR 3/2	5YR 2/1
35-40	4.15	5.58	13.83	11.97	8.44	10YR 3/2	5YR 2/1
40-45	2.78	4.76	13.44	10.61	8.50	10YR 3/2	5YR 2/1
45-50	4.85	4.64	12.62	9.96	8.56	10YR 3/3	5YR 3/1
50-55	4.41	4.95	11.03	4.39	8.45	5YR 4/4	5YR 3/4

surface of excavation. Three primary stratigraphic layers were recognized in the field and are described in chapter 2. All the analytic data for Column A are summarized in table 3.2.

Representative (upper, middle, and basal samples) particle size distributions for Column A are shown in percent and cumulative curves in figure 3.1. The mean particle size ranges from a minimum of 2.78 phi (40-45 cm) to 5.76 phi (25-30 cm) with standard deviations ranging from 4.43 (30-35 cm) to 5.58 (35-40 cm). All of these size distributions reflect extremely poor sorting in terms of the criteria described by Folk (1965:45-6). All the samples from Column A can be described as gravelly mud or gravelly muddy sand. With respect to the particle size distribution model (see Reineck and Singh 1980:132-38), size characteristics of three subpopulations (rolling, saltational, and suspension) are mixed. This fact indicates that: (1) the primary sediment source was most likely poorly sorted, as is typical of immature sedimentological environments such as Anahulu; (2) the most probable primary mode of transport was downslope surficial flow of colluvium, (i.e., not strictly aeolian or fluvial transport) carrying a mixture of gravel, sand, silt, and clay sized particles; a secondary mode of deposition was probably roof-fall with a contribution of angular particles of various size classes; (3) the environment of deposition remained relatively constant and stable; and (4) post-depositional alterations have probably been those associated primarily with pedogenic factors as opposed to sedimentological processes. Comparison of the Column A particle size data with the control sample suggests that the added source of sediment deposition is roof-fall (the gravel constitutent in the samples).

The data from other analyses provide results that are consistent with interpretations made on the basis of particle size distributions. Examination of grain shape and surface morphology revealed little variation from one sample to another and systematic analyses were not carried out. Inspection of the particles did show the predominance of angular and non-spherical forms, indicative of an immature age for the sediment.

The loss-on-ignition analyses for Column A show that organic matter is an important component in the sediment at almost all depths. The continuing addition of organics at the surface of the deposit (i.e., leaf litter, etc.) is comparable at greater depths by proportions of organic matter that must relate to human sources during the rockshelter's occupation. The lowest percentage of organic matter is at the base of the deposit, congruent with this interpretation. The percentage of carbonate throughout the column is comparable to that of organic matter, and can be interpreted as the similar effects of human agents in introduction of materials—especially shellfish and bone. While there are carbonates found in the non-archaeological control sample, the proportion is lower than that in the cultural deposits.

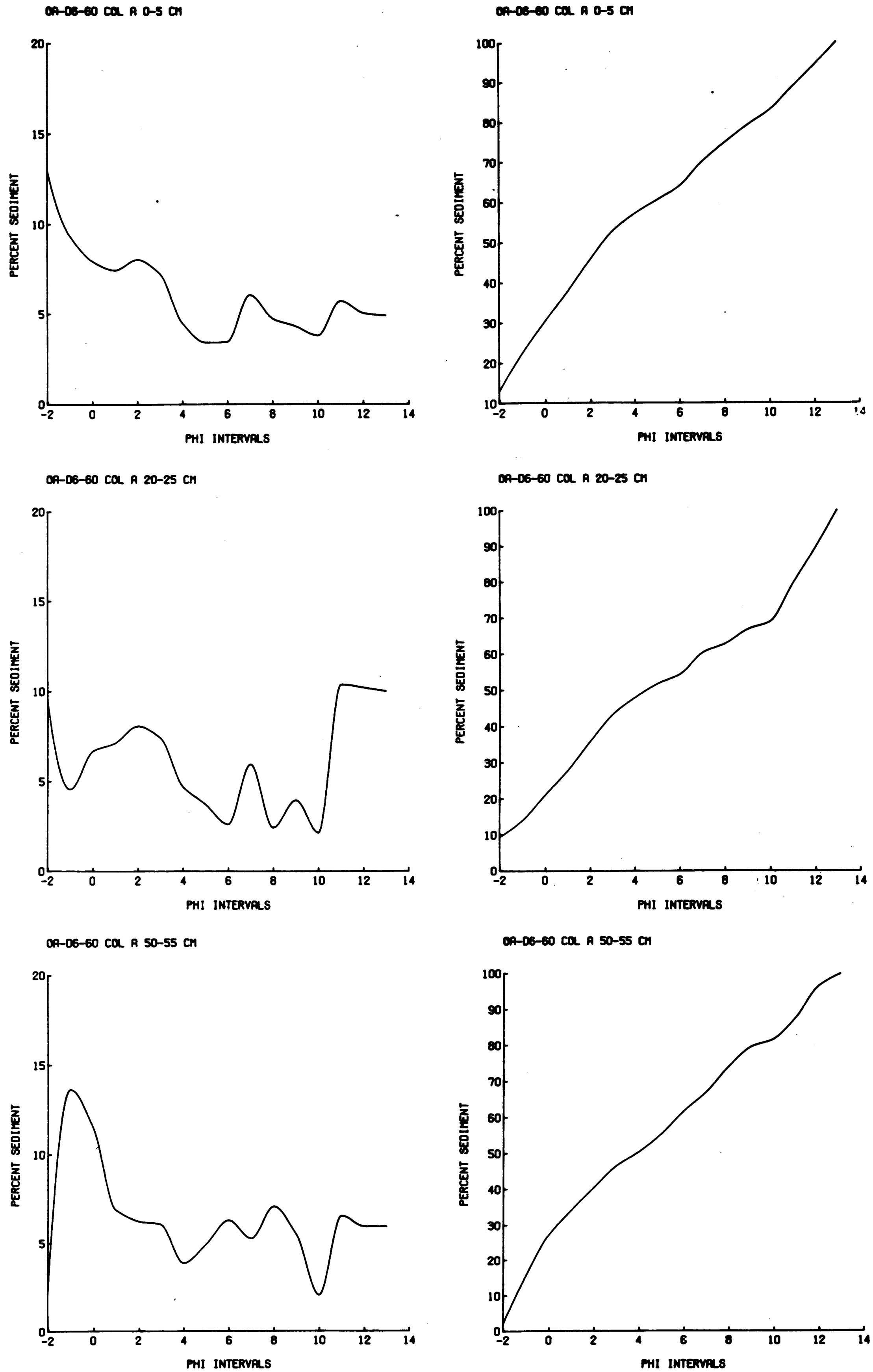


Figure 3.1. Grain size (phi scale) distributions for representative samples from Site D6-60, Column A.

The pH values from Column A are highly consistent at all levels. These moderately alkaline conditions result from the combined factors of natural conditions (compare with control sample pH of 7.65) and human additions of alkaline materials such as shell. The consistency of these values indicates that differential preservation due to variable pH is not a factor in archaeological and paleoecological analyses for this site.

Site D6-60, Column C

Column C (Unit D20) was taken from a deeper area of the Kuolulo rockshelter deposit than that represented in Column A. This column comprises 17 samples taken at 5 cm intervals with the column reaching a maximal depth of 85 centimeters below surface. All analytic data for Column C are summarized in table 3.3.

Representative (upper, middle, and lower samples) particle size distributions for Column C are shown in percent and cumulative curves in figure 3.2. The mean particle size ranges from a minimum of -0.83 phi at the base of the deposit (80-85 cm) to 3.98 phi (35-40 cm) with standard deviations ranging from 4.14 (25-30 cm) to 5.37 (0-5 cm). All of the samples show extremely poor sorting after Folk (1965:45-6). As with Column A the samples from Column C can be described in textural terms that include gravel, sand, and mud combinations. The size characteristics of three subpopulations are again represented and are mixed. The interpretation made for sources, transport agents (primarily colluvium with additions from roof-fall), the environment of deposition, and post-depositional alterations is largely comparable for those columns (A and C) of the same site. One difference that can be detected (see figs. 3.1 and 3.2) is the greater contribution of gravel sized sediment at the bottom and top of Column C. This greater proportion of gravel in the deposit contrasts with the sand and silt modes of most of the deposit and indicates a relative change in the importance of roof-fall as opposed to the deposition of mud by surficial flow.

In addition to particle size analyses on samples pretreated for iron removal, a second set of samples was analyzed with pretreatment for the removal of organic matter only. The distributions shown in figure 3.2 (dashed lines) reveal the bias that iron formed aggregates impose on particle size statistics. For example, the effect of iron bound particles is not constant across all the samples, but must vary with pedogenic factors. This is an important observation with implications for all sedimentological analyses performed in Hawaiian or other Oceanic environments. The disaggregation from iron pretreatment is of mostly clay and silt sized particles. Variation in the distributions shown in figure 3.2 may also reflect, to some unknown degree, the unavoidable sampling error between two sediment samples drawn from the same population.

The results obtained from other analyses of Colulmn C samples are also comparable to those discussed for Column A. Organic matter and carbonates show similar patterns of variation to that of Column A (suggesting reliable experimental results from strongly similar sediments). As table 3.3 illustrates, pH and color closely correspond from one column to the other.

Samples from Column C (representing the deepest deposit sampled for analysis) were examined for variation in grain shape and surficial texture of particles. Four samples selected from the top (0-5 cm), near the middle (25-30 cm and 45-50 cm), and at the base of the deposit (80-85 cm) were prepared at the 1.0 and 4.0 phi intervals for scanning electron microscope (SEM) inspection. The sediments prepared were not subjected to any of the pretreatments done for particle size analysis. SEM examination at magnifications ranging from 10X to 800X revealed no definitive quantitative differences with respect to classes of grain shape and roundness (e.g., figs. 3.3-3.6). In other words, the four samples from the column could not be objectively distinguished on shape and roundness criteria. Surficial texture has been primarily worked out for quartz grains, and did not apply to the weathered volcanic (virtually quartz-free) sediments found in the Anahulu deposits.

Site D6-36, Column B

Column B (Unit K18) was taken from a central area of the Ke'eke'e Iki rockshelter deposit. This column comprises 10 samples at 5 cm intervals with the column reaching a maximal depth of 50 cm below the surface. All analytic data for Column B are summarized in table 3.4.

Representative (upper, middle, and basal samples) particle size distributions for Column B are shown in percent and cumulative curves in figure 3.7. The mean particle size ranges from a minimum of 1.13 phi (10-15 cm) to 5.50 phi (35-40 cm) with standard deviations ranging from 3.91 (5-10 cm) to 4.99 at the base of the column (45-50 cm). The samples range from very to extremely poorly sorted (Folk 1965:45-6). As with the other column samples, these sediments can be described in textural terms that include gravel, sand, and mud combinations. The particle size distributions of Column B are more clearly bimodal than the other two columns. Gravel proportions are relatively low, with sand and silt modes. The source of these sediments is primarily surficial flow of sand and silt sized particles. The potential contribution from rockshelter roof-fall at this

TABLE 3.3

ANALYTIC DATA FOR COLUMN C (SITE D6-60)

Sample Depth (cm)	Mean Grain Size (phi)	s.d.	Organic Matter %	Carbonate %	pH	Color		Micro-constituents (n=300)			
						Dry	Moist	Shell	Charcoal	Bone	Glass*
0-5	3.24	5.37	17.50	9.32	7.92	5YR 3/4	5YR 3/2	0	0	0	0
5-10	3.91	5.33	13.92	5.25	8.25	5YR 3/4	5YR 3/2	0	0	0	0
10-15	2.16	4.92	14.60	10.56	8.67	5YR 3/2-3	5YR 2/2	3	0	0	1
15-20	3.42	4.57	14.04	13.99	8.62	10YR 3/2	5YR 2/1	10	8	0	2
20-25	3.19	4.35	15.47	16.79	8.58	10YR 3/2	5YR 2/1	7	9	0	0
25-30	2.82	4.14	14.64	15.79	8.54	10YR 3/2	5YR 2/1	6	8	2	0
30-35	3.92	5.22	14.66	15.02	8.70	10YR 3/2	5YR 2/1	6	6	1	0
35-40	3.98	4.41	14.80	16.20	8.71	10YR 3/2	5YR 2/1	2	11	1	0
40-45	1.54	4.97	14.27	17.19	8.62	10YR 3/2	5YR 2/1	2	8	0	1
45-50	2.94	4.36	14.53	16.40	8.77	10YR 3/2	5YR 2/1	18	3	0	0
50-55	3.54	4.54	13.43	15.77	8.69	10YR 3/2	5YR 2/1	4	7	0	1
55-60	2.79	4.61	13.94	15.62	8.46	10YR 3/2	5YR 2/1	7	6	0	0
60-65	2.33	4.48	16.20	15.78	8.61	10YR 3/2	5YR 2/2	4	5	3	1
65-70	2.67	4.34	14.46	15.43	8.43	10YR 3/3	5YR 3/2	18	3	4	0
70-75	2.60	4.27	11.64	10.51	8.60	10YR 3/3	5YR 3/2	7	1	0	0
75-80	2.17	4.20	7.02	4.67	8.70	10YR 4/3	5YR 3/3	0	3	0	0
80-85	-.83	4.54	6.73	3.02	8.74	5YR 3/4	5YR 3/3	0	0	0	0

* Volcanic glass micro-flakes

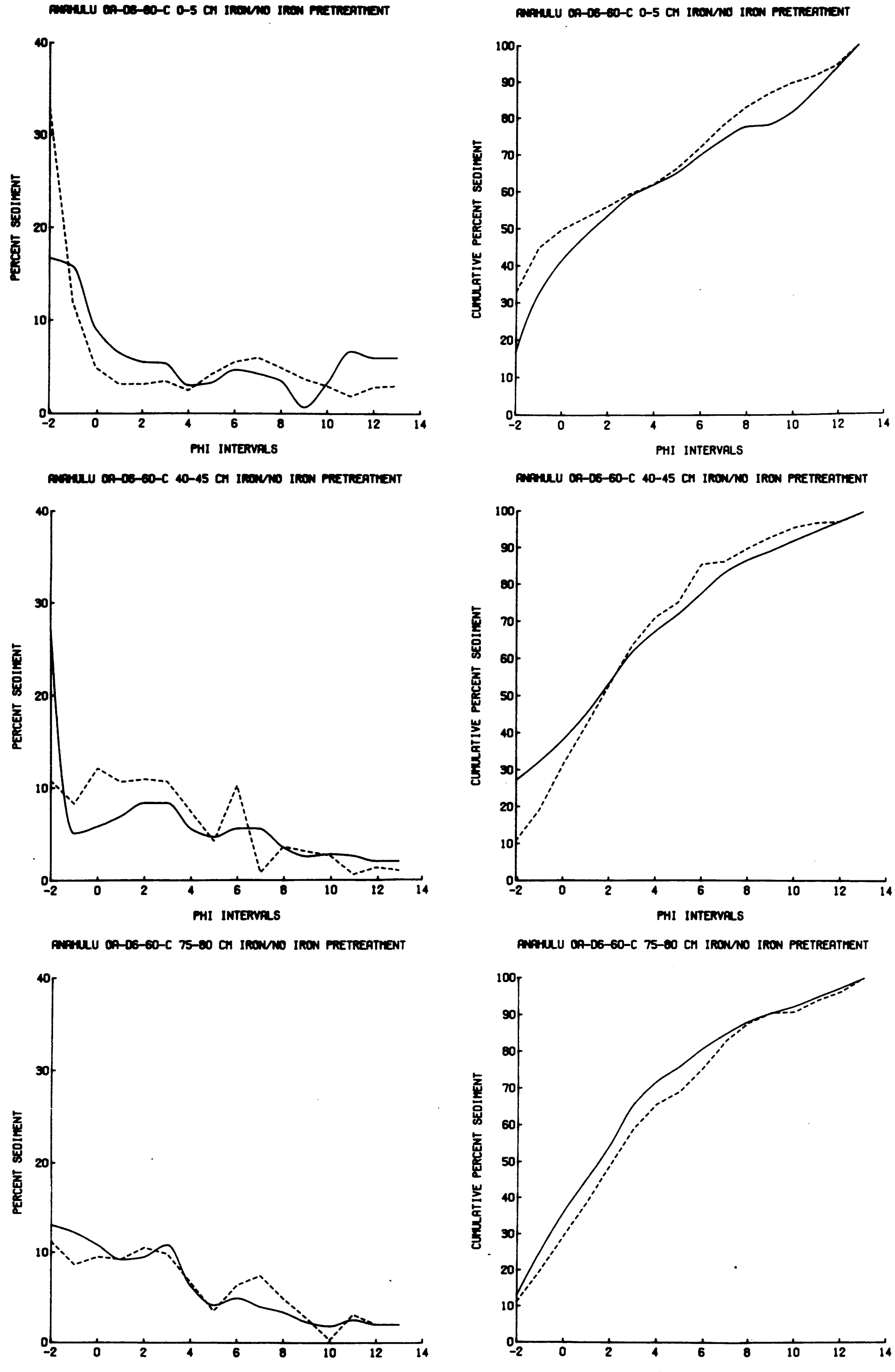
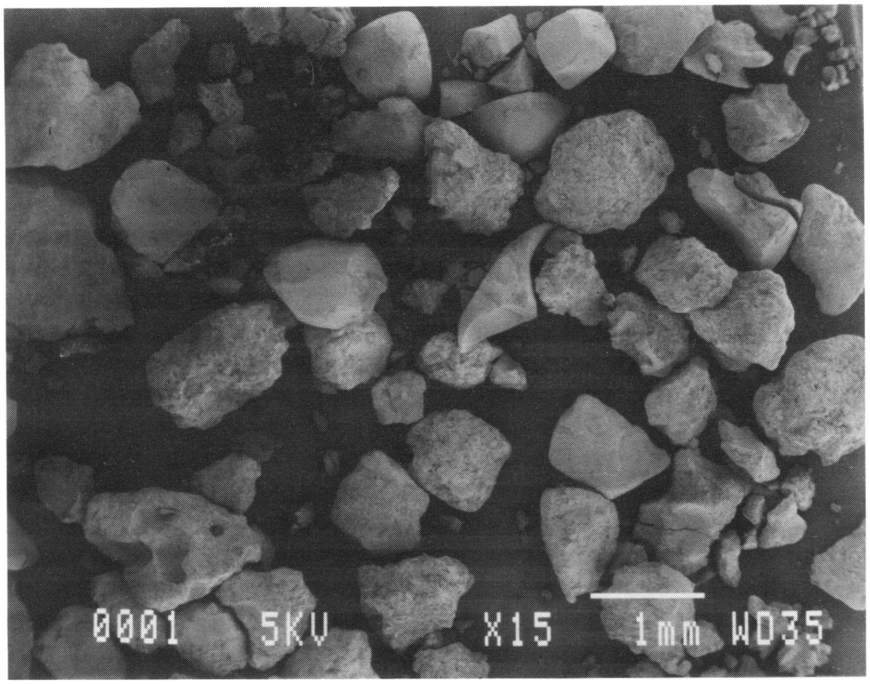


Figure 3.2. Grain size (phi scale) distributions of representative samples from Site D6-60, Column C; solid lines show samples pretreated for iron removal, dashed lines indicate samples with no iron pretreatment.



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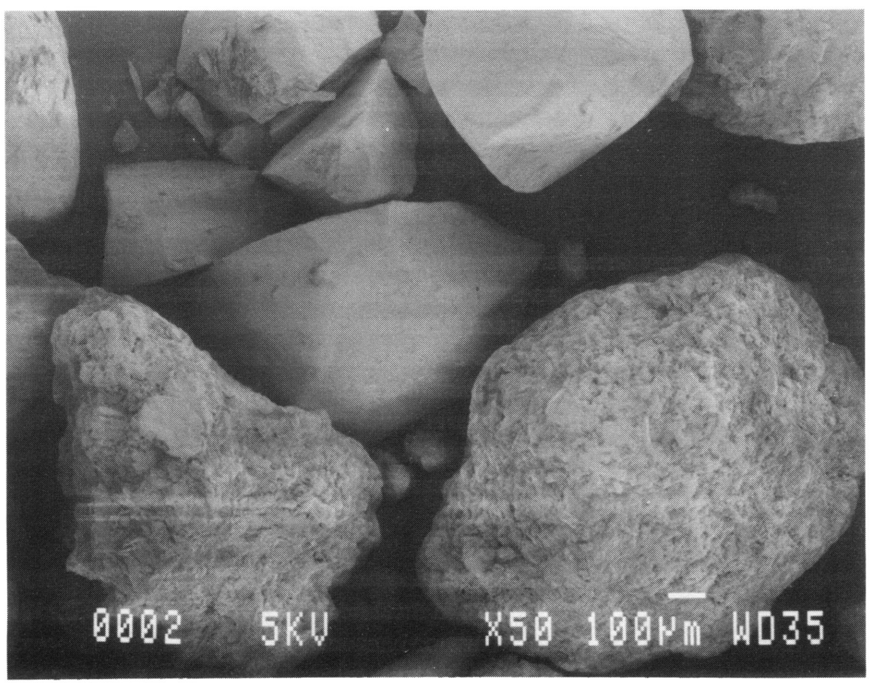
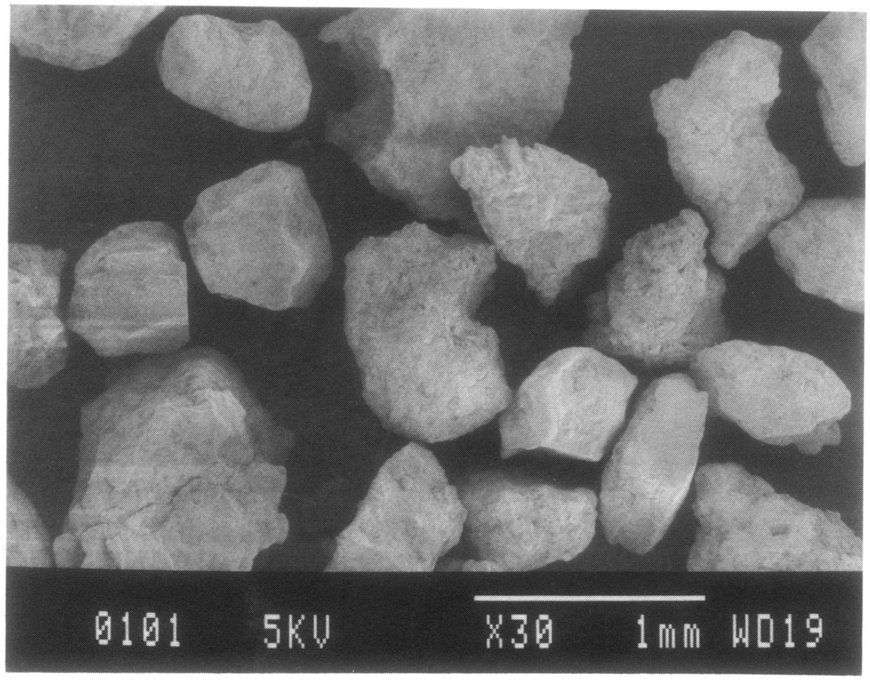


b

Figure 3.3. SEM photomicrographs of 1.0 phi grains from Site D6-60, Column C, 0-5 cm below surface: (a) sand grains at 15X magnification; (b) sand grains at 50X magnification; note grain angularity and surface textures.



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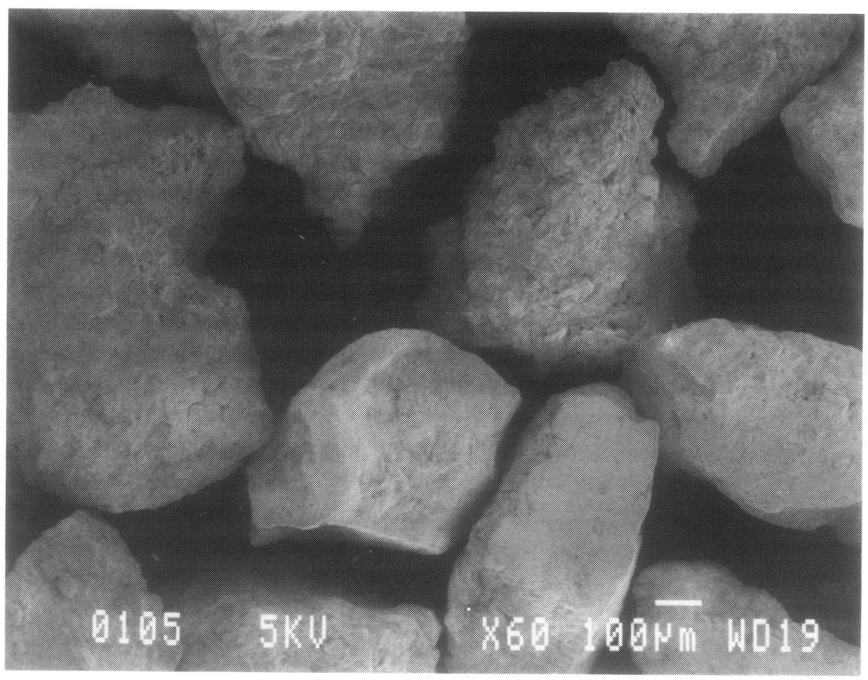

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Figure 3.4. SEM photomicrographs of 1.0 phi grains from Site D6-60, Column C, 45-50 cm below surface: (a) sand grains at 30X magnification; (b) sand grains at 60X magnification.

TABLE 3.4

ANALYTIC DATA FOR COLUMN B (SITE D6-36)

Sample Depth (cm)	Mean Grain Size (phi)	s.d.	Organic Matter %	Carbonates %	pH	Color Dry	Color Moist
0-5	2.19	3.81	12.73	11.18	8.15	7.5YR 3/2	10YR 2/1
5-10	3.36	3.33	12.82	12.57	9.00	7.5YR 3/2	10YR 2/1
10-15	1.92	5.03	15.17	11.74	9.01	7.5YR 3-4/2	10YR 2/1
15-20	4.18	4.45	14.25	14.48	9.17	7.5YR 3-4/2	10YR 2/1
20-25	4.23	4.37	13.37	17.15	9.05	7.5YR 4/2	10YR 3/1-2
25-30	5.56	4.35	12.97	15.20	9.12	10YR 4/2	10YR 3/1
30-35	5.11	4.54	12.69	14.54	9.12	10YR 4/2	10YR 3/1
35-40	5.79	4.36	13.34	14.82	9.17	10YR 4-5/2	10YR 3/1
40-45	5.47	4.50	12.48	11.79	9.13	10YR 4/3	10YR 3/2
45-50	4.93	4.99	9.11	16.00	9.10	10YR 5/3	10YR 3/2

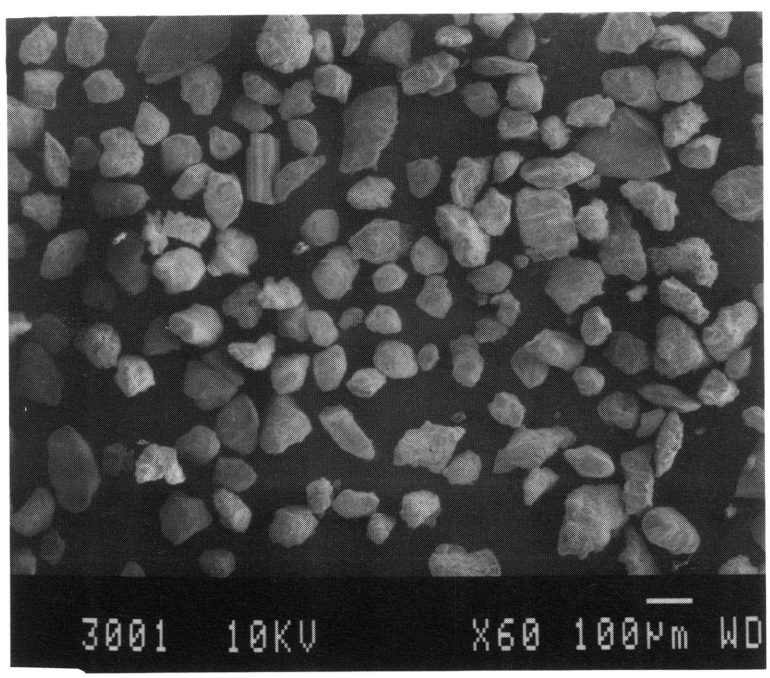
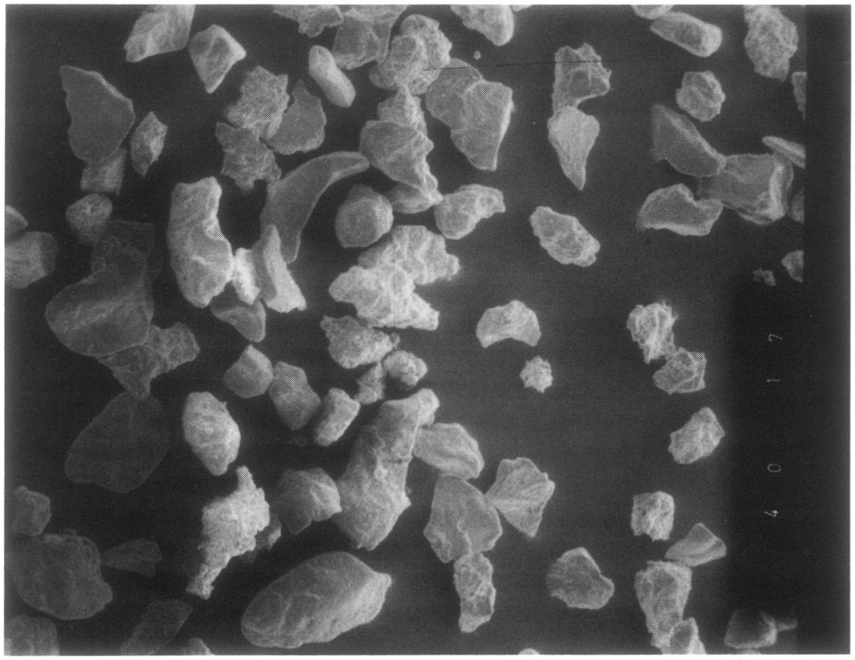


Figure 3.5. SEM photomicrograph of 4.0 phi (fine sand) grains from Site D6-60, Column C, 45-50 cm below surface; 60X magnification.



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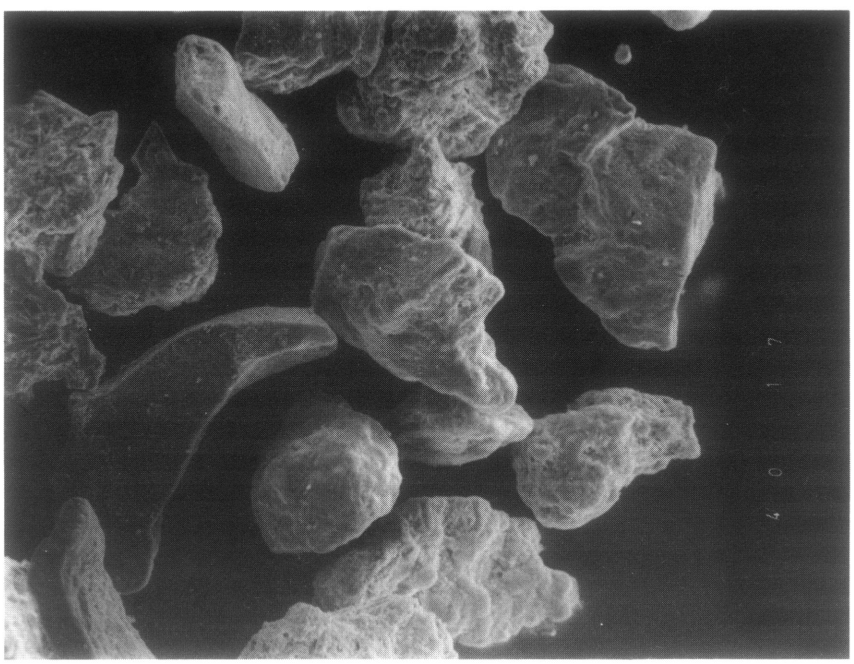

b

Figure 3.6. SEM photomicrographs of 4.0 phi (fine sand) grains from Site D6-60, Column C, 80-85 cm below surface: (a) fine sand grains at 80X magnification, note angularity of grains; (b) fine sand grains at 200X magnification, note surface textures.

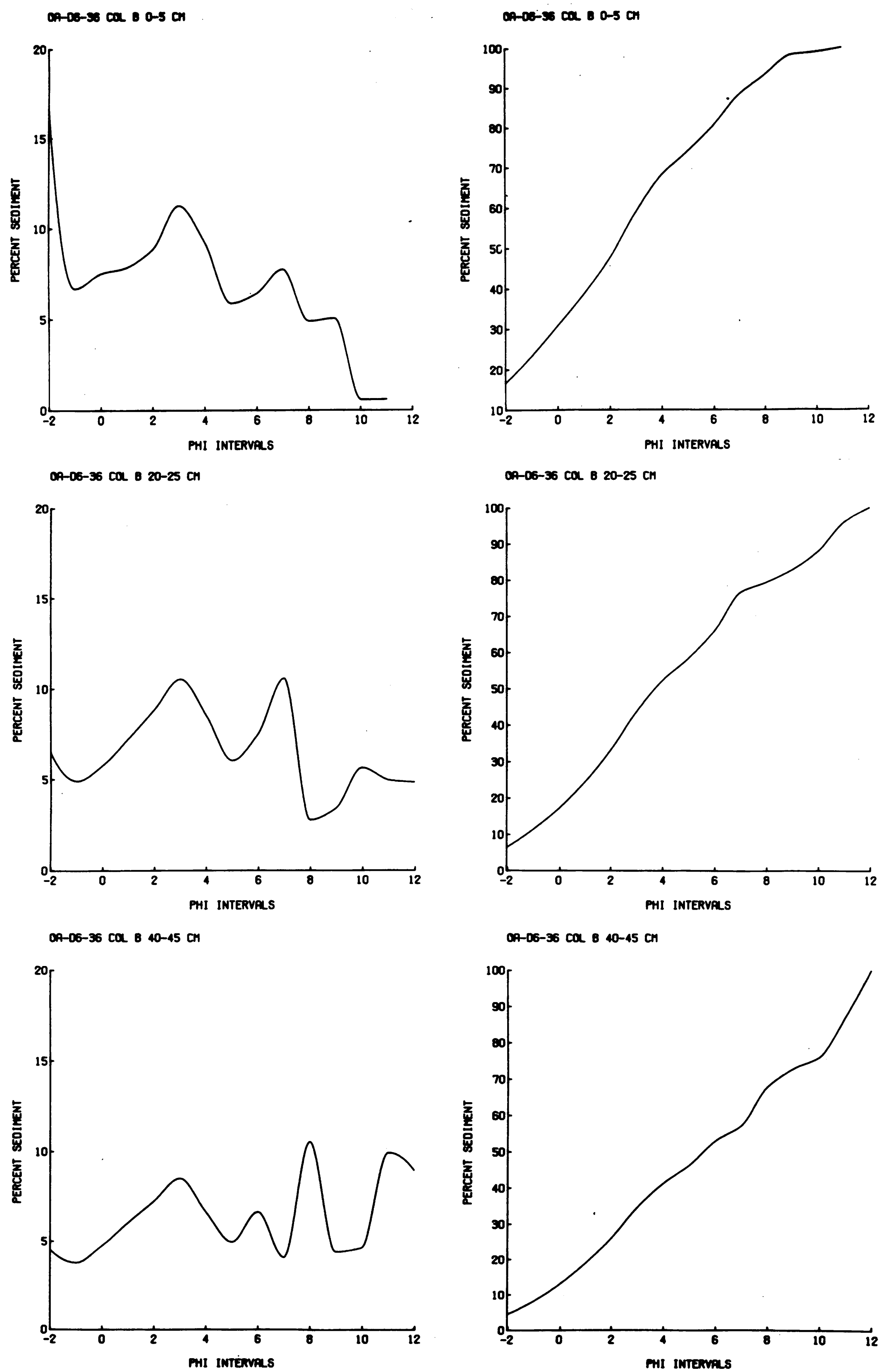

Figure 3.7. Grain size (phi scale) distributions for representative samples from Site D6-36, Column B.

site is apparently not as great as at Kuolulo rockshelter. The environment of deposition and post-depositional alterations appear to be comparable to Columns A and C, as evident in comparing tables 3.2, 3.3, and 3.4.

Site D6-58 Miscellaneous Samples

The Ke'eke'e Nui rockshelter (D6-58) was riddled with a complex series of subsurface features. As a result, no uninterrupted column representative of the sedimentological sequence could be obtained. Instead, samples were taken from various depths that reflected the depositional history independent from the constructional activities of prehistoric features. Table 3.5 provides the provenience and analytic data for the six samples analyzed from the Ke'eke'e Nui rockshelter.

Representative particle size distributions (fig. 3.8) are typical of those from the columns described above. The one exception is the basal deposit (fig. 3.8, bottom) that has a very strong mode in fine sand and coarse silt-sized sediment. This clearly represents fluvial transport in a depositional environment where finer sediments (fine silts and clays) were carried away in suspension. Subsequent to this depositional event, poorly sorted sediment, comparable to the other contexts analyzed, predominates. Other analyses, even though these samples do not derive from a continuous column sample, provide results comparable to the other sites reported.

CONCLUSIONS

As Farrand (1985:21) has recently pointed out, rockshelters commonly form sedimentological traps with associated prehistoric human activities. The resulting deposits are typically complex, polygenetic mixtures of immature sediments. The Anahulu rockshelters fit this description well.

The general conclusions that can be drawn from analyses of the samples from the three rockshelters include:

(1) The primary source of sediment is immature colluvium. (2) This sediment was transported in surficial flow (erosional and redepositional processes). These sediments remain very to extremely poorly sorted in their transport and their depositional context. A secondary source of sediment is roof-fall from the continuous weathering of the basaltic outcrops that form the rockshelters. A third factor recognized in an earlier study (Kirch 1979) is the aeolian deposition of silt and clay sized particles from the adjacent Ewa Plain sugarcane agriculture. Pedogenic factors (not examined in this study) are operative, even over short durations of time, and may account for some variation in the proportion of clay at various depths of the deposit (processes of eluviation and aggregation, e.g., free iron and clay).

TABLE 3.5

ANALYTIC DATA FOR SAMPLES FROM SITE D6-58

Sample Depth (cm)	Mean Grain Size (phi)	s.d.	Organic Matter %	Carbonates %	pH	Color Dry	Color Moist
10-15	5.88	4.64	13.81	7.40	9.94	7.5YR 4/2	10YR 2/1
15-20	5.26	4.68	11.96	14.45	8.79	7.5YR 4/2	10YR 2/1
20-25	5.60	4.71	18.17	12.15	8.43	7.5YR 4/2	10YR 2/1
35-40	4.98	5.04	10.20	14.18	9.37	7.5YR 4/2	10YR 2/1
40-45 (pit fill)	4.71	4.55	9.52	17.30	8.94	10YR 4/2	10YR 3/1
58-63 (basal layer)	4.21	3.19	10.44	4.81	8.57	10YR 4/3	10YR 3/2

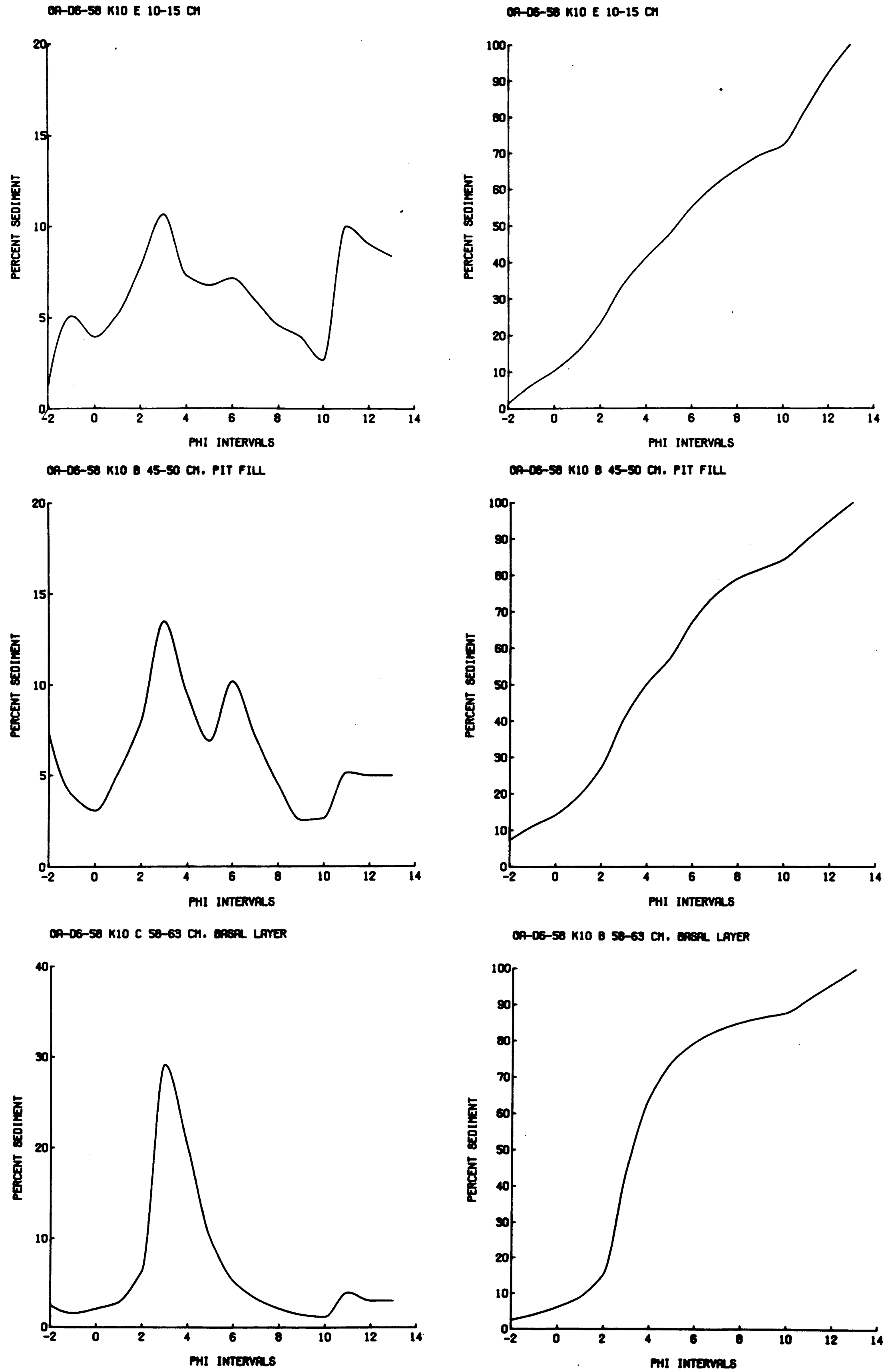

Figure 3.8. Grain size (phi scale) distributions for representative samples from Site D6-58, Unit K10.

(3) The environment of deposition has remained comparable in the rockshelters and there is no evidence for any major erosion or displacement of material once deposited.

(4) Post-depositional changes are more difficult to assess, especially given the poorly sorted sediments comprising all the sequences studied. As mentioned above, pedogenic factors, such as the transfer of clay across a forming soil profile, and chemical reactions, are those processes most visible in analytic terms. This does not preclude the possibility that an array of bioturbations have not affected the deposits to some degree (see Wood and Johnson 1978).

The major depositional episode represented in the rockshelters appears to begin with human occupation or use of the valley and continues at a more or less constant rate throughout the archaeological sequence. Thus, human activities must be interpreted as the fundamental cause behind sedimentological changes analyzed at the scale of the rockshelters alone. Removal of forest vegetation would allow for episodes of erosion and redeposition.

REFERENCES CITED

Anderson, J.U. 1961. An improved pretreatment for minerological analysis of samples containing organic matter. *Clays and Clay Minerals* 10:380-88.

Briner, G.P. 1963. Survey of clay minerals in some Victorian soils. *Proceedings of the Royal Society of Victoria* 77(1):191-95.

Dean, W.E., Jr. 1974. Determination of carbonate and organic matter in calcareous sedimentary rocks by loss-on-ignition: comparison with other methods. *Journal of Sedimentary Petrology* 44:242-48.

Farrand, W.R. 1975. Sediment analysis of a prehistoric rockshelter: the Abri Pataud. *Quarternary Reserach* 5:1-26.

_____. 1985. Rock shelter and cave sediments. In J.K. Stein and W.R. Farrand, eds., *Archaeological Sediments in Context*. Peopling of the Americas, 1:21-39. Center for the Study of Early Man, Orono.

Fladmark, K.R. 1982. Microdebitage analysis: initial considerations. *Journal of Archaeological Science* 9:205-20.

Folk, R.L. 1965. *Petrology of Sedimentary Rocks*. Hemphill Publishing Co., Austin, Texas.

Folk, R.L., and W.C. Ward. 1957. Brazos River Bar: a study in the significance of grain-size parameters. *Journal of Sedimentary Petrology* 27:3-26.

Galehouse, J.S. 1971. Point counting. In R. Carver, ed., *Procedures in Sedimentary Petrology*. pp. 385-407. Wiley and Sons, New York.

Gillieson, D. 1983. Geoarchaeological applications of scanning electron microscopy: some Australian examples. *The Artefact* 8(1-2):43-54.

Gordon, C.C., and J. Buikstra. 1981. Soil, pH, bone preservation, and sampling bias at mortuary sites. *American Antiquity* 46:566-71.

Jackson, M.L. 1969. *Soil Chemical Analysis: An Advanced Course*. 2nd ed. Department of Soil Science, University of Wisconsin, Wisconsin.

Kirch, P.V. 1979. *Late Prehistoric and Early Historic Settlement-Subsistence Systems in the Anahulu Valley, O'ahu*. Department of Anthropology Report 79-2. B.P. Bishop Museum, Honolulu.

Kunze, G.W. 1965. Pretreatment for mineralogical analysis. In C.A. Black, et al., eds., *Methods of Soil Analysis*, pp. 569-77. American Society of Agronomy, Madison.

Lavkulich, L.M., and J.H. Weins. 1970. Comparison of organic matter destruction by hydrogen peroxide and sodium hypochloride and its effects on selected mineral constituents. *Soil Science Society of America Proceedings* 34(5):755-58.

Powers, M.C. 1953. A new roundness scale for sedimentary particles. *Journal of Sedimentary Petrology* 23:117-19.

Reineck, H.E., and I.B. Singh. 1980. *Depositional Sedimentary Environments*. 2nd ed. Springer-Verlag, Berlin.

Shackley, M.L. 1975. *Archaeological Sediments: A Survey of Analytical Methods*. John Wiley and Sons, New York.

_____. 1981. *Environmental Archaeology*. George Allen and Unwin, London.

Stein, J.K. 1984. Organic matter and carbonates in archaeological sites. *Journal of Field Archaeology* 11:239-46.

_____. 1985. Interpreting sediments in cultural settings. In J.K. Stein and W.R. Farrand, eds., *Archaeological Sediments in Context*. Peopling of the Americas 1:5-19. Center for the Study of Early Man, Orono.

_____. 1987. Deposits for archaeologists. *Advances in Archaeological Method and Theory* 11:337-95.

Stein, J.K., and W.R. Farrand. 1985. Context and geoarchaeology: an introduction. In J.K. Stein and W.R. Farrand, eds., *Archaeological Sediments in Context*. Peopling of the Americas 1:1-3. Center for the Study of Early Man, Orono.

Stein, J.K., and G. Rapp Jr. 1985. Archaeological sediments: a largely untapped reservoir of information. In N.C. Wilkie and W.D.E. Coulson, eds., *Contributions to Aegan Archaeology*, pp. 143-59. Center for Ancient Studies, University of Minnesota, Publications in Ancient Studies No. 1, Minneapolis.

Sternberg, R.W., and J.S. Creager. 1961. Comparative efficiencies of size analysis by hydrometer and pipette methods. *Journal of Sedimentary Petrology* 31:96-100.

Visher, G.S. 1969. Grain size distributions and depositional processes. *Journal of Sedimentary Petrology* 39:1074-1106.

Wood, W.R., and D.L. Johnson. 1978. A survey of disturbance processes in archaeological site formation. In M.B. Schiffer, ed., *Advances in Archaeological Method and Theory* 1:351-81. Academic Press, New York.

CHAPTER FOUR

FAUNAL ASSEMBLAGES OF THE ANAHULU ROCKSHELTER SITES

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THE ANAHULU ROCKSHELTERS yielded small but important assemblages of both vertebrate and invertebrate faunal remains, providing significant information on patterns of prehistoric exploitation of both upper valley and coastal environments. Recognizing the problems associated with small sample sizes, our treatment of these assemblages will be primarily nominal, i.e., limited to presence/absence analysis of particular taxa. However, gross quantitative differences—both between the various shelters, and within shelters over time—will also be discussed.

METHODS

The faunal remains were recovered, in most cases, by sieving the excavated sediment through both 1/4 and 1/8 inch mesh screens. Materials recovered in each of these screen sizes were bagged separately in the field, and raw bone or element counts (NISP) were also tabulated separately by screen size. This permitted some assessment of the importance of using the smaller 1/8-inch mesh screens, which had not been standard practice in Hawaiian archaeology. In this chapter, however, we have combined the two screen-size classes to simplify the presentation of data. In the Bishop Museum laboratory, all vertebrate materials were segregated from other faunal or floral remains recovered in the sieves. The vertebrate faunal bone was then sorted by Collins into various identification categories, based on element type and degree of completeness. Fragmentary bone shafts and other non-diagnostic elements or fragments were sorted into general categories such as "small" or "medium vertebrate," "small" or "medium Aves," or "medium mammal." Elements with diagnostic features were identified with reference to the comparative systematic collections of the Bishop Museum Department of Zoology. When identification to species level was not absolutely certain, the closest species in the comparative collection is cited with the qualifier "cf." In some cases, especially with the native birds, identification could be taken only to the family level.

Following identification, faunal specimens were quantified in two ways. All faunal sorting classes were weighed to the nearest 0.1 gm. Specimens which had been identified at least to the family level or below were also counted, with annotations as to element type and age.

Invertebrate fauna, consisting primarily of marine molluscs, were also sorted and identified with reference to the systematic collections in the Bishop Museum Department of Zoology. Taxa were quantified by weighing to the nearest 0.1 gm.

[1]Sorting and identification of all vertebrate fauna from the Anahulu rockshelters was by Collins, who provided Kirch with raw data. This chapter was authored by Kirch, who bears any responsibility for errors or excesses of interpretation.

TABLE 4.1

NUMBER OF IDENTIFIED VERTEBRATE TAXA

SITE	MAMMALS	BIRDS	FISH	TOTAL TAXA	EX. VOL. (m^3)
D6-60	6	11	7	24	4.5
D6-58	4	6	7	17	2.0
D6-36	3	5	7	15	1.95

THE VERTEBRATE ASSEMBLAGES

The rockshelter vertebrate assemblages ranged in number of identified taxa (NTAXA) from 15 in Site D6-36, to 24 in D6-60 (table 4.1). As is evident in table 4.1, the number of identified taxa correlates with excavated volume, so that differences between the shelter assemblages in terms of the representation of specific taxa are probably not significant. Of the mammals, all sites contained domestic pig *(Sus scrofa)* and dog *(Canis familiaris)*, as well as scattered human remains (primarily isolated teeth). All sites also contained abundant remains of the Polynesian rat *(Rattus exulans)*, and in the upper levels, less frequent elements of the historically-introduced Norway rat *(Rattus norvegicus)* and of the European house mouse *(Mus domesticus)*. Aside from one cetacean fragment from D6-60, the other mammalian taxa are historically-introduced cat, and bovids (goat/sheep and cattle), from the upper cultural deposits. The birds include the domestic jungle fowl *(Gallus gallus)*, represented in all sites, as well as a range of indigenous and endemic land and seabirds. The birds are discussed in further detail below. The fish are all marine taxa, primarily reef or inshore species; these are also discussed further below.

Total weights of major vertebrate faunal sorting categories are provided in table 4.2. As can be seen from these figures, the percentage of identifiable mammal bone in each site was significantly greater than the percentages of identifiable bird or fish bone. That relatively little fish bone could be identified is a reflection of both the inadequate reference collections available, and the difficulty with which the most commonly occuring elements (vertebrae, scales, and

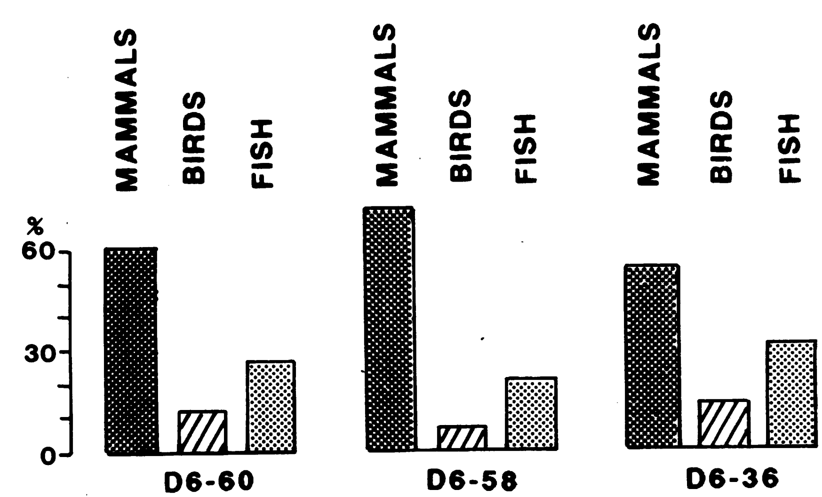

Figure 4.1. Composition of vertebrate faunal assemblages by weight.

TABLE 4.2

WEIGHTS OF VERTEBRATE FAUNAL ASSEMBLAGES BY MAJOR FAUNAL CATEGORIES

CATEGORY	D6-60 gm	D6-60 %	D6-58 gm	D6-58 %	D6-36 gm	D6-36 %
MAMMALS						
Identified Mammal	128.7		182.9		21.4	
Unidentified Medium Mammal	81.1		109.8		24.4	
Total Mammal	209.8	61	292.7	73	45.8	54
BIRDS						
Identified Bird	14.6		5.4		4.1	
Medium Bird (unid.)	24.0		16.8		7.1	
Small Bird (unid.)	1.6		0.5		0.3	
Total Bird	40.2	12	22.7	6	11.5	14
LAMNIFORMES	3.0	<1	1.4	<1	0.1	<1
FISH						
Identified Fish	12.5		12.3		4.4	
Unidentified Fish	75.9		71.9		22.1	
Total Fish	88.4	26	84.2	21	26.5	31
SMALL VERTEBRATE	0.8		—		0.4	
MEDIUM VERTEBRATE	2.2		1.4		—	
TOTALS	344.4		402.4		84.3	
Excavated volume (m^3)	4.5		2.0		1.95	
$\bar{x}$ bone gm/m^3 deposit	76.5		201.2		43.2	

rays) can be identified beyond the level of class. The relative composition of each rockshelter assemblage, by weight, in terms of the major categories "mammal," "bird," and "fish" is fairly consistent, as shown diagrammatically in figure 4.1 Mammal bones constitute from 54 to 73% of assemblages by weight; fish bones constitute from 21 to 31%, and bird bones from 6 to 14% by weight.

While the total number of taxa in each assemblage clearly correlates with excavated volume of rockshelter sediment, this is not the case with the gross size of vertebrate assemblages as measured by total weight (table 4.2). Although Site D6-58 had an excavated volume of less than one-half than at Site D6-60, the D6-58 vertebrate sample is significantly larger. These differences between rockshelter assemblages are evident when one compares the mean weight of vertebrate bones per cubic meter of excavated deposit (table 4.2). The differences between Sites D6-36 and -60 are probably not statistically significant, but Site -58 clearly contrasts with the former two. The density of vertebrate remains in Site D6-58 is 2.6 times that of Site D6-60, and 4.7 times that of D6-36. This suggests that the human behavioral patterns responsible for deposition of the faunal assemblages in these sites differed in some important way. Duration of occupation could account in part for these contrasts, but the most likely explanation is the *intensity* of occupation of Site D6-58

TABLE 4.3

NUMBER OF IDENTIFIED SPECIMENS OF VERTEBRATE FAUNA

TAXON	D6-60	D6-58	D6-36
MAMMALS			
Sus scrofa	27	43	18
Canis familiaris	34	20	21
Felis catus	1		
Ovis/Capra sp.		2	
Bovidae	1		
Cetacea (Delphinidae)	1		
Homo sapiens	4	2	3
Advanced artiodactyl		4	
BIRDS			
Procellariid cf. *P. phaeopygia*	4	1	1
Procellariid cf. *P. pacificus*		1	
Procellariid cf. *P. auricularis*	5	2	
Procellariid cf. *B. bulwerii*	3		1
Procellariid cf. *P. hypolenuca*	9		8
Medium Procellariid	4	3	1
Small Procellariid			2
Nycticorax nycticorax	1	1	
Gallus gallus	9	6	4
Muscicapidae	5		1
Laridae cf. *S. pomarinus*	1		
Sturnidae cf. *A. tristis*	2		
Meliphagidae cf. *Chaetoptila* spp.	1		
Drepanidinae cf. *Psittirostra* sp.		1	
Drepanidinae, Hemignathini, *Loxops* spp.	2		
Small Passeriform	4		
FISH			
Mullidae		1	
Labridae, *Bodianus* sp.	2	5	4
Labridae, *Thalassoma* sp.	1		
Labridae, *Coris* sp.	1	3	
Scaridae, *Scarus* sp.	4	3	1
Scaridae, *Calotomus* sp.	5	3	3
Acanthuridae, *Naso* sp.	6		
Monocanthidae, *Pervagor* sp.	29	19	13
Carangidae (*Caranx* sp.)			5
Sparidae, *Monotaxis grandoculis*			1
Acanthuridae		1	4
LAMNIFORMES	14	6	3
TOTAL NISP	180	127	94

during the late prehistoric period. As noted elsewhere, artifactual and stratigraphic evidence suggests that this site may have been permanently occupied during the one to two centuries prior to European contact, whereas the other shelters probably continued to be used on a temporary basis. Permanent utilization of Site D6-58 (associated with the "upper cultural deposit," see chapter 2) is the most likely explanation of the significantly higher concentration of vertebrate fauna in this site.

Numbers of identified specimens (NISP) of vertebrate fauna for those elements or element fragments that could be identified to the family level or below are quantified in table 4.3. (Faunal elements belonging to *Rattus* spp. or to *Mus* were quantified only by weight, and thus are not included in table 4.3.) These faunal categories are discussed further below.

Mammals

The most important mammalian remains from the rockshelters, in terms of cultural significance, are those of the pig and dog, both of which were transported to the Hawaiian Islands by Polynesian colonizers (Kirch 1985). Other than the small bones of *Rattus exulans*, dog and pig skeletal elements were the most commonly identified mammal bones in the assemblages (table 4.3). The cultural significance of dogs in early Hawai'i has been summarized by Tomich (1986:88-9), and dealt with more extensively by both Luomala (1960) and Titcomb (1969:2-24). The raising of dogs for food is clearly documented in a variety of early historic sources. The missionary William Ellis provides a typical account: "...in their feasts the flesh of the dog constitutes the principal meat" (1963:247). "Numbers of dogs, of rather a small size, and something like a terrier, are raised every year as an article of food. They are mostly fed on vegetables; and we have sometimes seen them kept in yards, with small houses to sleep in" (1963:249). Pigs were equally an important food item (Tomich 1986:120-21), but of greater cultural significance as pig flesh, unlike that of dog, could be consumed only by males and was frequently offered as an item of sacrifice in temple ritual (Valeri 1985:118-19, 228-29).

The relative proportions of pig and dog bones in the three rockshelters vary considerably, although given the small sample sizes the significance of this variation is uncertain. However, Site D6-58 is unique in the substantially greater numbers of pig than dog bones.

The ages of both pig and dog faunal elements were recorded whenever possible, using the general age categories "juvenile," "immature," and "adult." The frequency distributions by age category were remarkably consistent in all site assemblages. For pigs, approximately 25% of all specimens are of adults (over 3 years), with 75% from immature (ca. 6-36 months) or juvenile (less than 6 months) animals. In contrast, 65% of the dog faunal specimens from the rockshelters are of adults (over 18 month), with only 35% from immature (6-18 months) to juvenile (under 6 months) animals.

Site D6-60 yielded a single tooth of an unidentified member of the Delphinidae (dolphins and allies), from 35-40 cm in Unit D20. Eleven indigenous species of dolphins and killer whales inhabit the Hawaiian Islands (Tomich 1986:13-4), and the tooth is presumably from one of these species. Dolphin teeth are known to have been used as ornaments (Kirch 1985), and it is unlikely that the single tooth should be interpreted as signifying the consumption of dolphin flesh at this site. Tomich (1986:175) observes that the cetaceans were, at best, a minor food source for prehistoric Hawaiians, as evinced by "the lack of a distinctive nomenclature for the many species."

Bones of the Polynesian rat *(Rattus exulans)* were found throughout the cultural deposits in all sites. This species is known to have been transported by Polynesians throughout the Pacific (Tate 1951). The Hawaiians hunted rats for sport, with a miniature bow and arrow (Tomich 1986:42-3), but apparently did not eat them.

Birds

The most frequently represented bird species in the rockshelter assemblages is the Jungle Fowl, *Gallus gallus*. The species was purposely introduced by early human colonists throughout Oceania (Ball 1933), and in Hawai'i was used not only for food, but for ritual sacrifice, and for the sport of cock fighting (Berger 1981:177).

Equally important, and actually out-numbering *Gallus* as a combined category, are five species of procellariid seabirds (petrels and shearwaters). In the historic period, these species have been largely confined—as nesting populations—to the smaller offshore islets, and to the leeward chain (Nihoa to Kure Islands), where they are not subject to predation or habitat disturbance. However, recent paleontological and archaeological excavations on the main Hawaiian Islands have yielded large numbers of procellariid and other seabird skeletal remains (Olson and James 1982). This suggests that prior to the Polynesian colonization of the archipelago, and even well into the period of Polynesian occupation, substantial breeding populations of these birds were present on the main islands as well. Indeed, evidence from a number of archaeological sites (Kirch 1982) documents the heavy exploitation of seabird populations during early occupation phases.

TABLE 4.4

NUMBER OF IDENTIFIED SPECIMENS OF MAJOR VERTEBRATE CLASSES FOR UPPER AND LOWER CULTURAL DEPOSITS OF SITE D6-58

	SUS	CANIS	BIRD	FISH	TOTALS
Upper Cultural Deposit	34	14	5	24	77
Lower Cultural Deposit	4	3	6	12	25

Volumes: Upper ~ 0.6 m^3
Lower ~ 0.67 m^3

Puffinus pacificus, the Wedge-Tailed Shearwater, is represented by a single distal right ulna from Site D6-58. More frequently represented in both Sites D6-58 and -60 is *Puffinus auricularis*, Newell's (Townsend's) Shearwater, a species thought to be formerly "a common nesting bird on Hawaii, Maui, Molokai, Kauai" and probably other islands (Berger 1981:45). All three sites yielded representative specimens of *Pterodroma phaeopygia*, the Dark-rumped Petrel. Hawaiians considered the birds a delicacy, and obtained them by netting (Munro 1944:26 in Berger 1981). Of particular interest is the presence of substantial numbers of specimens of *Pterodroma hypoleuca*, the Bonin Petrel, from Sites D6-36 and -60. The Bonin Petrel's historically-documented range is limited to the Leeward Islands, as well as the Bonin and Volcano Islands (Berger 1981:48). Olson and James (1982:32) reported a few specimens from archaeological sites on Kaua'i, O'ahu, and Moloka'i. The presence of substantial numbers of this species in the Anahulu rockshelters further confirms the former extension of its breeding range to the main Hawaiian chain. A few specimens of *Bulweria bulwerii*, Bulwer's Petrel, were recovered from Sites D6-36 and -60. This species is known to nest on offshore islands throughout the main Hawaiian group (Berger 1981:49).

Sites D6-60 and -58 each yielded a single specimen of *Nycticorax nycticorax*, the Black-crowned Night Heron. This species is found on all of the main Hawaiian Islands, where it "inhabits marshes, ponds, streams, and lagoons" (Berger 1981:67).

The rockshelters also yielded small numbers of specimens of several endemic Hawaiian land birds. Sites D6-60 and -36 both produced specimens referrable to the family Muscicapidae (Old World Flycatchers). In Hawai'i, this family contains the single endemic species *Chasiempis sandwichensis*, or *Elepaio*, a common inhabitant of the native forests. Olson and James (1982:38) do not report any muscicapids from the archaeological deposits examined by them. Of substantial interest is a single anterior mandible of a Honeyeater (Meliphagidae), apparently from a species in the genus *Chaetoptila*. Historically, only a single species of *Chaetoptila (C. angustipluma*, the *Kioea)*, is recorded from the archipelago, its range restricted to the island of Hawai'i. However, Olson and James discovered the bones of a "large meliphagid, presumably *Chaetoptila*," in limestone sinks at Barbers Point, O'ahu (1982:39). Thus, the genus was evidently formerly present on O'ahu, although whether the O'ahu bird was a distinct species has not been determined.

No group of Hawiian birds has occasioned greater ornithological and evolutionary attention than the Honeycreepers (Subfamily Drepanidinae), which had radiated into more than 28 endemic species (Berger 1981:108-11). The Anahulu rockshelter deposits yielded three drepanid specimens. The two elements from Site D6-60 (a left and a right humerus, from different stratigraphic levels and units, and certainly representing two separate individuals) are both from species of the genus *Loxops*, within the tribe Hemignathini. Historically known members of the genus *Loxops* on O'ahu include the *Akepa (L. cocineus)* and the *Amakihi (L. virens*, now renamed *Hemignathus virens)*. The *Amakihi* tends to inhabit *ohia* forests of elevations above 1,000 feet ASL, and especially prefers to feed on the nectar of the *mamani* (Berger 1981:129). The *Akepa*—now nearly extinct on O'ahu—prefers *koa* forests, also at higher elevations (Berger 1981:151). The *Amakihi* is now uncommon on O'ahu, but was formerly abundant within its preferred habitats (Pratt et al., 1987:300). Olson and James (1982:41) reported fossil specimens referred to *Loxops* spp. and *Hemignathus* spp. from Moloka'i, O'ahu, and Maui. The third drepanid specimen is a distal left tibiotarsus from the basal level of Unit O11 in Site D6-58, and may be referred to a species of *Psittirostra* (in the tribe Psittirostrini). The only species of this genus known historically from O'ahu is the *O'u (P. psittacea)*, which was extinct by the end of the last century (Amadon 1950:170-72; Berger 1981:119). However, Olson and James (1982:40) report the fossil bones of at least one, and possibly more than one, undescribed extinct species of the genus *Psittirostra* from O'ahu localities. At this point, our Anahulu specimen cannot with confidence be referred to as a particular species of *Psittirostra*. Berger, quoting Wilson and Evans, notes that the feathers of the *O'u* were used by Hawaiians in their necklaces or *lei* (1981:119).

Site D6-60 also yielded a single specimen of the Pomarine Jaeger, *Stercorarius pomarinus*, a migratory species "regularly seen over offshore waters near the main Hawaiian Islands" (Berger 1981:232). The Common Myna, *Acridotheres tristis tristis*, introduced to Hawai'i in 1865 (Berger 1981:2003), is represented by two bones from the upper levels of Site D6-60.

Fish

The majority of fish bones, consisting of vertebrae, spines, and small cranial bones, could not be identified to a more precise taxonomic level than class. However, the distinctive dentaries, premaxillaries, and pharyngeal grinders of some labrids, scarids, and sparids, as well as the caudal tangs and dorsal spines of acanthurids and monocanthids, could be identified at least to generic level using a skeletal reference collection developed by the Bishop Museum Archaeology Laboratory. NISP of fish from the Anahulu rockshelters are given in table 4.3. The assemblage consists almost wholly of inshore reef species which could have been taken by a variety of fishing techniques, including angling, netting, and spearing. *Caranx* tends to frequent slightly deeper waters, such as the bays at Waialua and Waimea, and can be taken by shore casting where there is no reef. Of particular note is the large number of *Pervagor* specimens. Gosline and Brock (1960:295-96) report that *Pervagor spilosoma* "appears at certain times in great numbers." Titcomb (1972:119) said that the Hawaiians also knew of the occasioned mass appearances of monocanthids, and considered the phenomenon as a prophecy of the death of a great person. The rockshelters also yielded a number of shark teeth, of indeterminate species.

Temporal Trends

The usual cautions concerning small sample sizes must apply when attempting to determine any temporal trends in the Anahulu rockshelter faunal assemblages. However, certain major changes are evident in the deeper sequences from Sites D6-58 and -60. Table 4.4 summarizes the combined NISP values for major faunal categories from excavation units K10 and O11 in Site D6-58, segregated by upper and lower cultural deposits (see chapter 2). As the excavated volumes of the upper and lower deposits were nearly equal (0.6 and 0.67 m^3 respectively), differences in NISP between these deposits must reflect changing activity patterns, or depositional factors. As seen in table 4.4, the most significant difference is the substantial increase in numbers of pig and dog bones in the upper cultural deposit. Fish bones also increase by a factor of two, but the numbers of bird bones are nearly constant. These figures would support the interpretation that the lower and upper cultural deposits represent quite different kinds of occupation and use of the D6-58 shelter. The greater

TABLE 4.5

NUMBER OF IDENTIFIED SPECIMENS OF MAJOR VERTEBRATE CLASSES IN UNIT D20, SITE D6-60

DEPTH (cm)	*SUS*	*CANIS*	*GALLUS*	OTHER BIRD	FISH
0-25	1	0	0	2	2
25-40	5	2	0	5	8
40-60	4	1	1	2	7
60-80	0	0	0	5	7

density of bone, in itself, supports the interpretation of the upper cultural deposit as resulting from a more intense, perhaps permanent, occupation of the site. Such permanent occupation may have been associated with husbandry of pigs and dogs in the vicinity of the site, as is documented for the upper Anahulu Valley during the later, historic period (see Sahlins and Kirch, in prep.) Notably, however, the exploitation of wild birds did not change appreciably over time.

The situation in Site D6-60 is summarized in table 4.5, using only the NISP values from the deep, continuous sequence in Unit D20. This sequence also shows some increase in the deposition of domestic pig and dog bone (the absence of any dog or pig in the deepest 20 cm is notable), but the differences between higher and lower deposits do not contrast markedly as they do in Site D6-58. The faunal evidence from D6-60, as limited as it is, would tend to suggest that there was not any major change in the occupation or behavioral patterns at the site over time. Furthermore, the entire sequence in D6-60 (Unit D20) is more comparable to the lower cultural deposit at D6-58, than it is to the upper cultural deposit at the latter shelter.

THE INVERTEBRATE ASSEMBLAGES

The invertebrate faunal assemblages from all rockshelters were dominated by molluscs, with smaller quantities of sea urchins (Echinoidea) and of crustacea. The assemblages include at least 17 species of gastropods, 9 species of bivalves, and 7 species of sea urchin. The crustacean remains could not be identified more definitively. All of these taxa are either marine or estuarine in origin, and were brought to the sites from the coast and lower valley region. Invertebrate remains were recovered from all excavated units, and were further sorted and weighed by taxonomic category in the laboratory. As the frequencies of particular categories are fairly consistent between units and sites, however, we have confined the presentation of data to those from three sample units, one from each rockshelter (table 4.6). (The volumes of the three units are as follows: K17, 0.6 m^3; K10, 0.55 m^3; D20, 0.8 m^3.)

The density of invertebrate faunal remains varied considerably between rockshelters, mirroring the situation with the vertebrate fauna. Sites D6-36 and -60 have very nearly identical densities per cubic meter of cultural deposit: 177 gm/m^3 for D6-36 and 166 gm/m^3 for D6-60. The contrast with Site D6-58, which has 632 gm/m^3, is notable. Most of the high density in D6-58 derives from the upper cultural deposit. As noted above, the higher density of both vertebrate and invertebrate faunal remains in Site 58 is strong evidence of more intensive, and probably permanent, occupation, in contrast to less intensive and probably intermittent occupation at the other two shelters.

The invertebrate asssemblages are dominated by a small number of taxa, with five species of molluscs accounting for 55% or more of each assemblage by weight. These are the small cowrie *Cypraea caputserpentis*, and the bivalves *Brachiodontes cerebristriatus*, *Pinctada* spp., *Isognomon* spp., and *Tellina palatam*. All other molluscan species account for between 13 and 22% of assemblages by weight, while the crustacea account for only 1-2%. The relative composition of the three rockshelter invertebrate assemblages is diagrammed in figure 4.2.

Molluscs

The molluscan taxa represented in the rockshelters occur in a variety of marine and estuarine environments. The limpet *Cellana exarata*, or *opihi*, a delicacy at Hawaiian feasts even today, inhabits exposed rocky shores. Many of the gastropods, such as *Cypraea caputserpentis*, *Trochus intextus*, and *Turbo intercostalis*, are found on reef platforms, or in somewhat protected areas with a rocky substrate. The bivalve *Brachiodontes cerebristriatus*, which is plentiful in the rockshelter deposits, frequents limestone shorelines, and can tolerate considerable freshwater outflow, as at the mouth of the Anahulu Stream (Kay 1979:51). *Tellina palatam*, also a dominant in the rockshelter assemblages, is "found in silty sand inshore on fringing reefs and at depths of from 2 to 3 m" (Kay 1979:563).

A number of taxa derive from estuarine, brackish, or freshwater habitats. Among these is the gastropod *Theodoxus vespertinus*, which occurs "near the mouths of rivers and streams, in freshwater and in low salinity parts of estuaries" (Kay 1979:67). *Macoma dispar* is abundant in the silty bottoms of bays where there is a high freshwater discharge (Kay 1979:559), as at Anahulu. The gastropod *Neritina granosa*, an endemic to Hawai'i, is diadromous, with "larvae developing in the ocean and the young migrating upstream, where they settle on boulders" (Kay 1979:66). The species is no longer present in the Anahulu Stream, probably due to the heavy sediment load and irregularity of flow resulting from use of stream water for sugar cane plantation irrigation. However, at the time of prehistoric occupation of these sites, it is probable that *N. granosa* was present in the Anahulu Stream for a considerable distance inland.

The molluscan taxa present in the Anahulu rockshelters were thus collected from a full range of subtidal and supratidal marine habitats, as well as from the estuarine environments at the mouth of the Anahulu

TABLE 4.6

WEIGHTS OF INVERTEBRATE FAUNAL REMAINS (gm)

TAXON	Site D6-36 Unit K17	Site D6-58 Unit K10	Site D6-60 Unit D20
GASTROPODS			
Diodora spp.	0.0	0.6	0.0
Cellana exarata	0.4	0.8	
Trochus intextus	0.0	1.7	1.2
Turbo intercostalis (shell)	0.5	3.8	0.3
Turbo intercostalis (operculae)	0.0	4.1	0.1
Nerita picea	1.6	7.3	1.6
Nerita granosa	0.1	2.7	0.5
Theodoxus vespertinus	2.8	0.0	0.2
Littorina pintado	0.0	0.4	0.0
Planaxis labiosa	0.0	0.2	0.0
Strombus spp.	0.0	5.0	3.0
Hipponix imbricatus	0.0	0.0	0.1
Cypraea caputserpentis	14.6	37.1	18.1
Cypraea maculifera	0.0	4.7	0.0
Drupa ricinus	0.7	3.8	1.2
Arachis miser	0.1	0.0	0.1
Mitra assimilis	0.1	0.8	0.3
Conus spp.	0.7	5.3	6.4
BIVALVES			
Brachiodontes cerebristriatus	15.7	68.4	24.9
Pinctada spp.	7.1	15.3	2.8
Isognomon spp.	6.4	22.9	7.3
Codakia punctata	0.0	6.5	0.0
Ctena bella	0.0	0.3	0.0
Macoma dispar	0.0	0.5	0.0
Tellina elizabethae	0.0	1.5	0.0
Tellina palatam	27.8	101.3	20.8
Periglypta reticulata	0.0	2.8	0.0
POLYPLACOPHORA	0.0	0.0	0.1
UNIDENTIFIED MOLLUSCA	6.4	13.6	12.7
TOTAL MOLLUSCA	85.0	311.4	101.7
ECHINOIDEA			
Echinothrix diadema	0.0	0.7	0.0
Echinothrix calamaris	0.0	0.5	0.4
Echinometra mathaei	0.2	0.0	0.4
Echinometra oblonga	0.0	0.4	0.0
Pseudoboletia indiana	0.0	0.6	0.1
Heterocentrotus mammillatus	4.6	2.6	0.0
Colobocentrotus atratus	0.0	0.1	0.1
Echinoid test fragments	8.6	20.7	21.6
Echinoid mouth parts	6.2	7.4	6.1
TOTAL ECHINOIDEA	19.6	33.0	28.7
CRUSTACEA	1.5	3.4	2.8
TOTAL INVERTEBRATE	106.1	347.8	133.2

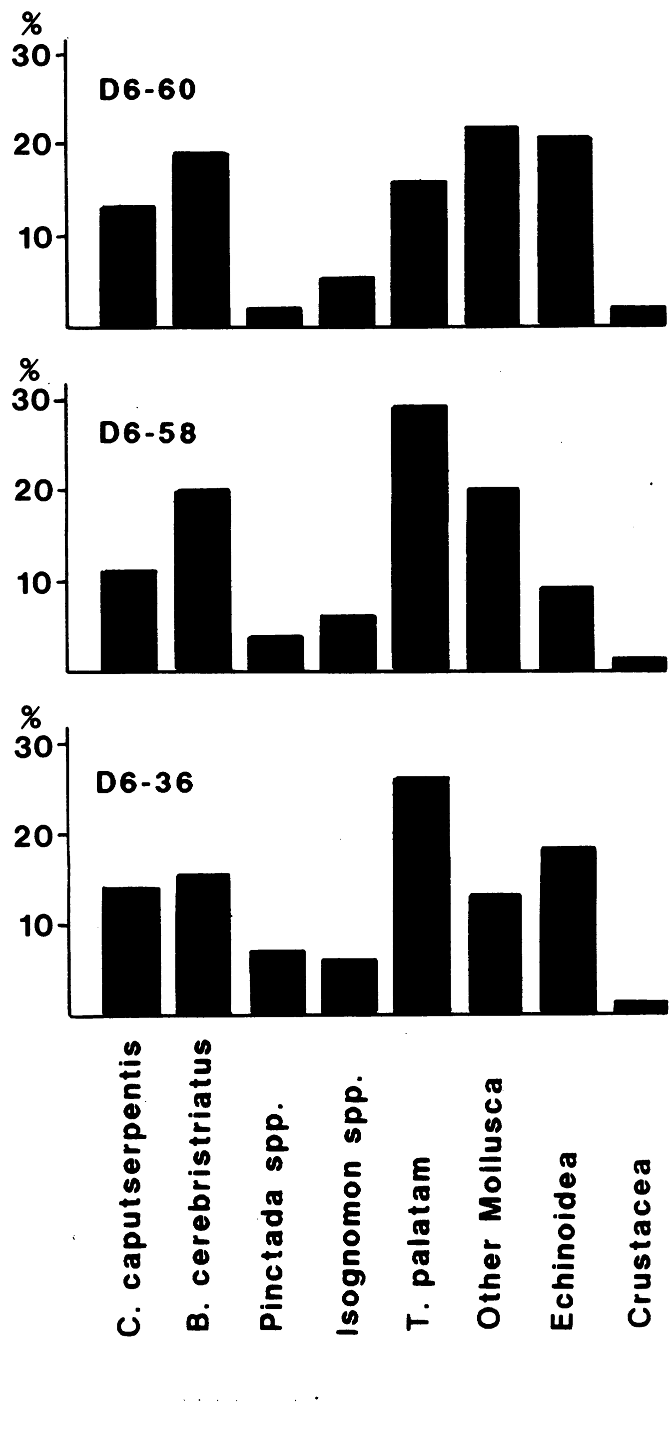

Figure 4.2. Relative frequencies of dominant invertebrate faunal categories in the rockshelter sites.

Stream, and in the case of *N. granosa,* from the stream bed itself.

Echinoidea

Only the spines of sea urchins present in the rockshelter deposits could be identified with confidence to the specific level. Small test fragments, and the calcareous jaws (known as "Aristotle's lantern," Edmonson 1946:86), actually constitute the bulk of echinoid remains by weight. All of the species represented in the Anahulu sites are common on Hawaiian reefs, or on rocky shorelines. The large spines of *Heterocentrotus mammillatus* were used as abraders by the the Hawaiians, although no abraded spines were recovered during our excavations. The other species doubtless represent food remains, as the soft parts of all sea urchins were regularly consumed.

Crustacea

The small and fragmented remains of crustacea from the Anahulu sites could not be further identified, owing to a lack of adequate reference collections or specialists willing to undertake this difficult task. They likely include grapsid or xanthid crabs of the Brachyrhyncha, and possibly spiny lobsters *(Panulirus* spp.).

Temporal Trends

Neither sites D6-36 or -60 display any significant temporal trends in the species distribution or quantity of invertebrate remains. In Site D6-60, the deep D20 unit shows a relatively uniform stratigraphic distribution of invertebrate remains. In Site D6-58, however, there is a significant difference in the density of invertebrate fauna between the upper and lower cultural deposits (table 4.7). This is especially so with the molluscs, which are about 2.5 times more densely concentrated in the upper cultural deposit than in the lower cultural deposit. This evidence reinforces our interpretation of a shift in the behavioral patterns at this shelter from earlier to later occupation phases.

TABLE 4.7

INVERTEBRATE FAUNA FROM UPPER AND LOWER CULTURAL DEPOSITS, SITE D6-58

	Shell	Echinodea	Crustacea
Upper	223.8 gm	16.0 gm	2.8 gm
Lower	87.3	12.2	0.5

SUMMARY

The rockshelter faunal assemblages provide significant information on the behavioral patterns of the Anahulu rockshelter occupants, and on the environment of the upper valley in prehistoric times:

(1) The occupants of all three shelters brought a variety of items from the coast, presumably for consumption in the shelters. These included fish, marine and estuarine molluscs, sea urchins, and crustacea. Clearly, the shelter occupants had regular access to the coast and to marine resources, although whether by direct exploitation, or by exchange with lowland residents, cannot be determined from the archaeological data. It is likely, however, that the shelter occupants were lowland residents, who utilized the interior rockshelters on a temporary basis, and thus carried marine foods with them when staying at the shelters for a period of time. The exception is the upper cultural deposit of D6-58, which appears to signal a permanent occupation. In this case too, continued access to coastal resources is also evident.

(2) The presence of skeletal elements from a number of seabird species whose modern breeding ranges are limited to small offshore islands suggests that these species were formerly present in the Anahulu Valley and adjacent environments, very likely on the cliffs of the middle and upper valley. Similarly, the presence of endemic landbirds such as honeycreepers, indicates an environment with substantial native forest habitat. It is likely that the rockshelters themselves served as base camps for the exploitation of nesting seabirds and forest birds in the middle and upper valley.

(3) Temporal trends within sites D6-36 and -60 do not show major differences in the faunal assemblages from lower and upper stratigraphic levels. However, a significant change has been documented between the lower and upper cultural deposits in D6-58. We believe that this supports the interpretation advanced elsewhere in this volume (chapter 2), that there was a shift from temporary use to permanent occupation of Site D6-58 in late prehistory. The quantitative differences between faunal assemblages in the three rockshelters also suggests that neither D6-36 nor -60 were at any period occupied as intensively as D6-58 in its later stages.

REFERENCES CITED

Amadon, D. 1950. *The Hawaiian Honeycreepers.* Bulletin American Museum of Natural History 95:151-262. New York.

Ball, S.C. 1933. *Jungle Fowls from Pacific Islands.* B.P. Bishop Museum Bulletin 108. Honolulu.

Berger, A.J. 1981. *Hawaiian Birdlife.* University of Hawaii Press. Honolulu. (Reprint of 1972 edition.)

Edmonson, C.H. 1946. *Reef and Shore Fauna of Hawaii.* B.P. Bishop Museum Special Publication 22. Honolulu.

Ellis, W. 1963. *Journal of William Ellis.* Advertiser Publishing Co. Honolulu. (Reprint of 1827 London edition.)

Gosline, W.A., and V.E. Brock. 1960. *Handbook of Hawaiian Fishes.* University of Hawaii Press. Honolulu.

Kay, E.A. 1979. *Hawaiian Marine Shells.* B.P. Bishop Museum Special Publication 64(4). Honolulu.

Kirch, P.V. 1982. The impact of the prehistoric Polynesians on the Hawaiian ecosystem. *Pacific Science* 36(1):1-14.

_____. 1985. *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory.* University of Hawaii Press. Honolulu.

Luomala, K. 1960. The native dog in the Polynesian system of values. In S. Diamond, ed., *Culture in History: Essays in Honor of Paul Radin*, pp. 190-240. Columbia University Press. New York.

Olson, S.L., and H.F. James. 1982. *Prodromus of the Fossil Avifauna of the Hawaiian Islands.* Smithsonian Contributions to Zoology 365. Washington D.C.

Pratt, H.D., P.L. Bruner, D.G. Berrett. 1987. *A Field Guide to the Birds of Hawaii and the Tropical Pacific.* Princeton University Press. Princeton.

Sahlins, M., and P.V. Kirch. in prep. *Anahulu: The Archaeology of History in the Early Sandwich Islands Kingdom.*

Tate, G.H.H. 1951. *The Rodents of Australia and New Guinea.* Bulletin American Museum of Natural History 97(4):187-430.

Titcomb, M. 1952. *Native Use of Fish in Hawaii.* Memoir 29, Polynesian Society. Wellington.

_____. 1969. *Dog and Man in the Ancient Pacific.* B.P. Bishop Museum Special Publication 59. Honolulu.

_____. 1972. *Native Use of Fish in Hawaii.* 2nd edition. University Press of Hawaii. Honolulu.

Tomich, P.Q. 1986. *Mammals in Hawai'i: A Synopsis and Notational Bibliography.* 2nd edition. Bishop Museum Special Publication 76. Bishop Museum Press. Honolulu.

Valeri, V. 1985. *Kingship and Sacrifice.* University of Chicago Press. Chicago.

CHAPTER FIVE

NON-MARINE MOLLUSCS FROM THE ROCKSHELTER SEDIMENTS

by Patrick V. Kirch

THE RECONSTRUCTION AND INTERPRETATION of former environments using non-marine molluscs from archaeological sites and sediments has a long history in some regions, especially the British Isles (Evans 1972) and parts of North America (Bobrowsky 1984). In the Pacific Islands including Hawai'i, however, analysis of non-marine molluscan shells from archaeological contexts has been applied only recently, although with significant results (e.g., Kirch 1975; Christensen and Kirch 1981, 1986; Christensen 1983, 1984). The Hawaiian Islands, due in part to their extreme geographical isolation and absence of both predators and competitors, witnessed impressive adaptive radiation in several faunal groups, including terrestrial and arboreal molluscs (Zimmerman 1948). The indigenous and endemic non-marine molluscan fauna of the Hawaiian Islands is estimated to have included about 1,061 endemic species. Many of these species are now extinct, particularly those from lowland habitats. Species tended to be highly localized, both geographically and to particular floral communities, making them good paleoenvironmental indicators.

Unfortunately, several factors have hindered the application of landsnail analysis in Hawaiian environmental reconstruction: (1) the unsettled taxonomy of many groups, especially at the species level; (2) the absence of good ecological data for many taxa, especially those now extinct; and (3) the lack of malacologists experienced with the Hawaiian fauna, and willing to undertake the laborious task of sorting and identifying large assemblages of fossil or subfossil snail shells from archaeological contexts. Fortunately, the author had some years ago received informal training in Pacific Islands malacology from Dr. Y. Kondo of the Bishop Museum, precipitating some early applications of non-marine molluscan analyses in archaeology (Kirch 1972, 1975). Subsequently, collaborative research between the author and Dr. Carl Christensen, formerly of the Bishop Museum Malacology Division, led to the development of standardized methods for analysis of landsnails from Hawaiian and other Pacific Islands archaeological contexts (Christensen 1983, 1984; Christensen and Kirch 1981, 1986; Kirch and Christensen, in press). Thus, when the Anahulu rockshelters were excavated in 1982, the extraction and identification of samples of non-marine molluscs from the shelter sediments was one of several techniques chosen to track the course of environmental change in the valley.

METHODS AND MATERIALS

Methods used in the analysis of landsnails from the Anahulu sites largely follow those reported by Christensen and Kirch (1986:53-6) and by Christensen (1983:450-51), the main difference being that in the Anahulu case, shells were extracted from the sediment samples by flotation rather than by wet sieving. Samples were analyzed from Sites D6-60 and -36. In both sites, the samples were taken as continuous columns in 5-cm sampling increments, from cleaned stratigraphic profiles carefully selected to avoid features or disturbances. (No continuous column samples could be taken from D6-58 because of stratigraphic disturbances.) These were the same columns used for the sediment and archaeobotanical analyses reported in chapters 3, 6, and 7. Indeed, the molluscs themselves were extracted using flotation by M. Allen as part of the initial stage of her archaeobotanical work (see chapter 6).

After extraction from the column samples, the landsnail assemblages were identified by the author, with assistance and checking of all identifications by C. Christensen.[1] Identifications were made both by reference to the published taxonomic literature, and by comparison to the type and synoptic collections of the Bishop Museum Division of Malacology. Where the condition of the specimens or the unsettled taxonomy of a particular group precluded precise identification, determination was made to the generic level only. The Anahulu specimens were deposited in the Bishop Museum collections, where they may be consulted as voucher specimens. In quantification, only intact shells, or fragments including the apex, were counted so as to avoid double counting of individuals.

Results of the identification and quantification of non-marine molluscs from the D6-60 and -36 column samples are presented in tables 5.1 and 5.2. No adjustments in specimen counts have been made for differential sample sizes (due to varying volumes and weights of sediment from each 5-cm level), but a standardized shells per milliliter of sediment is provided as an index to the concentration of shells in any sample, and the volumes and weights of floated sediment are also indicated. The environmental interpretation of these data will be presented following a systematic review of the taxa present in the rockshelter samples.

SYSTEMATIC REVIEW

Family HELICINIDAE

Pleuropoma sp.

A few specimens of an unidentified species of *Pleuropoma* were present in the D6-60 column, mostly at lower depths (especially 35-65 cm). This snail may be a variety of *P. laciniosa*, the most common of only two species known from the Ko'olau Mountain region of O'ahu Island (Neal 1934). Neal reports that these operculates are consistently terrestrial, living "in damp places in woods on dead leaves on the ground, some on damp rocks" (1934:4).

Family HYDROBIIDAE

Tryonia sp. ?

Four specimens of what may be a *Tryonia* sp. were found in the D6-60 column. Hydrobiids are aquatic snails, which could have derived from the nearby Anahulu Stream. Unfortunately, the Hawaiian representatives of the family are poorly known, and sparsely represented in the Bishop Museum collections. Thus, identification could not be taken to a more precise level.

Family ACHATINELLIDAE

The Achatinellidae is a relict family of pulmonate molluscs confined in its distribution to the Pacific Basin, with Hawai'i being the center of greatest specific-level diversity (Cooke and Kondo 1960). Several genera are abundantly represented in the Anahulu samples.

Lamellidea sp.

Specimens of *Lamellidea* were abundant in all stratigraphic levels of both rockshelters. At least some of these shells may be of the species *L. gracilis,* which occurs commonly throughout the islands up to 300 m elevation. Cooke and Kondo note that *Lamellidea* is both terrestrial and arboreal (1960:182). *L. gracilis* is "one of the few native land snails commonly found in association with non-native plant communities" (Christensen and Kirch 1986:57).

Elasmias sp.

Examples of this genus were very rare, only two occuring at the base of the D6-60 column, and one in the D6-36 column. Cooke and Kondo remark that "*Elasmias* have been taken alive in the Hawiian Islands only at altitudes of several hundred to 4,000 or 5,000 feet, most frequently along the edges of native forests" (1960:221). They appear to be associated with wet forests, and are not common in lowland fossil deposits.

Tornatellides spp.

Specimens of *Tornatellides* spp. were more abundant in both columns than those of any other taxon. More than one species is present, but identifying members of this genus is exceedingly difficult, particularly with immature or broken shells. There are 48 endemic species in the Hawaiian Islands (Cooke and Kondo 1960:247). Christensen and Kirch observe that "little is known of the ecological preferences of species

[1] I take this opportunity to thank Dr. Christensen for his substantial assistance in this work, and for his pleasant collaboration over several years in the subject of archaeo-malacology.

of *Tornatellides,"* but that they appear to have "a rather broad tolerance" for changing ecological conditions (1986:57).

Pacificella cf. *baldwini*

A few specimens of *P. baldwini* are present in both columns, especially at the base of the Site D6-36 column. The species is distributed throughout the larger Hawaiian Islands (Cooke and Kondo 1960:167), but little is recorded of its ecological preferences. Christensen (1983:435) notes that it may be tolerant of ecological disturbance.

Auriculella sp.

Two specimens of an unidentified species of *Auriculella* were recovered from the basal portion of the D6-60 column. The genus is endemic to the Hawaiian Islands, where it is arboreal, and usually confined to native wet forests.

Achatinella spp.

At least three species of *Achatinella* are represented, primarily from the basal levels of the D6-60 column, although there are also three individuals from the D6-36 column. One of these appears to be *A. decora.* Two other species can be distinguished from each other on the basis of their dextral and sinistral coiling, but could not be further identified with the material at hand. The polymorphic genus is endemic to the island of O'ahu (Cooke and Kondo 1960), where it has undergone extensive radiation (Welch 1938). All species of the genus are exlusively arboreal, and generally do not tolerate disturbed conditions or exotic vegetation. Consequently, the genus is today restricted to the higher elevation forests of the Ko'olau and Wai'anae Mountains, and its conservation status is in question.

Family AMASTRIDAE

The family Amastridae is a relict group of pulmonates endemic to the Hawaiian Islands (Pilsbry and Cooke 1914-1916).

Amastra spp.

Two species of the large-shelled genus *Amastra* are present in the D6-60 column only, from the basal levels. One of these is from the subgenus *Cyclamastra,* while the other is an unidentified dextral species of *Amastra* (s.s.). "For the greater part, these were shells of the plains and low elevations, down to near sea level. With the passing of the low forests these Amastras have become extinct, with few exceptions" (Pilsbry and Cooke 1914-1916:20).

Leptachatina spp.

The *Leptachatina* are somewhat smaller members of the Amastridae, represented in low frequencies in both sites. As most *Leptachatina* species are extinct, little is known of their ecology, although they evidently were associated with lowland forests.

Family PUPILLIDAE

Lyropupa spp.

Several species of both dextral and sinistral *Lyropupa* are represented in the collections, although the sinistral species is present only in Site D6-60. In the D6-60 column, *Lyropupa* is present throughout the sequence. The genus is terrestrial, associated with leaf litter or grass. Christensen and Kirch note that "dextral species of *Lyropupa* are generally restricted to arid low-elevation sites" (1986:58). The sinistral species, in contrast, "inhabit the humid forest zone where they may be found on mossy stones, fallen twigs, and dead leaves" (Pilsbry and Cooke 1918-1920:227).

Nesopupa spp.

Representatives of *Nesopupa* are found throughout the sediment columns of both sites, and include the species *N. newcombi* and *N. dispersa,* as well as at least one additional unidentified species. Both *N. newcombi* and *N. dispersa* are distributed throughout the main Hawaiian Islands. Both species appear to be associated with native dry forest (Christensen 1983:456-7).

Pronesopupa sp.

Only two individuals of an unidentified species of *Pronesopupa* were recovered, from the basal levels of the D6-60 column.

Gastrocopta servilis

G. servilis appears in the upper levels of both sites. It is a Neotropical species, first reported from the Hawaiian Islands in 1892 (Ancey 1892). The snail has been widely distributed throughout the islands of the Pacific region as a result of commerce (Christensen and Kirch 1986:59).

Family ENDODONTIDAE

Cookeconcha sp.

This is an endemic Hawaiian genus for which the species-level taxonomy remains unsettled (Solem 1982:275-76), thus precluding identification of the specimens occuring throughout the D6-60 column. Ecologically, *Cookeconcha* species "live on dead stumps and logs, and under the bark of dead trees, but also under fallen leaves" (Pilsbry and Vanatta 1906:783).

TABLE 5.1

NON-MARINE MOLLUSCS FROM COLUMN C, UNIT D20, SITE D6-60

TAXON		DEPTH INCREMENT (cm) 0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	TOTALS
Helicinidae	*Pleuropoma* sp.				1				2	1		4	4	2				1	15
Hydrobiidae	*Tryonia* ?			2					1					1					4
Achatinellidae	*Lamellidea*	12	4	3	24	39	20	19	7	14	9	13	10	7	8	24		1	214
	Elasmias sp.															2			2
	Tornatellides spp.	9	16	10	31	74	38	33	27	45	32	32	34	22	35	58		4	500
	Pacificella cf. *baldwini*						1				1							1	3
	Auriculella sp.												1				1		2
	Achatinella (A.) cf. *decora*														1				1
	Achatinella sp. (dextral)												1				1		2
	Achatinella sp. (sinistral)											1	4+	3	2		2		12+
	Achatinellid (misc. fragments)										2		+			1			3+
Amastridae	*Amastra* sp. (dextral)												2	7+	3+	2	1+		15+
	Amastra (Cyclamastra) sp.																1		1
	Leptachatina spp.	3	9			1			1				2	3	3	1			23
Pupillidae	*Lyropupa* spp. (dextral)		2	1	8	12	6	4	2		1		6	2	2	2			48
	Lyropupa spp. (sinistral)				1	1		1		1				1	1				6
	Nesopupa newcombi	6	4	1	10	9	4	3			4	1	1	5		41	2	2	95
	Nesopupa dispersa			1	1	5	3		5		3			1		2			21

TABLE 5.1, Continued

TAXON		DEPTH INCREMENT (cm) 0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	TOTALS
	Nesopupa spp. (unident.)								1	2		5							8
	Pronesopupa sp.												1			1			2
	Gastrocopta servilis	9	14	2															25
Endodontidae	*Cookeconcha* sp.			2		5	2			2		1	1		1	3			17
	Endodonta sp.												1	2	1	1	2		7
Succineidae	*Succinea* sp.				1			3		2	2	1	2	1	1			1	14
Helicarionidae	*Philonesia*	1													1	1	1		4
Zonitidae	*Hawaiia*	6	8			1													15
Ferussaciidae	*Cecilioides aperta*																	1	1
Subulinidae	*Lamellaxis clavulinum*	1																	1
	Lamellaxis gracilis												1						1
	Prosopeas achatinaceum	1																	1
	Sublinid unident.	3	2																5
TOTAL SPECIMENS		51	59	22	77	147	74	63	46	67	54	58	71	57	59	139	11	13	1,068
VOLUME OF SAMPLE (Ml)		300	450	400	450	450	450	500	500	400	450	500	500	450	500	500	100	200	
SPECIMENS/MILLILITER		170	131	55	171	326	164	126	92	167	120	116	142	126	118	278	110	65	

TABLE 5.2

NON-MARINE MOLLUSCS FROM COLUMN B, SITE D6-36

TAXON		DEPTH INCREMENT (cm) 0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	TOTALS
Achatinellidae	*Lamellidea*	8	1	8	5	3	1	2		4	12	44
	Elasmias sp.			1								1
	Tornatellides spp.	11		13	8	15	1	6	1	2	18	75
	Pacificella cf. *baldwini*	1		1	1					1	10*	14
	Achatinella sp. (dextral)						1					1
	Achatinella sp. (sinistral)		1			1						2
Amastridae	*Leptachatina* spp.	4	+									4+
Pupillidae	*Lyropupa* spp. (dextral)		1	5								6
	Nesopupa newcombi	1	2	7	3						1	14
	Nesopupa dispersa			1							+	1+
	Nesopupa spp. (unident.)					1						1
	Gastrocopta servilis	4										4
Succineidae	*Succinea* sp.		1							1		2
Subulinidae	*Lamellaxis gracilis*		+	1	1	1	1			1	3	8+
	Prosopeas achatinaceum	2	2									4
	Subulina actona	1	1									2
Bradybaenidae	*Bradybaena similaris*	1	1									2
TOTAL SNAILS		33	10+	37	18	21	4	8	1	9	44+	185
VOLUME OF SAMPLE (Ml)		250	300	300	100	150	75	50	30	150	75	
SPECIMENS/MILLILITER		132	33	123	180	140	53	160	33	60	586	

Endodonta sp.

Seven specimens of an unidentified *Endodonta* were recovered from the basal levels of the D6-60 column. As Solem (1982:275-77) notes, the specific-level taxonomy of this group remain unsettled, with perhaps only 13% of the collected species having been described and named. The probable ecological niche of this endodontid is, as for other members of the family, "litter-and-leaf-mould forest dwellers" (Solem 1976:100).

Family SUCCINEIDAE

Succinea sp.

Specimens of *Succinea* are found in both sites, especially in the lower half of the D6-60 column. *Succinea* are generally terrestrial, and are common in the lowland, more arid regions of the Hawaiian Islands. The Anahulu specimens may be *S. caduca*, a widely distributed species in the archipelago, associated with dry forest conditions, although a definitive determination could not be made.

Family HELICARIONIDAE

Philonesa sp.

A few specimens of *Philonesia* were present, from the base and top of the D6-60 column. The genus inhabits a wide range of habitats, and lacking a specific identification, no definitive ecological conditions can be inferred.

Family ZONITIDAE

Hawaiia sp.

A few specimens of *Hawaiia* are present in the upper levels of the D6-60 column. As Christensen (1983:461) remarks, most authorities regard the Hawaiian representatives of *Hawaiia* as conspecific with the North American species *H. minuscula*, and an adventive in the Hawaiian Islands. The snail was first reported from Hawai'i in 1854. The restriction of this species to the upper levels of the D6-60 column would appear to reinforce this interpretation of the species as an historic introduction to the islands.

Family FERRUSSACIIDAE

Ceciliodes aperta

Only one specimen of this species is present, from the base of the D6-60 column. The species is an historic introduction to the Hawaiian islands, and its presence deep in the D6-60 site can be explained by its burrowing habit.

Family SUBULINIDAE

Lamellaxis clavulinum

A single specimen of this exotic, widely distributed snail appears in the uppermost level of the D6-60 column.

Lamellaxis gracilis

A single specimen of *L. gracilis* was recovered from D6-60, but the species occurs throughout most of the D6-36 column. This adventive species is widely associated with indigenous cultivation systems in the Pacific, and is now known to have become established on many Pacific Islands in the prehistoric period (Christensen and Kirch 1981, 1986; Hunt 1981; Christensen 1984). Indeed, its presence in a landsnail assemblage is a good index of the presence of human activity and ecological disturbance.

Prosopeas achatinaceum

A few specimens of this historically-introduced species are present in the upper levels of both sites.

Subulina octona

Two specimens of this adventive, historically-introduced species are present from the top of the D6-36 column.

Family BRADYBAENIDAE

Bradybaena similaris

Two specimens of this large, adventive, historically-introduced species were recovered from the upper part of the D6-60 colulmn.

PALEOENVIRONMENTAL INTERPRETATION

The column from Unit D20 of Kuolulo rockshelter spans a period from the mid-fifteenth century up to the present, thus providing an opportunity to trace changing ecological conditions in the immediate vicinity of the site. The non-marine molluscan asemblages from this column have been plotted as a frequency diagram in figure 5.1, based on the data presented in table 5.1. (It should be noted that the two deepest samples (75-85 cm) consisted of only 11 and 13 specimens, and that sample size effects may have skewed the representation of particular taxa in these basal levels.) Before attempting to interpret this column, we must ask whether the patterns evident in figure 5.1 may simply reflect differing sample sizes (see also discussion of sample size effects in chapter 6). In fact, there is litle correlation between number of

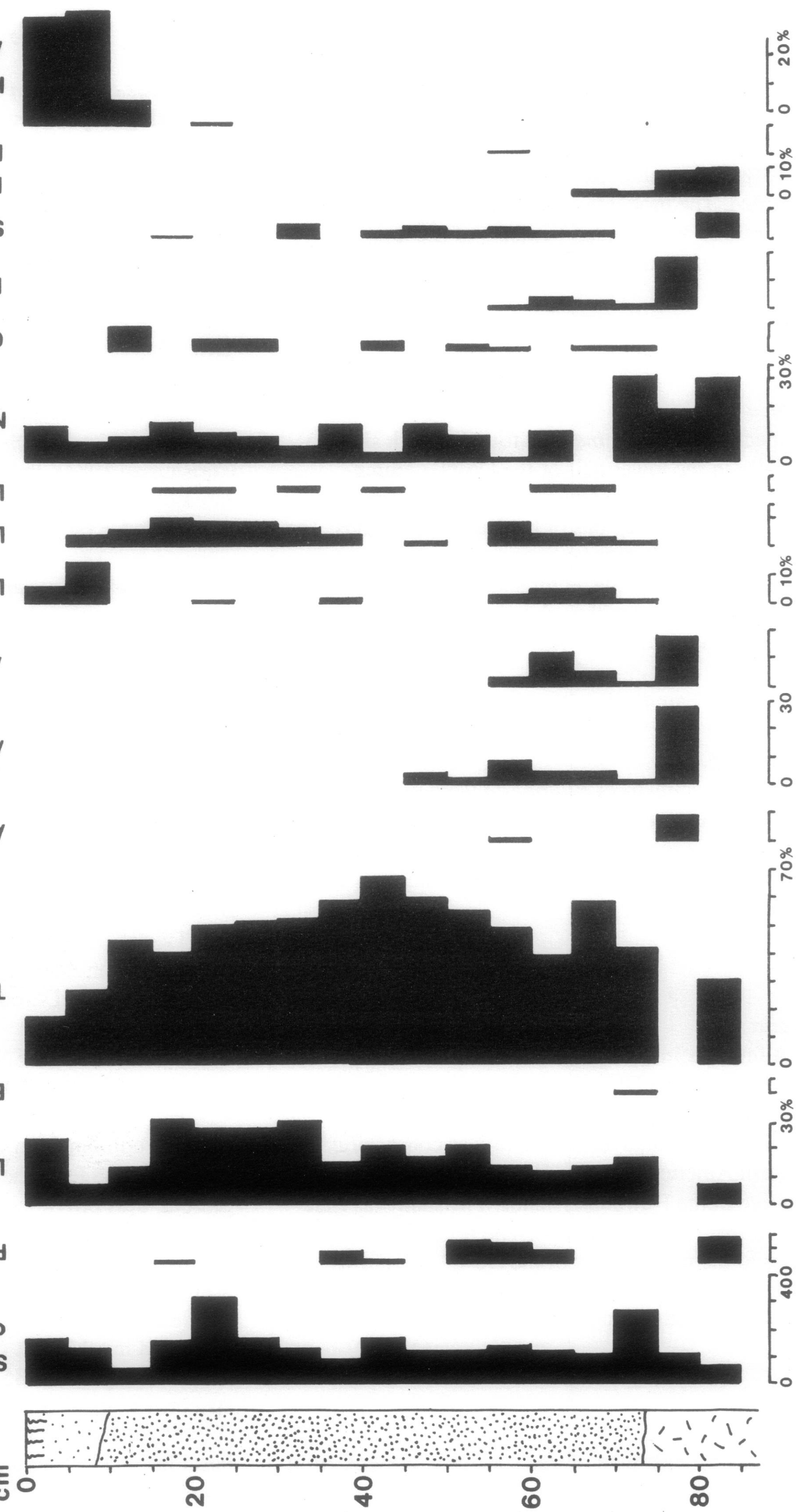

Figure 5.1. Relative frequencies of non-marine molluscs in the column from Unit D20, Site D6-60.

identified specimens (NISP) and number of identified taxa (NTAXA) in the D6-60 column (Pearson's $r=0.317$, $r^2=10\%$). Thus, changing patterns of *taxonomic richness* in the column are clearly meaningful in an ecological sense. On the other hand, the *relative frequencies* or abundances of particular taxa do appear to reflect sample size effects. *Lamellidea* and *Tornatellides* frequencies correlate significantly with NISP (Spearmen's rho values of 0.88 and 0.85, $p=0.001$, respectively). Thus, we must be very cautious in relying upon frequency data in interpreting the D6-60 landsnail sequences, and primary weight will be given to patterns of taxonomic richness (i.e., to nominal, or presence/absence, data).

The D20 column can be readily divided into three major phases on the basis of the non-marine molluscan fauna, each zone representing a somewhat different local ecology.

Zone 1 consists of the lowest six samples, from 55 cm to the base of the column, thus spanning the lowest 10-15 cm of the cultural deposit along with the underlying pre-occupation deposit. This zone is marked by the most diverse array of taxa in the entire column. Of particular note are the presence of *Auriculella, Achatinella, Amastra, Elasmias, Endodonta,* and *Philonesia,* taxa that do not occur in any samples higher in the column. In addition, the zone includes *Lamellidea, Pleuropoma* in some units, *Tornatellides, Leptachatina, Lyropupa* of both dextral and sinistral forms, *Nesopupa, Cookeconcha,* and *Succinea.* The presence of the arboreal *Auriculella* and *Achatinella,* of the large, extinct *Amastra,* and of such taxa as *Pleuropoma, Elasmias, Endodonta,* and *Philonesia* that prefer wetter microenvironments can all be taken to indicate a dense (if not fully closed) canopy, forested environment at this time period. The overall picture indicated by Zone 1 is of an undisturbed mesic native forest.

Zone 2 spans the 8 to 9 sample units from 55 cm up to 10/15 cm below surface, that is, the major portion of the prehistoric cultural deposit. *Auriculella, Achatinella, Amastra, Elasmias, Endodonta,* and *Philonesia* are absent from this zone. This zone is dominated by *Tornatellides* and *Lamellidea,* with lesser frequencies of *Pleuropoma, Leptachatina, Lyropupa, Nesopupa, Cookeconcha,* and *Succinea.* The upper part of the zone is marked by increasing frequency of *Lamellidea* and dextral *Lyropupa,* with decreases in *Pleuropoma, Tornatellides,* and *Succinea.* Zone 2 contrasts markedly with Zone 1, and indicates a period of significant local environmental change. In particular, the absence of arboreal snails suggests the removal or opening up of the former tree canopy, and the extirpation of taxa requiring wet microenvironments suggests a concomitant trend toward drier conditions. These changes were almost certainly the result of human interference with the local vegetation, probably due to clearing of forest, for shifting cultivations, in the vicinity of the site. It is noteworthy that the anthropophilic snail *Lamellaxis gracilis,* intimately associated with Polynesian gardening activity, appears in the 55-60 cm level of the column.

Zone 3 consists of the upper two or three samples, from 0-10/15 cm below surface. This zone is marked by the presence, in high frequencies, of the historically adventive taxa *Gastrocopta, Hawaiia,* and subulinids, by a marked decrease in the native *Tornatellides* and dextral *Lyropupa,* and by the total disappearance of *Succinea, Cookeconcha,* sinistral *Lyropupa,* and *Pleuropoma.* This zone thus reflects the major environmental changes associated with the historic-period introduction of exotic vegetation, as well as the deforestation of the lowlands due to the introduction of grazing animals.

The column from Ke'eke'e Iki rockshelter spans a shorter time period than that from D6-60, and thus correlates with Zones 2 and 3 of the latter column. The paleoenvironmental picture from D6-36 closely matches that summarized above for D6-60. In the D6-36 column, the lower 8 sampling units correlate with Zone 2, the period of prehistoric human interference in the mid-valley ecosystem. Thus, these samples lack such wet forest taxa as *Auriculella, Amastra, Cookeconcha, Endodonta,* or *Philonesia,* as well as the sinistral *Lyropupa* and the *Pleuropoma.* Also, the Polynesian anthropophilic snail *Lamellaxis gracilis* is present in most of these sample units, a good marker of gardening activity in the vicinity of the site. The upper two sample units (0-10 cm) correlate with Zone 3, with high frequencies of the historic adventives *Gastrocopta, Prosopeas, Subulina,* and *Bradybaena.*

In sum, the non-marine molluscs contained within the rockshelter sediments of Sites D6-60 and D6-36 present a consistent picture of local environmental changes in the middle Anahulu Valley, from about the mid-fifteenth century up into the historic period. At the time Kuolulo Shelter was first occupied, the site was situated within a relatively undisturbed, closed or dense canopy native forest. This forest was quickly opened up through human clearance, presumably for shifting cultivation, with the more open conditions maintained throughout the prehistoric occupation period. There is some suggestion of increasingly open or arid conditions in the later part of the prehistoric period. A final phase of marked ecological change occured with the historic introduction of exotic flora and fauna.

REFERENCES CITED

Ancey, C.F. 1892. Etudes sur la faune malacologique des Iles Sandwich. *Memoirs de la Sociétè Zoologiques Française* 5:708-22.

Bobrowsky, P.T. 1984. The history and science of gastropods in archaeology. *American Antiquity* 49:77-93.

Christensen, C.C. 1983. Analysis of land snails. In J. Clark and P. Kirch, eds., *Archaeological Investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawaii*, pp. 449-71. Anthropology Dept. Report 83-1. B.P. Bishop Museum. Honolulu.

_____. 1984. Analysis of nonmarine mollusks. In A.R. Schilt, *Subsistence and Conflict in Kona, Hawaii*, pp. 355-76. Anthropology Dept. Report 84-1. B.P. Bishop Museum. Honolulu.

Christensen, C.C., and P.V. Kirch. 1981. Non-marine molluscs from archaeological sites on Tikopia, Solomon Islands. *Pacific Science* 35:75-88.

_____. 1986. Nonmarine mollusks and ecological change at Barbers Point, O'ahu, Hawai'i. *B.P. Bishop Museum Occasional Papers* 26:52-80.

Cooke, C.M., Jr., and Y. Kondo. 1960. *Revision of Tornatellinidae and Achatinellidae*. B.P. Bishop Museum Bulletin 221. Honolulu.

Evans, J.G. 1972. *Land Snails in Archaeology*. Seminar Press. London.

Hunt, T.L. 1981. New evidence for early horticulture in Fiji. *Journal of the Polynesian Soceity* 90:259-69.

Kirch, P.V. 1972. Subfossil non-marine gastropods from Molokai, Hawaiian Islands. *The Nautilus* 86(1):23.

_____. 1975. Excavations at Sites A1-3 and A1-4: early settlement and ecology in Halawa Valley. In P.V. Kirch and M. Kelly, eds., *Prehistory and Ecology in a Windward Hawaiian Valley*, pp. 17-70. Pacific Anthropological Records No. 24. Department of Anthropology, Bishop Museum. Honolulu.

Kirch, P.V., and C.C. Christensen. in press. Extinct achatinellid landsnails from Easter Island: biogeographic, ecological, and archaeological implications. *Burke Museum Contributions in Anthropology and Natural History*.

Neal, M.C. 1934. *Hawaiian Helicinidae*. B.P. Bishop Museum Bulletin 125. Honolulu.

Pilsbry, H.A., and C.M. Cooke, Jr. 1915-16. *Manual of Conchology, Vol. 23. Appendix to Amastridae, Tornatellinidae*. Academy of Natural Sciences. Philadelphia.

_____. 1918-20. *Manual of Conchology, Vol. 25, Pupillidae*. Academy of Natural Sciences. Philadelphia.

Pilsbry, H.A., and Vanatta. 1906. New Hawaiian species of *Endodonta* and *Opeas*. *Proceedings of the Academy of Natural Sciencs, Philadelphia* 1905:783-86.

Solem, A. 1976. *Endodontid Land Snails from Pacific Islands. Part I: Family Endodontidae*. Field Museum of Natural History. Chicago.

_____. 1982. *Endodontid Land Snails from Pacific Islands. Part II: Families Punctidae and Charopidae, Zoogeography*. Field Museum of Natural History. Chicago.

Welch, D'A.A. 1938. *Distribution and Variation of Achatinella mustelina Mighels in the Waianae Mountains, Oahu*. B.P. Bishop Museum Bulletin 152. Honolulu.

Zimmerman, E.C. 1948. *Insects of Hawaii, Vol. 1, Introduction*. University of Hawaii Press. Honolulu.

CHAPTER SIX

ARCHAEOBOTANICAL ASSEMBLAGES FROM THE ANAHULU ROCKSHELTERS

by Melinda S. Allen

THE HAWAIIAN LANDSCAPE at contact was the product of a lengthy and dynamic interaction between human populations and the environment. The extant Hawaiian flora in particular reflects three inter-related anthropogenic processes: (1) biotic dispersals by Polynesian colonists, both intentional and accidental; (2) reduction, extirpation, and disjunction of native species as a result of deforestation, anthropogenic dispersals, and direct human competition; and (3) creation and maintenance of anthropogenic environments. These three processes were repeated throughout Hawaiian prehistory at different scales, intensities, and rates in various localities, and they continue today. Their role in the transformation of one Hawaiian valley system, Anahulu Valley on the northwest coast of O'ahu Island, is the focus of this paper, as evidenced through the analysis of archaeobotanical assemblages from three inland rockshelters.

Our understanding of changes in the native Hawaiian vegetation has been aided by several lines of paleobotanical inquiry including wood-charcoal analyses, flotation studies, ethnohistoric research, palynology, and phytolith work (see review in Allen 1984a). Analysis of fine-grained archaeological sediments has identified the prehistoric presence of a suite of weedy taxa associated with human occupations, some which were once thought to be European introductions; these taxa were probably inadvertant Polynesian introductions given their pan-Pacific occurrence and consistent agricultural associations (Allen 1981; see also St. John 1976). Wood-charcoal studies indicate both the removal of native forest and reduction in the number of species in the ecologically more fragile dryland zones (Murakami 1983a,b,c; see also McEldowney 1983). Similarly, ethnohistoric research suggests that most of the lowland forest had been replaced with agricultural fields by the time of European contact (cf. McEldowney 1976).

The present research centers on archaeobotanical materials from a series of archaeological sites within the Anahulu Valley. Prior work in the area indicated that the relatively dry rockshelters favored botanical preservation (Kirch 1979:46-7). In light of this, special care was taken to recover plant materials during excavation and several bulk sediment samples were taken for flotation. This study considers temporal trends in the mid-valley vegetation as reflected in three column samples from Kuolulo (D6-60) and Ke'eke'e Iki (D6-36) rockshelters. Secondly, prehistoric plant utilization is addressed through a series of discrete feature samples from the Ke'eke'e Nui (D6-58) rockshelter.

The vegetation within Anahulu Valley today is a mixture of introduced and native elements, with the former predominating in the lower valley and the latter in the upper valley (see also Kirch 1979:5-7; chapter 1). Vegetation zonation within Anahulu is comparable to that described by Hosaka (1937) for Kipapa gulch, another large leeward O'ahu valley system. As in Kipapa, the lower Anahulu Valley is characterized by a xerophytic flora, including *koa-haole (Leucaena leucocephala* [Lam.] de Wit), prickly pear *(Opuntia*

TABLE 6.1

VOLUME, WEIGHT, NUMBER OF SEEDS, AND NUMBER OF TAXA BY SAMPLE

Sample	Volume (ml)	Weight (gm)	No. Carbonized Seeds	No. Carbonized Taxa[a]
Site D6-60 (Kuoluluo Shelter), Column A				
*0-5 cm	350	366	0	0
5-10 cm	350	364	5	2
10-15 cm	300	280	7	3
15-20 cm	150	162	23	7
20-25 cm	250	279	18	4
25-30 cm	150	172	18	4
30-35 cm	200	232	27	4
35-40 cm	300	318	31	5
40-45 cm	350	430	16	3
45-50 cm	300	346	24	4
Site D6-36 (Ke'eke'e Shelter), Column B				
*0-5 cm	250	318	0	0
5-10 cm	300	342	4	3
10-15 cm	300	343	11	4
15-20 cm	100	132	4	2
20-25 cm	150	140	3	3
25-30 cm	75	62	12	4
30-35 cm	50	61	3	2
*35-40 cm	30	72	0	0
40-45 cm	150	180	2	1
*45-50 cm	75	90	0	0
Site D6-60 (Kuolulo Shelter), Column C				
*0-5 cm	300	347	0	0
*5-10 cm	450	551	0	0
10-15 cm	400	481	8	2
15-20 cm	450	455	27	8
20-25 cm	450	481	44	8
25-30 cm	450	478	33	8
30-35 cm	500	471	27	6
35-40 cm	500	471	23	7
40-45 cm	400	443	27	7
45-50 cm	450	451	30	7
50-55 cm	500	597	26	2
55-60 cm	500	493	26	4
60-65 cm	450	492	26	5
65-70 cm	500	591	30	3
70-75 cm	500	584	48	5
*75-80 cm	100	166	0	0
*80-85 cm	200	294	0	0

* These samples are not included in fig. 6.2 or in the reported statistics.

a The number of carbonized taxa for each sample does not include non-diagnostic unidentified specimens which may potentially include one or more taxa.

b NA=information not available.

TABLE 6.1, Continued

Lab Designation & Provenience	Volume (ml)	Weight (gm)	No. Carbonized Seeds	No. Carbonized Taxa[a]
Feature Samples				
Site D6-58				
Unit 011				
(A) Fe 6 (oven) 15-18 cmbs	500	501	10	1
(B) Fe 6 (oven) 17-21 cmbs	500	605	3	2
(D) Lens 72-74 cmbs	500	643	19	2
(E) Fe 9 (ash lens) 74-77 cmbs	500	576	13	2
(F) Fe 9 (ash lens) 80-85 cmbs	500	594	55	11
Unit K10				
(G) Fe 1 (sm hearth) 17-28 cmbs	NA[b]	NA[b]	65	10
(H) Fe 5 (oven) 55-65 cmbs	500	444	19	1

a The number of carbonized taxa for each sample does not include non-diagnostic unidentifiedspecimens which may potentially include one or more taxa.
b NA=information not available.

megacantha Salm-Dyck), lantana *(Lantana camara* L.), and a host of other weedy exotics. The middle valley corresponds to Hosaka's "Guava Zone" and is more mesic in composition. *Koa-haole* continues and Christmas berry *(Schinus terebinthifolius* Raddi) becomes an important element. Candlenut *(Aleurites molucanna* [L.] Willd.) frequents the wetter areas, such as gully bottoms. In this zone, several economic plants, including both traditional Polynesian cultigens and historic introductions, are closely associated with the archaeological structural remains. Coffee, bananas, sweet potato, and taro are feral, while formerly cultivated lime, orange, mango, and coconut trees persist. Only the upper valley has a predominantly native vegetation cover, comparable in composition to Hosaka's "Koa Zone" *(Acacia koa* Gray); this grades into a higher elevation "Ohia Zone," dominated by the native *Metrosideros collina* (J.R. and G. Forst.) Gray.

METHODS

In the field, the three column samples were taken in 5 cm increments, varying in volume from 30 to 500 ml (table 6.1). Samples of more variable sizes were taken from discrete features; in all but two cases, 500 ml of each feature sample were analyzed.

All samples were processed in the laboratory using a water sepearation device adapted from Hommon (1983:19-20, 23), a smaller and simpler version of the one described by Watson (1976). Whenever possible a sample of at least 500 ml was processed; unprocessed portions of several samples are currently conserved in the Archaeology Division of the B.P. Bishop Museum in Honolulu. Floated materials were passed through standard geologic wire mesh screens of 4, 2, 1.5, and .5 mm size during flotation and then air-dried separately. This portion of the analysis was conducted by B.P. Bishop Museum archaeological laboratory assistant Mary Riford.

Dried flotation samples were sorted under a binocular microscope at 8X. All material from each size fraction was sorted, the bulk of which consisted of unidentifiable charcoal fragments. The heavy fraction (i.e., that which did not float) was not analyzed. Identifications are based on comparisons with B.P. Bishop Museum Herbarium collections and a vouchered reference collection of seeds and other plant parts. The term "seed" is used here in a general sense to include a variety of seed/fruit types including caryopses, arils, and mericarps. All Latin names follow St. John (1973) unless otherwise noted.

In the following discussion, the designation "cf." indicates that the cited taxon is the most likely candidate. However, because of the small amount or poor condition of the materials recovered, or the absence of appropriate materials (i.e., reproductive parts), a conclusive identification is not possible. Use of the designation "?" indicates that the specimen resembles the cited taxon, but may resemble other taxa as well.

In the following tables, counts are provided for individual seeds. Other materials which cannot be identified as "natural units" are treated as attributes rather than variables (see Grayson 1981). Problems inherent in quantification of plant materials and the relationship of these measures to the parameters of interest are discussed in more detail below.

RESULTS

Forty-four samples, totaling approximately 14 liters of sediment, were processed. Twenty taxa were identified at least to the family level and over half of these were carbonized (see table 6.2). In addition, 32 unidentified but diagnostic carbonized taxa were recorded. The present study focuses on the carbonized specimens because of the difficulty of determining the origins of non-carbonized plant remains, particularly small seeds (see Lopinot and Brussell 1982; Keepax 1977; Minnis 1981). Modern seeds can be introduced into archaeological contexts by several mechanisms, including soil-burrowing insects and rodents, aerial contamination during field work, and during the flotation process. Herein, except in the case of traditional cultigens, a conservative approach is taken and non-carbonized materials are considered recent contaminants.

For carbonized taxa which could be identified to the family level, and for traditional cultigens, the preferred habitat, phytogeographical distribution, previous archaeological occurrences, and ethnographically documented uses are discussed below. The distribution of carbonized specimens and traditional cultigens by sample units is provided in tables 6.3 to 6.6.

SYSTEMATIC REVIEW

MONOCOTYLEDONS
Family CYPERACEAE

Eleocharis sp. *(kohekohe)*

Eleocharis is a small sedge represented in the Hawaiian Isands by six species: two native, three adventive, and one recent introduction. This genus is frequently associated with wet environments such as freshwater marshes and cultivated wetlands (Stemmermann 1981:42-3). The bristles at the base of the fruit aid in animal dispersal. There are no ethonographically recorded uses for the genus. An archaeological example from Anahulu is illustrated in fig. 6.1. In addition to *Eleocharis,* seeds of two unidentified sedges were recovered from several samples; one of these may be a species of *Carex.*

Family GRAMINEAE

Eragrostis sp. *('emoloa, kalamalo)*

This genus includes twelve native Hawaiian species, all of which are low herbs. The recovered seeds most closely resemble *E. variabilis* (Gaud.) Hbd., a perennial grass which frequently occurs under mesic conditions. Once widespread in the islands, Hitchcock (1974:103) recorded it as the dominant species on the foothills behind Honolulu in the early 1900's. Archaeologically, *Eragrostis* has also been recovered

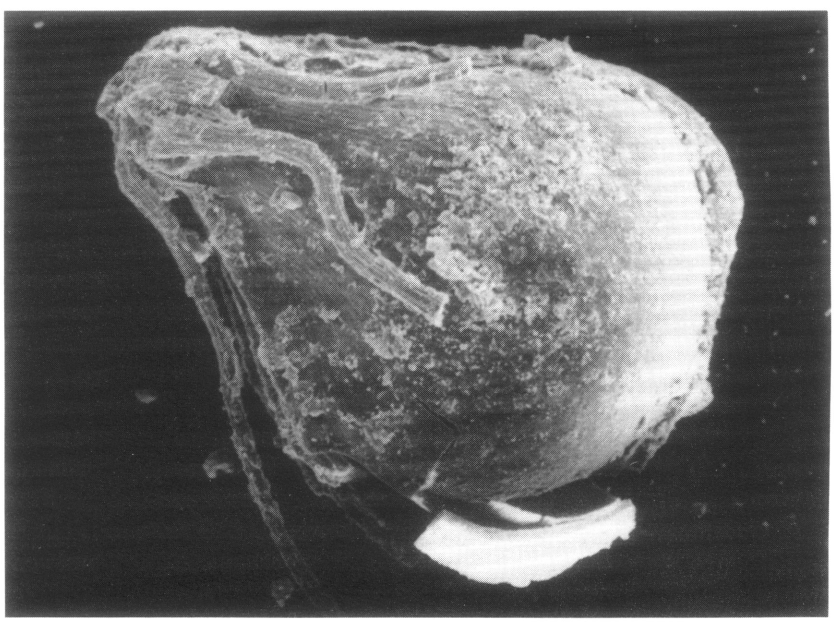

Figure 6.1. A carbonized *Eleocharis* achene with bristles partially intact, Kuolulo shelter (80X).

TABLE 6.2

SUMMARY OF IDENTIFIED TAXA

Taxonomic Identification	Carbonized or Not	Plant Part
Pterophyta		
Unidentified	NC	stem
Monocotyledon		
Araceae (?)	NC	corm
cf. *Colocasia esculenta*		
Cyperaceae		
Eleocharis sp.	C	seed
Unid cf. *Carex*	C	seed
Unidentified sp. (spp.)	C	seeds
Gramineae		
Eragrostis sp.	C	seed
Unidentified	NC/C	seed
Dicotyledon		
Amaranthaceae	NC	seed
Chenopodiaceae		
Chenopodium cf. *oahuense*	NC/C	seed
Compositae (?)	NC	seed
Cucurbitaceae		
Lagenaria siceraria	C	seed/fruit
Sicyos sp.	NC/C	seed
Euphorbiaceae		
Aleurites cf. *molucanna*	NC/C	testa
Leguminosae		
Unidentified	C	seed
Malvaceae		
Sida sp.	C	seed
Mrytaceae		
Psidium sp.	NC	seed/fruit
Oxalidaceae		
Oxalis cf. *corniculata*	NC	seed
Rubiaceae (?)		
cf. *Morinda citrifolia*	NC	seed
Sapindaceae		
Melia azedarach	NC	fruit
Solanaceae		
Solanum sp.	NC/C	seed
Sterculiaceae		
Waltheria cf. *americana*	C	seed

TABLE 6.3

DISTRIBUTION OF CARBONIZED SEEDS BY LEVEL FOR COLUMN A SITE D6-60 (KUOLULO SHELTER)

TAXA[a]	LEVELS 1	2	3	4	5	6	7	8	9	10
Chenopodiaceae										
Chenopodium	—	3	5	13	11	12	21	26	13	21
Cucurbitaceae										
Lagenaria rind	—	—	—	—	—	—	?	—	—	—
Sicyos	—	1	—	2	—	1	—	—	—	1
Euphorbiaceae										
Aleurites testa[b]	—	—	X	X	X	X	X	X	X	—
Gramineae										
Eragrostis	—	—	—	1	3	4	4	1	—	1
Unidentified rhizome/stem	—	—	—	X	—	—	X	X	—	—
Leguminosae										
Unidentified Seed	—	—	—	1	1	—	—	1	—	—
Malvaceae										
Sida	—	—	1	—	—	1	—	—	—	1
Solanaceae										
Solanum	—	—	—	2	—	—	—	—	—	—
Sterculiaceae										
Waltheria	—	—	1	—	—	—	—	—	1	—
Unidentified Seed F	—	—	—	—	—	—	1	—	—	—
Unidentified Seed H	—	—	—	1	—	—	—	—	—	—
Unidentified Seed I	—	—	—	—	—	—	1	—	—	—
Unidentified Seed J	—	—	—	—	—	—	—	1	—	—
Unidentified Seed K	—	—	—	3	3	—	—	—	—	—
Unidentified Seed L	—	—	—	—	—	—	—	1	—	—
Unidentified Seed M	—	—	—	—	—	—	—	—	1	—
Non-diagnostic Unid. Seeds	—	1	—	—	—	—	—	1	1	—
Total No. of Taxa[c]	0	2	3	7	4	4	4	5	3	4
Total Carbonized Seeds	0	5	7	23	18	18	27	31	16	24

a All specimens are seeds unless otherwise indicated.
b Both carbonized and uncarbonized testae are included here.
c These totals do not include non-diagnostic unidentified specimens which could represent one or more taxa.

TABLE 6.4

DISTRIBUTION OF CARBONIZED SEEDS BY LEVEL FOR COLUMN C SITE D6-60 (KUOLULO SHELTER)

TAXA[b]	LEVELS[a]													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Chenopodiaceae														
Chenopodium	—	7	14	25	19	21	15	18	19	21	20	20	27	42
Cucurbitaceae														
Lagenaria seed	—	—	—	1?	—	—	—	—	—	—	—	—	—	—
Lagenaria rind	—	—	?	?	?	—	—	X	X	—	X	?	—	—
Sicyos	—	—	2	6	2	1	—	1	3	—	—	3	1	3
Cyperaceae														
Eleocharis	—	—	1	—	—	—	—	1	1	—	2	1	2	—
Unid cf. *Carex*	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Unidentified	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Euphorbiaceae														
Aleurites testa[c]	X	—	X	X	X	X	X	X	X	X	X	—	X	X
Gramineae														
Eragrostis	—	1	6	2	4	—	3	2	2	5	3	—	—	—
Unidentified seed	—	—	—	1	—	1	1	—	—	—	1	—	—	—
Unidentified rhizome/stem	—	—	—	X	X	X	X	X	X	X	X	X	—	—
Leguminosae														
Unidentified Seed	—	—	—	—	—	—	1	1	—	—	—	—	—	—
Malvaceae														
Sida	—	—	1	—	1	—	—	—	—	—	—	—	—	1
Solanaceae														
Solanum	—	—	1	3	3	2	1	1	2	—	—	1	—	1
Sterculiaceae														
Waltheria	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Unidentified Seed A	—	—	—	—	1	—	—	—	1	—	—	—	—	—
Unidentified Seed N	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Unidentified Seed O	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Unidentified Seed P	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Unidentified Seed Q	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Unidentified Seed R	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Unidentified Seed S	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Unidentified Seed T	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Unidentified Seed U	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Unidentified Seed W	—	—	—	—	—	—	—	1	—	—	—	—	—	—
Unidentified Seed X	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Unidentified Seed Y	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Non-diagnostic Unid. Seeds	—	—	—	3	1	—	—	2	1	—	—	—	—	—
Total No. of Taxa[d]	0	2	8	8	8	6	7	7	7	2	4	5	3	5
Total Carbonized Seeds	0	8	27	44	33	27	23	27	30	26	26	26	30	48

a No specimens were recovered from levels 1, 16, and 17.
b All specimens are seeds unless otherwise indicated.
c Both carbonized and uncarbonized testae are included here.
d These totals do not include non-diagnostic unidentified specimens which could represent one or more taxa.

TABLE 6.5

DISTRIBUTION OF CARBONIZED SEEDS BY LEVEL FOR COLUMN B SITE D6-36 (KE'EKE'E IKI SHELTER)

TAXA[a]	LEVELS 1	2	3	4	5	6	7	8	9	10
Chenopodiaceae										
Chenopodium	—	2	6	3	1	8	2	—	2	—
Cucurbitaceae										
Lagenaria seed	—	—	—	—	—	—	1	—	—	—
Cyperaceae										
Unidentified cf. *Carex*	—	—	—	—	1	1	—	—	—	—
Unidentified seed	—	1	—	—	—	—	—	—	—	—
Euphorbiaceae										
Aleurites testa[b]	—	X	X	X	—	—	—	—	—	—
Gramineae										
Eragrostis	—	—	1	—	—	1	—	—	—	—
Unidentified rhizome/stem	—	—	X	X	—	—	—	—	—	—
Unidentified Seed A	—	—	—	1	—	—	—	—	—	—
Unidentified Seed C	—	—	—	—	1	—	—	—	—	—
Unidentified Seed D	—	—	1	—	—	1	—	—	—	—
Unidentified Seed E	—	1	—	—	—	—	—	—	—	—
Unidentified Seed K	—	—	2	—	—	—	—	—	—	—
Non-diagnostic Unid. Seeds	—	—	1	—	—	1	—	—	—	—
Total No. of Taxa[c]	0	3	4	2	3	4	2	0	1	0
Total Carbonized Seeds	0	4	11	4	3	12	3	0	2	0

a All specimens are seeds unless otherwise indicated.
b Both carbonized and uncarbonized testae are included here.
c These totals do not include non-diagnostic unidentified specimens which could represent one or more taxa.

from cultural deposits on Kaho'olawe (Allen 1984b) and at Kuakini, North Kona (Allen 1984c). There are no ethnographically known uses for the genus.

Unidentified sp(p).

In addition to *Eragrostis*, rhizomes, stems, and seeds of one or more unidentified grass species were recovered.

Family CHENOPODIACEAE

Chenopodium cf. *oahuense* (Meyen) Aellen
('aweoweo, 'aheahea)

Seven species of *Chenopodium* occur in the Hawaiian Islands. Of these, five are European introductions and two are endemic. *C. oahuense* is the more common endemic species, while *C. pekeloi* Deg., Deg. and Aellen is restricted to Moloka'i. The archaeological specimens compare well with *C. oahuense* on the basis of seed coat sculpturing.

C. oahuense has been recorded from sea level to 2,515 m elevation (Hart and Neal 1940:264). Although generally found as a shrub today, arborescent individuals were apparently formerly more common. Hillebrand (1981:380), for example, observed a 12 to 15 foot tree in the upper woods of Mauna Kea. Selling (1948) used *C. oahuense* as a key indicator species in his Hawaiian pollen sequence. He suggested it moved into areas of previously mesophytic vegetation when the local climate became increasingly arid.

TABLE 6.6

CARBONIZED TAXA FROM CULTURAL FEATURES SITE D6-58 (KE'EKE'E NUI SHELTER)

TAXA[a]	LAB DESIGNATION						
	A	B	D	E	F	G	H
Chenopodiaceae							
Chenopodium	9	—	10	8	34	23	19
Cucurbitaceae							
Lagenaria seed	—	—	—	—	2	—	—
Lagenaria rind	—	X	—	—	—	—	—
Sicyos	—	—	—	—	1	—	—
Cyperaceae							
Eleocharis	—	—	—	—	—	10	—
Unidentified sp(p).	—	1	—	—	—	1	—
Unidentified cf. *Carex*	—	—	4	—	4	1	—
Euphorbiaceae							
Aleurites testa[b]	X	X	X	X	X	X	—
Gramineae							
Eragrostis	—	—	—	—	—	13	—
Unidentified stems	—	—	—	—	—	X	—
Leguminosae							
Unidentified seed	—	1	—	—	—	—	—
Malvaceae							
Sida	—	—	—	4	1?	—	—
Solanaceae							
Solanum	—	—	—	—	5	4	—
Unidentified Seed A	—	—	—	—	2	—	—
Unidentified Seed K	—	—	—	—	—	1	—
Unidentified Seed Z	—	—	—	—	1	—	—
Unidentified Seed AA	—	—	—	—	1	—	—
Unidentified Seed BB	—	—	—	—	1	—	—
Unidentified Seed CC	—	—	—	—	1	—	—
Unidentified Seed DD	—	—	—	—	—	3	—
Unidentified Seed EE	—	—	—	—	—	2	—
Unidentified Seed FF	—	—	—	—	—	3	—
Non-diagnostic Unid. Seeds	1	1	5	1	2	4	—
Total No. of Taxa[c]	1	2	2	2	11	10	1
Total Carbonized Seeds	10	3	19	13	55	65	19

a All specimens are seeds unless otherwise indicated.
b Both carbonized and uncarbonized testae are included here.
c These totals do not include non-diagnostic unidentified specimens which could represent one or more taxa.

A single individual of *Chenopodium* produces thousands of seeds on an annual basis. Each seed is enclosed within a glandular utricle which aids in dispersal. It is the most ubiquitous seed in Hawaiian archaeobotanical assemblages; Allen (1983b) suggests it may have been a common agricultural fallow component in drier localities. *Chenopodium* wood-charcoal has also been recovered from several archaeological contexts (Murakami 1983a,b,c; chapter 7, this volume) which could in part account for the presence of seeds within features. An alternative possibility is that *Chenopodium* was used as a food (see discussion in Allen 1983b:164-7), as has been recorded ethnographically (Malo 1951:23; Hillebrand 1981:380; Buck 1964:6; Handy and Handy 1972:235).

Family CUCURBITACEAE

Lagenaria siceraria (Mollina) Standl *(ipu)*

One complete seed and two fragments of *Lagenaria siceraria* were recovered from the column samples; several pieces of possible fruit exocarp were also found. *Lagenaria* was a Hawaiian cultigen typically grown in drier localities (Handy and Handy 1972:212-22). Gourd rinds are commonly encountered in archaeobotanical assemblages, particularly those from rockshelters. Ethnographic accounts indicate that gourds were used for water and storage containers; immature specimens were edible. The occurrence of *Lagenaria* seeds in the Ke'eke'e Iki shelter may indicate that gourds were grown in the vicinity or that gourds were cleaned and prepared for use in the rockshelter.

Sicyos sp. *('anunu)*

Sicyos is a native Hawaiian genus with several representatives. All are climbing vines which tend to inhabit drier localities. Archaeologically, the seeds have also been recovered from Kaho'olawe Island (Allen 1983b, 1984b). There are no recorded uses for *Sicyos;* although not generally recognized as edible, the leaves of many cucurbits are palatable (cf. Purseglove 1968:100-36) and its use as a dietary supplement should not be excluded.

Family EUPHORBIACEAE

Aleurites cf. *molucanna* (L.) Willd. *(kukui)*

The hard seed testae of *Aleurites* were distributed throughout the samples and one kernal (the endosperm) was identified. *Aleurites,* or candlenut, is a common component of Hawaiian forests in areas which have been previously inhabited. It is considered to be a Polynesian introduction to the islands (St. John 1973:210). Although this has not been decisively documented, at present there is no evidence to the contrary. *Aleurites* thrives in mesophytic forests.

Ethnographically, the oily kernals were burnt as a source of light; several kernals strung on a coconut mid-rib or other foundation provided a reasonably strong light with each kernal buring for two to three minutes (Buck 1964:107). The kernals are also part of a traditional Hawaiian condiment *('inamona).*

The hard seed coats are the most ubiquitous, and often dominant, botanical component of Hawaiian archaeological sites. The kernals have also been recovered archaeologically from the Mauna Kea Adze Quarry (Allen 1981).

Family LEGUMINOSAE

Unidentified sp.

These seeds measure ca. 2 to 3 mm in length; the location of the hilum places them within the subfamily Papilionoidea. Unfortunately, within legume subfamilies the seeds are often morphologically quite similar, differing primarily in size and surface coloring. The archaeological seeds compare reasonably well with *Tephrosia,* a common native weed which occurs in mesic areas, but may resemble other taxa as well. Similar legume seeds have been recorded from other Hawaiian archaeobotanical assemblages (table 6.7).

Family MALVACEAE

Sida sp. *('ilima)*

The genus *Sida* includes seven extant Hawaiian representatives, three of which are native. *Sida fallax* is the most common native species, occurring in drier localities from sea level to an altitude of more than 610 m (Neal 1965:552). The seeds (actually the endosperm) of these species are virtually indistinguishable; in contrast the outer seed cases, which are not present on the archaeological specimens, are quite distinctive. In addition to known species, the possibility of extinct types should be considered. Botanist David Nelson of the 1778 Cook Expedition collected two species of *Sida* from the Kona District, Hawai'i Island which have not been observed since (St. John 1976). Other regions of Hawai'i may also have harbored unique species which were never collected. The Hawaiian representatives of this genus are common in dry areas and frequently occur as weeds under disturbed conditions.

Several ethnographic uses have been recorded for *Sida.* These include use of the roots and flowers as medicinals, woody stems for slats in house construction, and supple stems for "temporary baskets" (Neal 1965:553).

Family SOLANACEAE

Solanum sp.

Several probable *Solanum* seeds were recovered; many seeds of this family are morphologically similar. Of those species examined, however, the archaeological materials compare most closely with *S. nigrum* L. *(popolo). S. nigrum* is a herbaceous weed frequently associated with cultivation. The taxon may have been inadvertantly introduced into the Hawaiian Islands by Polynesian colonizers on rootstocks such as taro *(Colocasia esculenta* [L.] Schott). Alternatively, the plant could have been a purposive introduction given its ethnographically recorded medicinal properties (Neal 1965:744) and its edible berries and leaves (Hillebrand 1981:307; Buck 1964:6; Parham 1943).

Family STERCULIACEAE

Waltheria cf. *americana* L. *(hi'aloa, 'uhaloa)*

Two native Hawaiian species are recorded for this genus but one is rare *(W. pyrolaefolia* Gray) and its status as a distinct species is debatable (C. Lamoureux, pers. comm., 1982). *W. americana* is a perennial which occurs in arid and disturbed contexts, generally at lower elevations. The plant has been ethnographically recorded as a medicinal (Neal 1965:575; Territorial Board of Health 1922).

EXPECTATIONS AND LIMITATIONS OF THE STUDY

A Model of Temporal Change in the Valley Vegetation

A simple model derived from the ecological literature (Mueller-Dombois and Ellenberg 1974; May 1978) predicts the sequence of vegetation changes which would accompany the gradual conversion of a previously unoccupied Hawaiian valley into a productive agricultural system.

Archaeological evidence suggests that initial use of the Anahulu rockshelters was temporary and intermittent (chapter 2, this volume). During this early period, some weedy lowland taxa, particularly those adapted to animal dispersal, might first appear in the rockshelter deposits. Early activities in the middle valley might also have included the creation of small "forest gardens" of the kind described in the ethnographic literature (Handy and Handy 1972) for famine relief and for use during forays into the island interior. The impact of these activities on the native vegetation, however, would have been quite localized and would be difficult to identify archaeologically.

Larger scale agricultural endeavors should be more clearly recognizable in the archaeobotanical record. Clearance of native vegetation would result in a decrease in the abundance of native taxa. The richness values (i.e., number of taxa) for native species might also decline as rarer forest elements were removed. Concomitantly, weedy taxa would increase in both abundance and richness. These patterns would be expected to occur contemporaneously in a number of sites.

If shifting cultivation were practiced in the valley, successional sequences might be observable. The succession literature (e.g., Tilman 1984:213-300; May 1978; Smathers and Mueller-Dombois 1974) predicts a pattern of few weedy taxa early in a succession sequence, followed by increasing species enrichment and increasing arboreal elements. Given that shifting cultivation follows a rotational sequence of cropping and fallow, the valley vegetation would consist of a mosaic of different successional progressions at any given time. This latter pattern might not be archaeologically detectable, however, given the resolution of current dating techniques.

A shift to permanent agriculture, specifically irrigated field systems, would be reflected in a further reduction, or possibly the disappearance, of native taxa from the archaeobotanical record. The development of permanent irrigated fields might be accompanied by the establishment of a new and distinctive suite of hydrophilic weeds.

Using the results from the three column samples, the Anahulu archaeobotanical assemblages were compared with the sequence of vegetation changes outlined above. Deriving from two separate shelters, the columns potentially offered two independent monitors of major vegetation changes within the valley over a period of roughly 500 years (chapter 2, this volume). The earliest date, A.D. 1280-1430 (corrected), derives from the basal ash lens of the Ke'eke'e Nui shelter. A second sample from the same shelter indicates continued use into the period A.D. 1500 to 1700, while a third sample is indistinguishable from modern. In the Kuolulo shelter a radiocarbon sample from near the base of Column C provided a corrected date of A.D. 1412-1465, indicating that this column represents paleoenvironmental conditions which postcede initial middle valley use. Similarly, a Ke'eke'e Iki shelter sample yielded a date in the A.D. 1600-1700 range; thus Column B also reflects valley conditions after several hundred years of occupation and probably after the establishment of shifting cultivation. Dates from the pondfield features (Kirch and Spriggs, in press), in combination with the ethnohistoric literature, indicate that these irrigated systems were not established until the historic period.

Cultural Plant Utilization

Hearth and oven features are likely traps for discard materials from food processing, or for food remains themselves. In the Anahulu case, such features were regarded as possible sources of information on cultigens being grown in the vally, or on the exploitation of native plant resources. Also of interest was a pattern of taxonomic richness identified in an earlier analysis of Kaho'olawe Island archaeobotanical materials (Allen 1984b). On Kaho'olawe, samples from large earth ovens *(imu)* tended to have richer seed assemblages than those from small hearths. Allen suggested this difference might be related to feature functions, specifically the use of plant materials in the oven steaming process. The small hearths on Kaho'olawe, on the other hand, were comparatively richer in bone and shell but contained few seeds.

Consideration of Sample Size

The measurement of relative abundances and taxonomic richness are critical to the monitoring of vegetation trends and analysis of other archaeobotanical patterns. These measures have recently received considerable attention in the zooarchaeological literature (e.g., Grayson 1979, 1981, 1984), but their importance for archaeobotanical studies has been neglected. The statistical relationships between these two measures (relative abundance and richness) and sample size (number of identified specimens or NISP) are considered here in some detail before further interpretation of the Anahulu evidence.

The absolute number of any one taxon in the Anahulu assemblages is generally so small that a consideration of relative abundance is not meaningful. As discussed below, this is a clear indication that larger samples must be processed in the future. The exception is *Chenopodium,* which occurs in all three column samples and in six out of seven features. As a potential indicator of disturbance, temporal and spatial variation in the relative abundance of this taxon relative to others could be ecologically significant. Alternatively, variability in *Chenopodium* abundances might be nothing more than a reflection of variability in NISP. Looking at Column C, the column with the greatest temporal duration and the largest NISP values, Spearman's rho rank-order correlation coefficient indicates that NISP and the relative abundance of *Chenopodium* are not significantly correlated (rs=-.198, p=.517). A similar situation holds for Column A (rs=.477, p=.195). When the levels with very small NISP values are removed (cf. Grayson 1984:121), the correlations are further reduced (Column C: rs=-.078, p=.809; Column A: rs=.378, p=.403). Column B, unfortunately, has such small NISP values that the relative abundance of *Chenopodium* in that column can not be meaningfully evaluated. Thus, changes in the relative abundance of *Chenopodium* may signify important ecological changes (see discussion in next section).

Changing taxonomic richness (NTAXA) values was a second parameter of interest here. Grayson (1984:131-67) also discusses the potential statistical relationship between NISP and NTAXA. As with relative abundance, if variation in NTAXA cannot be deomonstrated to be independent from NISP, then cultural or ecological interpretations of variability in NTAXA are of questionable validity. For Column C, the correlation between log10 NTAXA and log10 NISP is not highly significant (r=.554, p=.025), and the correlation is greatly reduced when level 3 with its small NISP value is removed (r=.186, p= .281). Conversely, log10 NTAXA and log10 NISP *are* highly correlated in the case of Colum A (r=.8095, p=.004), but the correlation is significantly reduced when the strata with small NISP values are removed (r=.6273, p=.048). When the feature samples are considered as a group, the correlation between NISP and NTAXA is even stronger (r=.945, p>.001), with NISP accounting for over 87% of the variation in NTAXA. The small number of cases, however, makes interpretation of this correlation somewhat problematic. The foregoing suggests that only in the case of Column C can we discuss changes in richness values and be confident that these changes are independent of changing sample sizes.

In this study, sample size was also considered in terms of the volume of sediment processed. This parameter was of interest from two perspectives. First, in a given environment can we predict the volume of sediment needed so as to avoid sample size problems? Second, does the relative homogeneity (or heterogeneity) of seed densities across samples inform on accumulation mechanisms, including those of a cultural nature.

The volumes of sediment processed from the column samples were statistically compared with NTAXA and NISP recovered (see fig. 6.2). NISP is moderately correlated with sample volume (r=.648, p>.001), with the latter accounting for 40% of the variation in NISP. This suggests that seed densities are fairly homogeneous within the deposits. Independent analysis of sedimentological characters (chapter 3, this volume) further suggests continuous, even sediment accumulation of a relatively unchanging nature throughout the occupation of sites D6-36 and -60. Thus, the seeds present may represent natural seed "rain" rather than cultural activities. Methodologically, the results suggest that under similar conditions of constant sediment deposition it may be possible to predict adequate sample volumes for processing after some initial trial runs. For NTAXA, there is a low correlation with sample volume (r=.435, p<.01), suggesting that other factors are more important in determining NTAXA.

In the case of the feature samples, sample volume was a constant. Nevertheless, the feature samples were quite variable in NISP and NTAXA, even more so than the colulmn samples which were derived from different sample volumes. This suggests that other factors are controlling NISP and NTAXA. Potential sources of variation include functional differences between the features or variable preservation contexts (see further discussion below). The evidence suggests that assessing representative sample volumes for processing from features may be more problematic and analysis of the entire feature rather than samples may be necessary.

The Role of Accumulation Mechanisms

Knowledge of the accumulation mechanisms involved in deposit formation is important in terms of: (1) understanding the quantitative relationship between the recovered sample and the target population (usually the environment and/or subsistence); and (2) identifying the agent responsible for the materials deposited. Figure 6.3 models the more important factors which may intervene between two common target variables and the archaeobotanical sample (additional factors may enter during the analysis itself). The left hand side of the diagram emphasizes cultural biases, while the right hand side outlines natural factors. At each step these biases alter the quantitative relationship between the target population and the archaeological sample. Species may be differentially affected depending on their economic importance or associations with economic plants, natural modes of dispersal, morphological characteristics relevant to physical transport, and physio-chemical characters which affect preservation potential. Furthermore, differential seed production may skew the record in favor of heavy producers as is the case with pollen (Davis 1963).

Given that these mechanisms are difficult to reliably identify, the relationship between the quantitative structure of the target variables and the sample remains imprecise (see Grayson 1981). For example, variability in natural seed abundances is difficult to impossible to separate from that which might reflect changing ecological conditions or cultural factors. Grayson (1981) suggests that for single site assemblages, taxa should be treated as attributes and presence/absence analysis used. While presence/absence studies are not without inherent hazards, they employ fewer assumptions than techniques based on taxonomic abundances. If ordinal or greater level of measurement is desired, then it is necessary to obtain parallel sequences of changing taxonomic frequencies from other localities within the same region (cf. Grayson 1984). Only then can the vagaries of preservation and deposition be discounted.

A second critical factor in interpretation of archaeobotanical assemblages lies in discerning between natural and cultural depositional agents. Many seeds may be incorporated into archaeological sediments through natural seed "rain." The depositional agent(s) responsible for small seeds, such as those considered here, would be the most difficult to identify. Furthermore, even if a cultural agent can be demonstrated, it is quite difficult to determine what the economic importance of a given taxa might be on archaeological criteria alone. This issue is considered in more detail below.

DISCUSSION OF THE ANAHULU ASSEMBLAGE

Vegetation Change

The sequence of vegetation changes modeled above predicts a trend of decreasing abundance and richness values for native taxa, and increasing values for weedy and exotic taxa through time. Unfortunately, the Anahulu seeds generally occur in such small numbers that changing abundances cannot be assessed. Furthermore, no native taxa which might represent natural forest conditions were identified. Significantly, the basal ash feature in Site D6-58 (Sample F) has a high richness value and some (or all) of the unidentified taxa may be native forest elements. However, even in this basal feature, a *Lagenaria* seed and the weedy *Solanum* were recovered, suggesting the possibility of agricultural activities within the middle valley at this time (A.D. 1280-1430).

Turning to the chronologically later column samples, weedy taxa are again present from the earliest levels. Taxa which are thought to represent disturbance of the basis of their ecological habits include *Solanum, Sida,* and *Waltheria*. Although these are native genera, they would not normally occur within a mature mesic forest. They might, however, grow in forest openings or on the exposed, rocky valley walls. These three taxa are present throughout the column samples. Unfortunately, their numbers are too small to evaluate changing frequencies and no trends are evident on nominal assessment either.

Aleurites, often associated with native Hawaiian activities and environmental modification, is also quite common in the samples. It appears throughout Column

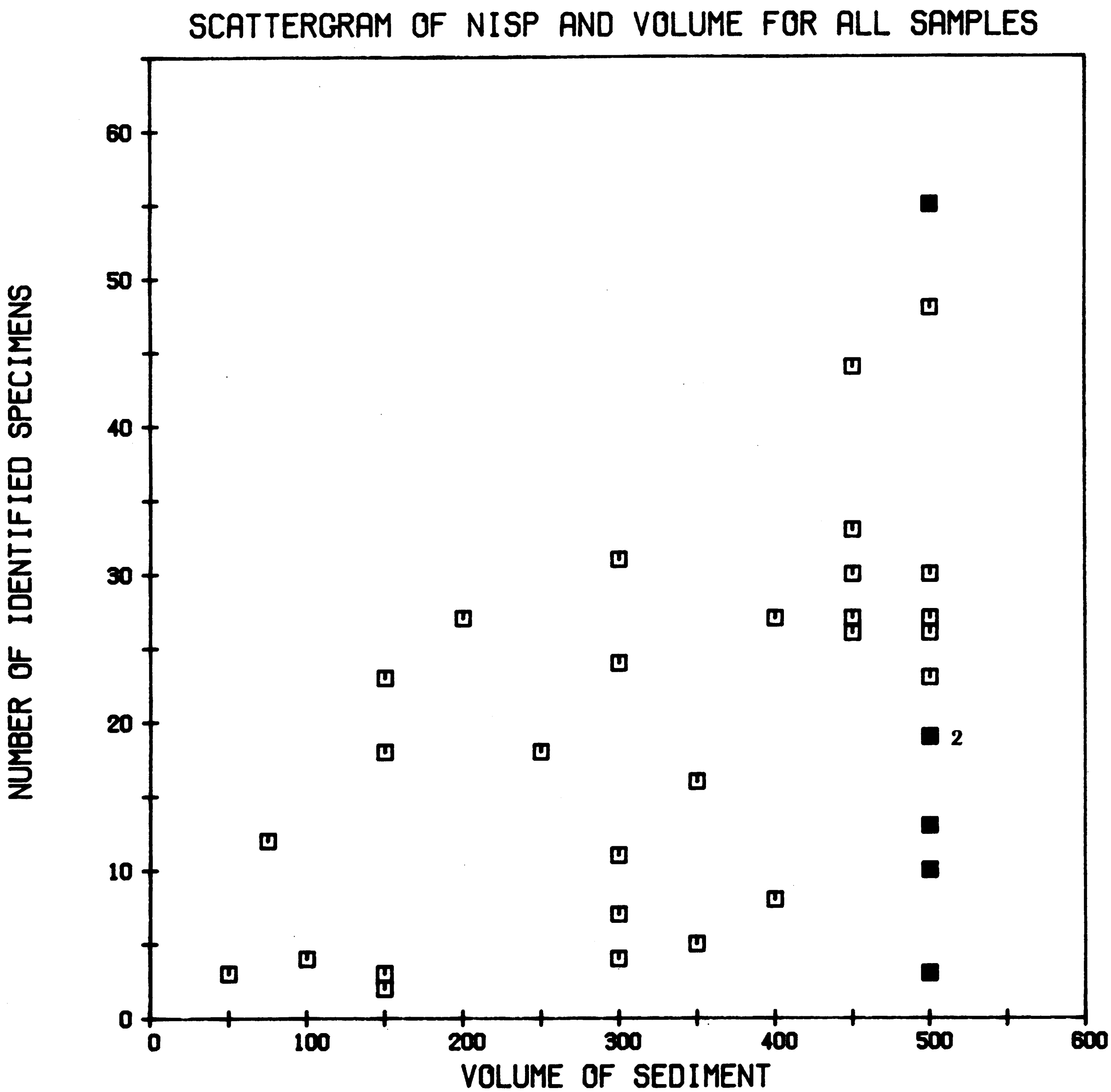

Figure 6.2. Scattergram of the number of identified specimens (NISP) and volume for all samples.

C, sporadically within Column A, but is absent from Column B. *Aleurites* nuts could have been brought to the shelters for lighting, however, its presence in the wood-charcoal samples suggests it was growing in the valley (see chapter 7, this volume).

By far the most abundant taxon is *Chenopodium*. When the taxa are rank-ordered, *Chenopodium* assumes a clear position of dominance in 28 out of the 29 column samples which contained carbonized seeds. *Chenopodium oahuense* is an endemic shrub which *could* have formed part of the natural vegetation, although on the basis of its present distributions it would not be expected to occur under mesic forest settings. The proclivity for disturbance conditions of both the native Hawaiian species (Environmental Impact Study Corp. 1977:17-8), and of the family in general (Asch and Asch 1977:6), led Allen (1983b) to suggest that it may have been a common agricultural fallow component in prehistoric Hawaiian settings. In the Anahulu assemblages, *Chenopodium* ocurs in higher frequencies in the earlier levels of Column C and probably reflects human disturbance. It is also

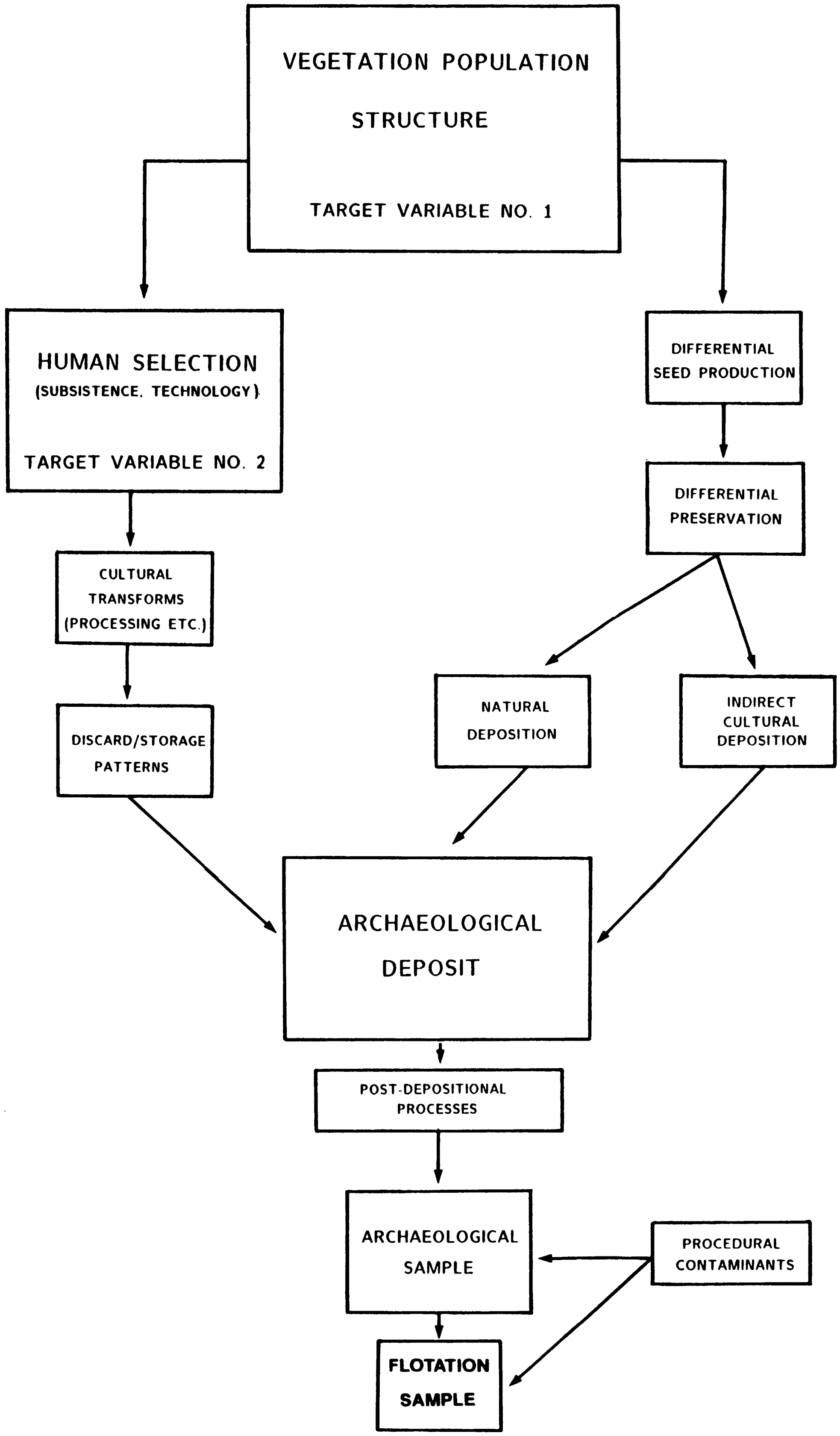

Figure 6.3. Factors intervening between archaeological sample and target variables.

interesting that the relative abundances of *Chenopodium* and taxonomic richness are negatively correlated (rs=-.901, p=.001), suggesting that as the number of other taxa increased, *Chenopodium* growth was suppresssed (fig. 6.4). One explanation is that early disturbance was limited in scale. The subsequent increases in the number of other weeds would thus reflect a change in the scale and intensity of human disturbance, i.e., an expansion of agricultural activities.

In general, these samples suggest disturbed conditions throughout the time period represented in the columns and features. When the archaeobotanical assemblages alone are considered, the most parsimonious interpretation is that the disturbance was agricultural in nature. Alternatively, the samples might reflect disturbance in the immediate environment of the shelters.

The wood-charcoal samples from Site D6-60 Column C (chapter 7, this volume), also suggest a human-modified environment in the vicinity of the shelter dating to the earliest sample levels. Wood-charcoal of two Polynesian introductions, *Eugenia malaccensis* (mountain apple) and *Artrocarpus altilis*, (breadfruit) occurs throughout the column. Although

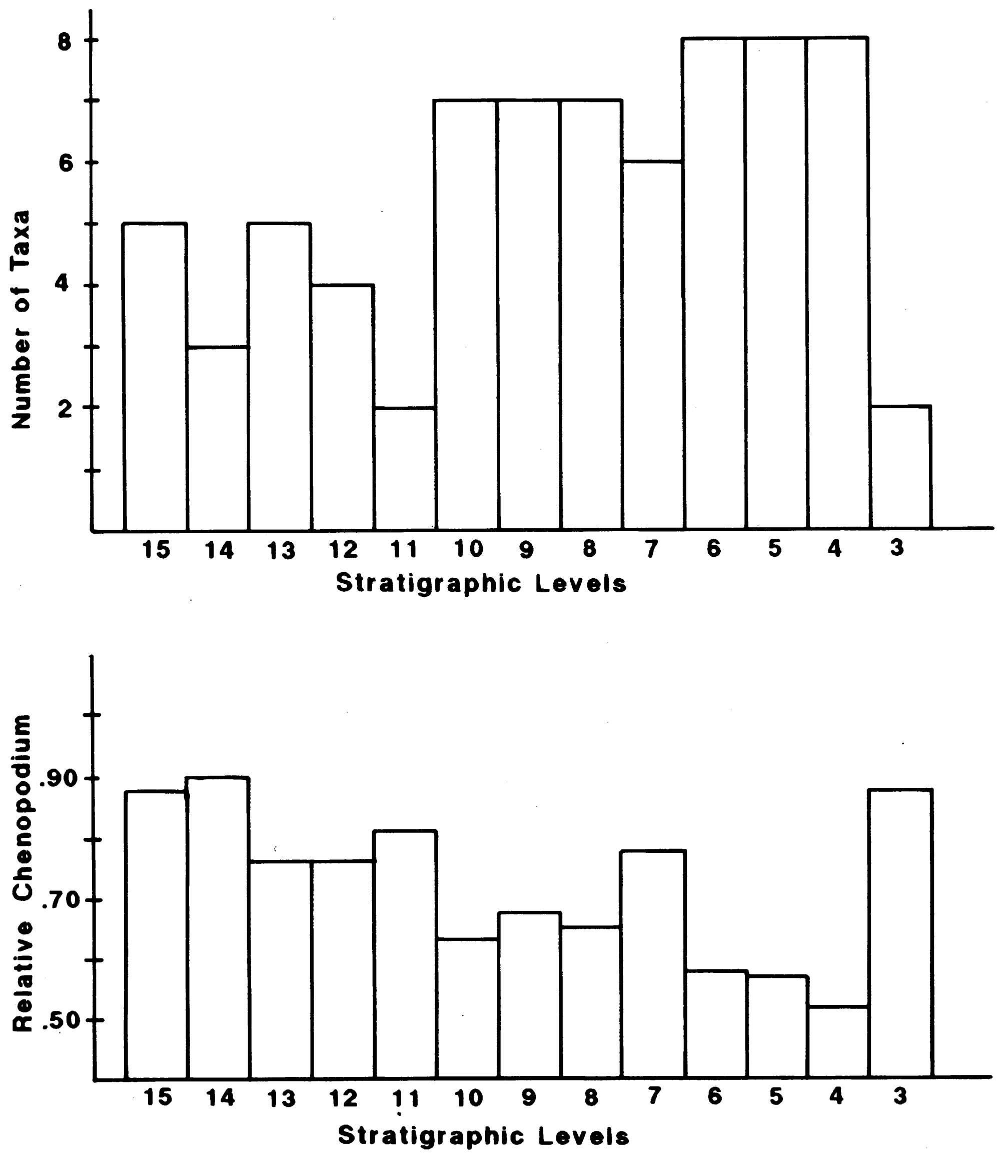

Figure 6.4. Comparison of NISP, NTAXA, and relative abundance of *Chenopodium* by stratigraphic level for Column C.

elements of the native forest are represented, there are no distinct trends in the taxonomic composition of the samples.

In contrast, the land snail assemblages show clear trends from completely native assemblages, to those including a Polynesian agricultural associate, to those with historic European introductions (chapter 4, this volume). The appearance of anthropophilic landsnails in levels 11/12 of Column C correlates with the increase in taxonomic richness of seeds noted above. This provides independent evidence for an increase in the scale and intensity of agricultural activities later in the sequence.

The possibility of a new suite of hydrophilic weeds showing up in conjunction with the establishment of pondfield systems in the early historic period was noted above. No such changes, however, were noted.

Subsistence and Plant Utilization

Archaeobotanical remains of two traditional cultigens were recovered: *Colocasia* (taro) and *Lagenaria* (gourd). Both are poorly represented in the analyzed samples and their presence may, but does not necessarily, indicate local cultivation. Several European-introduced cultigens including rice, beans, tobacco, figs, various citrus fruits and coffee are known to have been grown in the valley since the mid-1800s. Significantly, none are represented in these rockshelter samples and hence the seed data coroborates other evidence which suggests minimal use of rockshelters during the historic period.

The discussion of weedy taxa above assumes that these seeds were part of the natural seed "rain." Alternatively, they may represent plants directly utilized. Notably, the Anahulu seed assemblage is similar in species composition to those recorded for other Hawaiian localities (table 6.7). *Chenopodium* and *Waltheria* are the most common taxa, occurring in seven out of eight assemblages. The archaeological contexts represented here include a subalpine rockshelter at 3780 m elevation (Mauna Kea), coastal localities (Kalahuipua'a, Kaunakakai, Kaho'olawe), xeric leeward inland areas (Kawela, Kuakini, Waimea-Kawaihae, Kaho'olawe), and the mesic middle Anahulu Valley. The recurrence of these same taxa in several sites and across varied habitats is strong evidence that: (1) they are part of an anthropogenic plant community which accompanied a variety of Hawaiian activities; or alternatively, (2) they are important components of prehistoric Hawaiian ethnobotany, dietary, medicinal, or otherwise. At present there are no unambiguous criteria for separating direct plant use from natural seed "rain" of the surrounding vegetation. While ethnographically documented cultigens are generally assumed to reflect direct use, such a claim is more difficult to make for small seeds of weedy and/or anthropophilic plants.

In discerning between these two alternatives, contextual information will be important and sedimentary analysis in particular may be critical. One promising line of inquiry is grain size analysis, a technique used in determining sediment source, mode, and agent of deposition. In conjunction with an archaeobotanical study of Eastern Woodland earth ovens, morphologically and functionally similar to Hawaiian oven features, Whittaker (1985) analyzed the grain size characteristics of her sample matrices. The results provided strong evidence that the seeds recovered were deposited during post-use infilling and were not directly associated with feature use.

Variability in Feature Samples

The highly variable NISP and NTAXA values for the feature samples have already been commented on above. Keeping in mind that this variability in NTAXA has been shown to be highly correlaed with NISP, the following patterns were observed across feature types. Sample F (Unit O11, Feature 9), an ash deposit, has the highest species richness with 12 taxa. As noted earlier, this sample may reflect the pre-occupation vegetation of the area. Sample G (Unit K10, Fe 1), a small scoop hearth, also has a high species richness with at least 10 taxa. Sample H (Unit K10, Fe 5), an earth oven, contained only *Chenopodium* seeds. Samples A and B from a single earth oven (Unit O11, Fe 6) are both poor in taxa. The remaining samples contained small numbers of seeds and were taxonomically poor. These include Sample D (a small lens) and Sample E (from the upper part of Ke'eke'e Nui ash deposit). In sum, no distinctive patterns emerge on the basis of interpreted functional differences, but the number of features considered here is quite small. In comparison with the Kaho'olawe samples, the relative taxonomic richness values for ovens versus small hearths are reversed.

CONCLUSIONS

This analysis of the Anahulu archaeobotanical assemblages raises several concerns for future work. First, larger seed assemblages will be necessary if the problems of sample size effects are to be averted. This preliminary assessment suggests that increasing the volume of sediment to be processed will probably be necessary (seed density will undoubtedly vary with the particular environment), but a prescribed sample amount will be especially difficult to predict for cultural features.

TABLE 6.7

COMPARISON OF SEED ASSEMBLAGES FROM VARIOUS HAWAIIAN ARCHAEOLOGICAL LOCALITIES

TAXA	ARCHAEOLOGICAL LOCALITIES[a] KALA	KK	KAW	KLWE	KUA	WK	ANA	MK
Cyperaceae								
Eleocharis	—	—	—	—	—	—	+	—
Gramineae								
Eragrostis	—	—	—	+	+	—	+	—
Chenopodiaceae								
Chenopodium	+	+	—	+	+	+	+	+
Convolvulaceae	+	—	+	+	—	+	+	+
Cucurbitaceae								
Lagenaria	+	—	+	+	+	+	+	—
Sicyos	—	—	—	+	—	—	+	—
Euphorbiaceae								
Aleurites	+	—	+	+	+	+	+	+
Leguminosae	—	+	—	+	+	—	+	—
Malvaceae								
Sida	—	—	—	+	+	+	+	—
Solanaceae								
Solanum	—	—	—	+	+	+	+	—
Sterculiaceae								
Waltheria	+	+	—	+	+	+	+	—
Total No. of Taxa	5	3	3	10	8	7	11	3

a Locality References:

KALA: Kalahuipua'a, Hawai'i (Allen 1983a)
KK: Kaunakakai, Moloka'i (Allen 1982a)
KLWE: Kaho'olawe Island (Allen 1983b; 1984b)
KAW: Kawela, Moloka'i (Allen 1982b)
WK: Waimea-Kawaihae Road Corridor, Hawai'i (Allen 1983c)
KUA: Kuakini Road Corridor, Hawai'i (Allen 1984c)
ANA: Anahulu, O'ahu (this volume)
MK: Mauna Kea Adze Quarry, Hawai'i (Allen 1981)

Second, the mechanisms involved in the accumulation of archaeobotanical assemblages must be considered. Sedimentological studies of grain size may be particularly helpful in assessing whether the seeds within a particular feature are related to feature function or post-depositional infilling. Similarly, identification of the mode(s) and agent(s) of deposition in deep deposits, where column samples might be obtained, can be useful. Given the problems of differing accumulation mechanisms, repetitive patterns from a series of localities are needed before ordinal (or greater) level of measurement can be achieved.

Third, if temporal trends are of interest, continuous column samples, rather than bulk feature samples, will be the most useful. Comparison of land snails, wood-charcoal, and archaeobotanical assemblages from the same columns, where sediment accumulation mechanisms may be reasonably comparable and can be evaluated, will allow for more fine-grained paleoenvironmental reconstructions.

Fourth, the value of an interdisciplinary approach has again been demonstrated (see also Clark and Kirch 1983; Schilt 1984). The addition of sedimentological studies holds particular promise. The integration of varied lines of evidence in this case was greatly facilitated by Kirch's use of a column sampling design wherein a series of samples were drawn from a single deposit of significant temporal duration.

Finally, and most importantly, if we are to understand the significance of archaeobotanical assemblages in either cultural or ecological terms, field sampling will need to proceed with particular problem orientations in mind. In order to address questions of the relationship between plant remains and feature functions, for example, feature types will need to be rigorously defined and a sufficient number of features from a given locality sampled. If we are to understand plant utilization in cultural contexts then it will be necessary to control for natural seed "rain" under similar sedimentological conditions—a problem possibly remedied by control samples from non-cultural contexts in adjacent localities. The presence of botanical materials in Hawaiian archaeological sediments has now been amply demonstrated and some interesting ecological and ethnobotanical issues raised. In the future, field sampling designs explicitly framed around paleobotanical concerns should greatly enhance our understanding of the recovered archaeobotanical material.

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REFERENCES CITED

Allen, M.S. 1981. "An analysis of the Mauna Kea adze quarry archaeobotanical assemblage." M.A. thesis, University of Hawaii. Honolulu.

_____. 1982a. Report on the archaeobotanical materials from Kaunakakai, Molokai. In K. Shun, *Archaeological Reconnaissance Survey and Test Excavations of the Wastewater Treatment Facility Area, Kaunakakai, Molokai*, Appendix, pp. 30-3. Department of Anthropology, Bishop Museum. Submitted to CH2M Hill. Maui, Hawaii.

_____. 1982b. Preliminary report on archaeobotanical materials of Kawela T113 rockshelter. Ms. on file at the Department of Anthropology, Bishop Museum. Honolulu.

_____. 1983a. Analysis of plant remains from 1982 excavations at Site 342. In R.J. Hommon, *Archaeological Data Recovery at Site 342 Kalahuipua'a, Hawaii*, pp. 52-62. Science Management, Inc. Submitted to Mauna Lani Resort, Inc. Hawaii.

_____. 1983b. Report on the palaeoethnobotanical remains recovered from Kaho'olawe Island. In R.J. Hommon, *Kahoolawe Archaeological Excavations 1981*, Appendix B, pp. 168-88. Prepared by Science Management, Inc. for U.S. Department of the Navy, Pacific Division, Naval Facilities Engineering Command. Pearl Harbor.

_____. 1983c. Analysis of archaeobotanical material. In J.T. Clark and P.V. Kirch, eds., *Archaeological Investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawaii*, Report 14, pp. 384-400. Anthropology Dept. Report Series 83-1, Bishop Museum. Honolulu.

_____. 1984a. A review of archaeology and paleoethnobotany in Hawaii. *Hawaiian Archaeology* 1:19-30.

_____. 1984b. Kaho'olawe archaeobotanical materials. Manuscript on file with Paul H. Rosendahl, Inc., Hilo, Hawai'i and with author.

_____. 1984c. Analysis of selected paleoethnobotanical materials. In R. Schilt, *Subsistence and Conflict in Kona, Hawaii*, pp. 377-83. Anthropology Dept. Report Series 84-1, B.P. Bishop Museum. Honolulu.

Asch, D.L., and N.B. Asch. 1977. Chenopod as cultigen: A re-evaluation of some prehistoric collections from eastern North America. *Mid-Continental Journal of Archaeology* 2:3-45.

Buck, P.J. (Te Rangi Hiroa). 1964. *Arts and Crafts of Hawaii*. B.P. Bishop Museum Special Publication 45. Honolulu.

Clark, J.T., and P.V. Kirch. 1983. *Archaeological investigations of the Mudland-Waimea-Kawaihae Road Corridor, Island of Hawai'i: An Interdisciplinary Study of an Environmental Transect*. Anthropology Dept. Report Series 83-1, B.P. Bishop Museum. Honolulu.

Davis, M. 1963. On the theory of pollen analysis. *American Journal of Science* 261:897-912.

Environmental Impact Study Corp. 1977. A report on the Botanical Survey for the Installation Environmental Impact Statement, U.S. Army Support Command, Hawaii, Pohakuloa Section. Prepared for the Department of Army Corp of Engineers. Honolulu.

Grayson, D.K. 1979. On the quantification of vertebrate archaeofaunas. In M.B. Schiffer, ed., *Advances in Archaeological Method and Theory*, vol. 2:199-237. Academic Press. New York.

_____. 1981. A critical view of the use of archaeological vertebrates in paleoenvironmental reconstruction. *Journal of Ethnobiology* 1:28-38.

_____. 1984. *Quantitative Zooarchaeology*. Academic Press. New York.

Handy, E.S.C., and E.G. Handy. 1972. *Native Planters in Old Hawaii*. B.P. Bishop Museum Bulletin 233.

Hart, C., and M.C. Neal. 1940. The Plant Ecology of Mauna Kea, Hawaii. *Ecology* 21:237-66.

Hillebrand, W.I. 1981. *Flora of the Hawaiian Islands.* Lubrecht and Cramer. Monticello. (Facsimile of the 1888 edition).

Hitchcock, A.S. 1974. *The Grasses of Hawaii.* B.P. Bishop Museum Memoir Vol. VIII, No. 3. (Reprint of the 1922 edition).

Hommon, R.J. 1983. *Kaho'olawe Archaeological Excavations 1981.* Prepared by Science Management, Inc. for the U.S. Department of the Navy, Pacific Division, Naval Facilities Engineering Command. Pearl Harbor.

Hosaka, E.V. 1937. Ecological and floristic studies in Kipapa Gulch, Oahu. *B.P. Bishop Museum Occasional Papers* XIII (17):175-232.

Keepax, C. 1977. Contamination of archaeological deposits by seeds of modern origin with particular reference to the use of flotation machines. *Journal of Archaeological Science* 4:221-29.

Kirch, P.V. 1979. *Late Prehistoric and Early Historic Settlement-Subsistence Systems in the Anahulu Valley, O'ahu.* Anthropology Dept. Report Series 79-2, B.P. Bishop Museum. Honolulu.

Kirch, P.V., and M.J.T. Spriggs. in press. A radiocarbon chronology for the upper Anahulu Valley, O'ahu. *Hawaiian Archaeology.*

Lopinot, N.H., and D.E. Brussell. 1982. Assessing uncarbonized seeds from open-air sites in mesic environments: an example from southern Illinois. *Journal of Archaeological Science* 9:95-108.

McEldowney, H. 1983. A description of major vegetation patterns in the Waimea-Kawaihae region during the early historic period. In J.T Clark and P.V.Kirch, eds. *Archaeological Investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawaii,* Report 16, pp. 407-48. Anthropology Dept. Report Series 83-1, Bishop Museum. Honolulu.

_____.1976. *Archaeological and Historical Literature Search and Research Design. Lava Flow Control Study, Hilo, Hawai'i.* Prepared for U.S. Army Engineer Div., Pacific Ocean, Honolulu by Dept. of Anthropology, B.P. Bishop Museum.

Malo, D. 1951. *Hawaiian Antiquities.* B.P. Bishop Museum Special Publication 2. Honolulu.

May, R.M. 1978. The evolution of ecological systems. *Scientific American* 239(3):118-33.

Minnis, P.E. 1981. Seeds in archaeological sites: sources and some interpretive problems. *American Antiquity* 46:143-52.

Mueller-Dombois, D., and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology.* John Wiley and Sons. New York.

Murakami, G. 1983a. Identification of charcoal from Kaho'olawe archaeological sites. In R.J. Hommon, *Kahoolawe Archaeological Excavations 1981,* Appendix b, pp. 168-88. Prepared by Science Management, Inc. for U.S. Department of the Navy, Pacific Division, Naval Facilities Engineering Command. Pearl Harbor.

_____. 1983b. Analysis of charcoal from archaeological contexts. In J.T. Clark and P.V. Kirch, eds., *Archaeological Investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawaii,* Report 20, pp. 514-513. Anthropology Dept. Report Series 83-1, Bishop Museum. Honolulu.

_____. 1983c. Identification of charcoal from Kaho'olawe. Manuscript on file with Paul H. Rosendahl, Inc., Hilo, Hawai'i and with author.

Neal, M.C. 1965. *In Gardens of Hawaii.* B.P. Bishop Museum Special Publication 50. Honolulu.

Parham, H.B.R. 1943. *Fiji Native Plants.* Polynesian Society Memoir no. 16.

Purseglove, J.W. 1968. *Tropical Crops: Dicotyledons.* Longman. London.

Schilt, R. 1984. *Subsistence and Conflict in Kona, Hawai'i.* Anthropology Dept. Report Series 84-1, B.P. Bishop Museum. Honolulu.

Selling, O.H. 1948. *Studies in Hawaiian Pollen Statistics. Part III.* B.P. Bishop Museum Special Publication 39. Honolulu.

Smathers, G.A., and D. Mueller-Dombois. 1974. *Invasion and Recovery of Vegetation After a Volcanic Eruption in Hawaii.* National Park Service Scientific Monograph Series No. 5.

Stemmermann, L. 1981. *A Guide to Pacific Wetland Plants.* U.S. Army Corps of Engineers, Honolulu.

St. John, H. 1973. *A List of Flowering Plants in Hawaii.* Pacific Tropical Botanical Garden Memoir 1. Lawai, Hawaii.

_____. 1976. New species of Hawaiian plants collected by David Nelson in 1779. *Pacific Science* 30:7-44.

Territorial Board of Health. 1922. *Hawaiian Herbs of Medicinal Value.* Charles E. Tuttle Co. Rutland (Facsimile reprint).

Tilman, D. 1988. *Plant Strategies and the Dynamics and Structure of Plant Communities.* Princeton Univ. Press. Princeton.

Watson, P.J. 1976. In pursuit of prehistoric subsistence: a comparative account of some contemporary flotation techniques. *Midcontinental Journal of Archaeology* 1:77-100.

Whittaker, F. 1985. Archaeobotany from an Evolutionary Perspective. Paper presented at the 50th Annual Meeting of the Society for American Archaeology. Denver.

CHAPTER SEVEN

IDENTIFICATION OF CHARCOAL FROM KUOLULO ROCKSHELTER

by Gail M. Murakami

IDENTIFICATION OF CHARCOAL from archaeological sites can add valuable information toward our understanding of the life of the ancient Hawaiians (Murakami 1983a,b). The vegetation changes which may be indicators of their relationship with the environment are often recorded in the charcoal found at such sites.

The present study utilized charcoal obtained from an 80 cm column in Site D6-60 (Unit D20) in the Anahulu Valley. Analysis of this column provided an opportunity to test whether a chronology of cultural activity and vegetation change could be established at the site.

METHODS

The 80 cm deep column from unit D20 was collected in 5 cm layers. Each charcoal sample was sorted into groups based on the anatomy of the freshly fractured transverse section as seen under a 40X magnification dissecting microscope. After all the samples had been sorted in this manner, the groups from all samples were resorted into larger groups or types. Thus the macroscopic characters were used to determine the distribution of each type. Representatives of each type, occurring in the combined levels of 0-20, 30-40, 50-60, and 75-80 cm were then selected for embedding in Spurr's epoxy resin (Spurr 1969) in a procedure modified from Smith and Gannon (1973).

Thin sections of the plastic embedded charcoal were made with a steel knife on a sliding microtome. Permanent microscope slides of the sections were prepared.

Identifications were made by comparing the thin sections of the charcoal with those of known woods. This reference material is part of a study on the anatomy of Hawaiian woods. Permission for its use was obtained from Dr. Charles Lamoureux of the Botany Department at the University of Hawaii. The Botany Department also provided the facilities for processing the charcoal.

RESULTS

The fifteen 5 cm levels in the column were sorted into 199 groups and resorted into 56 types. Fifty-seven charcoal pieces from the 31 types which occurred in the combined levels 30-40 and 50-60 cm as well as all representatives in the 0-20 and 75-80 cm levels were embedded and sectioned.

Thirteen taxa were identified (table 7.1) and are described in the review which follows. The distribution of these taxa is given in table 7.2. The unknown taxa distribution is summarized in table 7.3.

TABLE 7.1

IDENTIFIED TAXA

SCIENTIFIC NAME	COMMON NAME	ORIGIN
Amaranthaceae		
Nototrichium sp.	*kulu'i*	E
Araliaceae		
Reynoldsia sp.	*'ohe*	E
Celastraceae		
Perrottetia sandwicense Gray	*olomea*	E
Chenopodiaceae		
Chenopodium oahuense (Meyen) Aellen	*'aheahea, 'aweoweo*	E
Euphorbiaceae		
Euphorbia spp.	*'akoko*	(E)
Leguminosae		
Acacia koa Gray	*koa*	E
Moraceae		
Artocarpus altilis (Parkins. ex Z) Fosb.	*'ulu*, (breadfruit)	P
Myrtaceae		
Eugenia malaccensis L.	*'ohi'a-'ai*	P
Oleaceae		
Osmanthus sandwicensis (Gray) Knobl.	*olopua*	E
Rubiaceae		
Canthium odoratum (Forst. f.) Seem.	*alahe'e*	I
Santalaceae		
Santalum sp.	*'ili-ahi*, (sandalwood)	E
Solonaceae		
Nothocestrum sp.	*'aiea*	E
Urticaceae		
Pipturus sp.	*mamaki*	(E)

Nomenclature follows St. John (1973). For each taxon the following information is provided:

1. Scientific name.
2. Common English name or Hawaiian name, when known.
3. Origin. The following symbols are used:
   E = endemic to the Hawaiian Islands, i.e., occurring nowhere else in the world.
   I = indigenous, i.e., native to the Hawaiian Islands but also occurring naturally (without the aid of man) elsewhere.
   X = exotic, i.e., plants of accidental or deliberate introduction after the Western discovery of the islands (post-1778).
   P = Polynesian introduction, plants brought by the Polynesian immigrants prior to Captain Cook's discovery of the islands.
   (E) = probably endemic species although genus not restricted to the Hawaiian Islands.

TABLE 7.2

DISTRIBUTION OF IDENTIFIED TAXA EXPRESSED AS PERCENT OF SAMPLE WEIGHT

TAXON	Column depth in cm													
	0-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	75-80
Acacia koa										12				
Artocarpus altilis	11*		3	2		5	x **	3	1			2		
Canthium odoratum										2			14	
Chenopodium oahuense			2		2	3	6		3	2	4	2		
Eugenia malaccensis			5	8	6	2	6	14	8	14	6	3		4
Euphorbia spp.	6	43	14	48	20	25	33	29	13	16	38	9	14	17
Nothocestrum sp.						2		6	5			10		17
Nototrichium sp.					2									
Osmanthus sandwicensis		5	8	x		4						3		
Perrottetia sandwicensis			3		x	4			2	2			14	
Pipturus sp.											x			
Reynoldsia sp.				2	2	4		3				2		
Santalum sp.				x	2					2	2			

* _ underlined number = sample from which representative type was taken
** x = less than 0.5%

TABLE 7.3

DISTRIBUTION OF UNIDENTIFIED TAXA EXPRESSED AS PERCENT OF SAMPLE WEIGHT

TAXON NO.	Column depth in cm													
	0-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	75-80
1			1	12	1	7			6				14	
2				9			6	3	x					
3			1	5		x	8			x	5			9
4	6		11	x		13	4	12	12			3		
5		5				2	x	11						
6				17	x	22	2	8	10		6	7	14	26
7	22	2		64	8		6	19		26	13	16		
8									4	9				
9					8	13	12		8		12	16		9
10	6		10	6				3				2		
11					2						x			
12						x								
13				2	12	7	2					6		
14			4		9		6						14	
15								2						
16				7		4				12				
17								12						
18														9
19		5												

REVIEW OF IDENTIFIED TAXA

Family AMARANTHACEAE

Nototrichium sp. *(kulu'i)*

There are three species in this endemic genus. Two are shrubs several feet tall found in the lowlands and the other is a tree 15-20 feet tall from the lower forest zone between 2,000 and 3,000 feet in elevation (Rock 1913). *Nototrichium* is generally found in dry regions such as xerophytic forests or on lava fields.

The wood which is light when fresh carbonizes to dense hard charcoal. The characteristics of the family were clearly visible under the dissecting scope in the one charcoal piece recovered from the 25-30 cm level.

Family ARALIACEAE

Reynoldsia sp. *('ohe)*

Eight endemic species are listed in St. John (1973) for this Polynesian genus. *Reynoldsia* is a tree, 15-60 feet tall, peculiar to the very dry districts of the lowland zone (Rock 1913). Like *Erythrina (wiliwili)*, *Reynoldsia* sheds its leaves in the winter to bloom on bare branches. The soft wood was used for making stilts for a game called *kukuluae'o* (Malo 1898).

Carbonized remains of *Reynoldsia* were found in low numbers (2-5%) in five of ten levels between 25 and 65 cm.

Family CELASTRACEAE

Perrottetia sandwicensis Gray *(olomea)*

This endemic species grows as shrubs or trees 10-18 feet in height in dry or wet regions ranging from 1,000 to 6,000 feet in elevation (Rock 1913). The wood was used to produce fire by rubbing against the softer *hau (Hibiscus tiliaceus* L.) (Malo 1898).

Carbonized *Perrottetia* was found in low numbers in several levels between 15 and 70 cm.

Family CHENOPODIACEAE

Chenopodium oahuense (Meyen) Aellen *('aheahea, 'aweoweo)*

This endemic species is usually a shrub in the coastal lowlands but is believed to have been arborescent at higher elevations. Hillebrand (1888) wrote that he saw *Chenopodium* "arborescent, with a woody trunk, and 12-15 feet high, in the upper woods of Mauna Kea" and recently a worm-eaten trunk 18 cm in diameter was collected at Pohakuloa at 6,200 feet elevation on Mauna Kea (Warshauer and McEldowney, FRW 3586). Despite the size that *Chenopodium* may have attained, its soft wood was probably not used by the ancient Hawaiians. Its leaves, however, were cooked and eaten (Hillebrand 1888; Malo 1989).

Charcoal of *Chenopodium* was found in eight of the eleven levels between 15 and 65 cm.

Family EUPHORIBIACEAE

Euphorbia spp. *('akoko)*

There are 16 species and numerous varieties of *Euphorbia* endemic to Hawaii. These shrubs or small trees may be found in coastal environments as well as wet forests. The milky sap was once considered a possible source for rubber (Rock 1913). The Hawaiians valued *'akoko* for firewood (Hillebrand 1888).

Charcoal which resembles the various forms of *Euphorbia* was found in every level in the 80 cm column.

Family LEGUMINOSAE

Acacia koa Gray *(koa)*

One of the largest endemic trees in Hawaii, at higher elevations *koa* may exceed 80 feet in height and not branch until 40 feet or more above the ground. This straight trunk was especially useful for canoes as well as paddles, surfboards, and calabashes (Malo 1898). Today, although *koa* forests have been narrowed from their natural range of 600-5,000 feet in elevation mainly by cattle (Rock 1913), the wood is still valued.

Charcoal resembling *koa* was found only in the 50-55 cm level.

Family MORACEAE

Artocarpus altilis (Parkins. ex Z) Fosb. *('ulu,* breadfruit)

Artocarpus was carried by the Polynesians in their migrations. Only one variety is found in the Hawaiian Islands, but as many as 24 subspecies or varieties are distinguished by native names in Samoa, Fiji, and Tahiti (Rock 1913). Hawaiian *'ulu* seldom bears seeds and thus is found near native dwellings or in valleys of the lowlands where cultivated by suckers. The wood of the 40-60+ feet tall trees was used in construction of doors of houses and for canoe hulls (Malo 1898). The bark of the young shoot was made into rough tapa (Malo 1898). The latex was used as caulking for canoes and birdlime (Neal 1965). The fruit was baked or pounded into *poi* for food (Rock 1913).

Charcoal which resembles *'ulu* was found in eight of the thirteen levels between 0 and 65 cm.

Family MYRTACEAE

Eugenia malaccensis L. *('ohi'a-'ai)*

This native of Malaysia, introduced into Hawaii by early Polynesian settlers, can be found on all islands in the lowest forest zone up to 1,800 feet in elevation (Rock 1913). It is a relative of *'ohi'a-lehua (Metrosideros collina* spp. *polymorpha)* and may attain a height of 50 feet. The Hawaiians obtained a red tapa dye from the bark and used crushed leaves and bark medicinally.

Charcoal resembling *'ohi'a-'ai* was found in all levels except one between 15 and 80 cm.

Family OLEACEAE

Osmanthus sanwicensis (Gray) Knobl. *(olopua)*

This endemic tree which is often 60 feet tall can be found in the lower forest zone at 600-4,000 feet elevation (Rock 1913). The wood from *olopua* was made into adze handles (Rock 1913), digging sticks (Neal 1965), house posts, and weapons (Buck 1957). Malo (1898) notes that *olopua* wood burned when green.

Charcoal resembling *olopua* wood was found in five of the twelve levels between 10 and 65 cm.

Family RUBIACEAE

Canthium odoratum (Forst. f.) Seem. *(alahe'e)*

This small indigenous tree which may be up to 20 feet tall is found in dry regions of the lowlands or the lower forest zone up to 2,000 feet elevation (Rock 1913). The hard wood of *alahe'e* was used by the Hawaiians for digging sticks (Buck 1957).

Carbonized wood resembling *alahe'e* was found in the 50-55 and 75-80 cm levels.

Family SANTALACEAE

Santalum sp. *('ili-ahi*, sandalwood)

The most recent treatment of Hawaiian *Santalum* recognizes four endemic species and several varieties found mostly in dry or mesic regions (Stemmermann 1980a). Their habits range from low shrubs on the coast to trees 65 feet tall in upper mesic environments. These root parasites depend on other plants for nutrition until established. The fragrant heartwood was the first major export item of the Hawaiian Islands and was used by the Hawaiians to perfume tapa (Neal 1965).

Charcoal resembling *Santalum* was found in four of nine levels in the 20 to 60 cm range.

Family SOLANACEAE

Nothocestrum sp. *('aiea)*

The three species of this endemic genus are small trees, 15 to 35 feet tall, found in dry regions to rain forests (Rock 1913). The soft wood of *'aiea* was used for canoes (Malo 1898), thatching sticks, and fire making (Pukui and Elbert 1957).

Charcoal of *'aiea* was found in five of nine levels in the 30 to 80 cm depths of the column.

Family URTICACEAE

Pipturus sp. *(mamaki)*

The thirteen endemic species of *Pipturus* in Hawaii are usually small shrubs and occasionally 30 feet tall trees which inhabit mesophytic forests in the 1,500 to 4,000 foot elevational range (Rock 1913). The Hawaiians used the bark for tapa making (Buck 1957; Malo 1898) and the fruits for medicine (Rock 1913).

The single find of *Pipturus* charcoal was recovered from the 55-60 cm level.

DISCUSSION

Limitations of Study

The identification of wood charcoal from archaeological sites is a relatively new technique in Hawai'i and has yet to realize its full potential. The identifications made in this study were limited by the availability of microscope slides and/or complete descriptions of known woods as well as by the unknown range of variation in wood anatomy for both the comparative and charcoal material. The Hawaiian wood collection at the University of Hawaii, although encompassing nearly half of the woody species, is mainly a survey collection rather than the basis for studies in wood variation. The few genera which have been studied for anatomical variation have shown that differences exist between and within individuals of the same species (Sastrapradja and Lamoureux 1969; Stemmermann 1980b). Identifications can be made more readily in genera for which the range of variation is known, because the anatomical features characteristic of the genus as a whole are better defined.

Determining frequencies of charcoal within a level or successive levels is difficult because of the unknown degree of preservation. Soft woods such as *Erythrina (wiliwili)* or *Reynoldsia ('ohe)* are very fragile when carbonized and may not survive crushing or wet environments. Incompletely carbonized woods may be subject to fungal or microbial attack.

Vegetation Patterns Indicated by Charcoal

Of the 13 identified taxa, two are from dry regions (xeric environments), six range from dry regions to the lower forest zone (xeric to mesic environments), three are found only in mesic environments, and one is cultivated today mainly in mesic regions. The possible vegetation types indicated above and the possibility that twelve (perhaps all) of these taxa were used by the Hawaiians suggests that the woods were selectively collected from plants growing nearby the site in a mesic environment.

Among the plants selectively collected by the Hawaiians, four were much used during the time span represented by the column. The presence of *Artocarpus altilis ('ulu), Chenopodium oahuense ('aweoweo),* and *Eugenia malaccensis ('ohi'a-'ai)* in the column is indicative of actively cultivated food sources. Although *Eugenia* is today naturalized in mesic forests, *Artocarpus* had to be cultivated by man and *Chenopodium* might have been encouraged to grow in fallow fields (Allen, chapter 6, this volume).

Euphorbia, on the other hand, was not used for food. Its presence in every level of the column strengthens its possible importance as firewood (Hillebrand 1888). *Euphorbia* charcoal has been found in two other sites, Waimea-Kawaihae (Murakami 1983a) and Kaho'olawe (Murakami 1983b). In each site a large group of charcoal exhibited a range of anatomical variation beyond that of the reference material but possibly within the range expected of taxa growing in differing environments. The hypothesis that this large group represents the wide ranging and anatomically variable *Euphorbia* is supported by Carlquist's study of the Hawaiian, Macaronesian, and cactoid African species (1970). The variation seen in the charcoal was within the range demonstrated in Carlquist's study of Hawaiian *Euphorbia*.

It was hoped that a column of charcoal representing a continuum of activity might be used to formulate a chronology of vegetation changes due to human activity. An increase of introduced plants in the charcoal might reflect an increase in cultural activity and the cultivation of these plants. A decreased representation of native vegetation might suggest decreased availability in the immediate vicinity. However, the relative proportions of each layer (level) remained about the same with an average of 17% from introduced, 31% from native, and 52% from unidentified plants. This suggests a consistent and perhaps constant impact on the vegetation.

The present analysis was not able to detect changes in the vegetation. The answers may be locked, in part, in the identities of the unknown taxa. In addition, a vegetation survey of the study area is necessary to determine how well the vegetation has survived the impact of cultural activity indicated by the column.

The data does suggest that the two introduced plants, *Artocarpus altilis ('ulu)* and *Eugenia malaccensis ('ohi'a-ai)*, represented in much of the column at a constant frequency, were already well established at the time that the rockshelter was first used. The vegetation of the area may already have been modified by human activities such as the cultivation of introduced plants before the site was ever used. This chronology would then explain why no drastic vegetation changes were detected in the column.

REFERENCES CITED

Allen, M.S. In prep. Kaho'olawe archaeobotanical materials.

Buck, P.H. (Te Rangi Hiroa). 1957. *Arts and Crafts of Hawaii*. B.P. Bishop Museum Special Publication 45. Bishop Museum Press. Honolulu.

Carlquist, S. 1970. Wood anatomy of Hawaiian, Macaronesian, and other species of *Euphorbia*. *Botanical Journal Linnean Society* Suppl. I 63:181-93.

Hillebrand, W. 1888. *Flora of the Hawaiian Islands*. Reprinted by Hafner Publishing Company. New York, 1965.

Malo, D. 1898. *Hawaiian Antiquities*. B.P. Bishop Museum Special Publication 2. 2nd Edition (reprinted 1971). Bishop Museum Press. Honolulu.

Murakami, G.M. 1983a. Analysis of charcoal from archaeological contexts. In J.T. Clark and P.V. Kirch, eds., *Archaeological Investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawai'i: An Interdisciplinary Study of an Envirionmental Transect*. Dept. of Anthropology Report 83-1, pp. 514-24. B.P. Bishop Museum. Honolulu.

_____. 1983b. Identification of charcoal from Kaho'olawe archaeological sites. In R.J. Hommon, *Kaho'olawe Archaeological Excavations* 1981. pp. 168-88. Prepared by Science Management Inc. for the U.S. Department of the Navy, Pacific Division, Naval Facilities Engineering Command. Pearl Harbor.

Neal, M.C. 1965. *In Gardens of Hawaii*. B.P. Bishop Museum Special Publication 50. Bishop Museum Press. Honolulu.

Pukui, M.K., and S.H. Elbert. 1957. *Hawaiian-English Dictionary*. University of Hawaii Press. Honolulu.

Rock, J.F. 1913. *The Indigenous Trees of the Hawaiian Islands*. Privately published. Honolulu.

Sastrapradja, D.S., and C. Lamoureux. 1969. Variation in wood anatomy of Hawaiian *Metrosideros* (Myrtaceae). *Annales Bogorienses* 5(1):1-83.

Smith, F.H., and B.L. Gannon. 1973. Sectioning of charcoals and dry ancient woods. *American Antiquity* 38(4):468-72.

Spurr, A.H. 1969. A low-viscosity epoxy resin embedding medium for electron microscopy. *Journal of Ultrastructural Research* 26:31-43.

St. John, H. 1973. *List of Flowering Plants in Hawaii.* Pacific Tropical Botanical Garden Memoir Number 1. Honolulu.

Stemmermann, L. 1980a. Observations on the genus *Santalum* (Santalaceae) in Hawai'i. *Pacific Science* 24:41-54.

_____. 1980b. Vegetative anatomy of the Hawaiian species of *Santalum* (Santalaceae). *Pacific Science* 34:55-75.

CHAPTER EIGHT

THE PORTABLE ARTIFACT ASSEMBLAGES

by Patrick V. Kirch

THE ROCKSHELTER EXCAVATIONS yielded a combined collection of 2,388 portable artifacts of indigenous manufacture, summarized in table 8.1. A large proportion of the collection (82%) consists of cores and flakes of volcanic glass; nonetheless, a fairly broad range of Hawaiian material culture types is represented. These are systematically described below, with notes on their stratigraphic distributions in individual sites, and comparisons with excavated assemblages from other sites both on O'ahu and throughout the archipelago.

The rockshelters also yielded various artifacts of foreign manufacture dating to the post-European contact or historic period. These are only briefly summarized in this monograph, as they will be the subject of a more detailed study elsewhere.

FISHING EQUIPMENT

Small quantities of fishing equipment, principally one-piece fishhooks, were recovered from each of the rockshelters. Notably absent were any of the several types of large sinker (for octopus fishing, bottom fishing, and for nets) commonly found in Hawaiian sites.

One-Piece Fishhooks

Twelve fragments of one-piece hooks were recovered, all manufactured of pearl shell (probably *Isognomon* sp.). These hooks are uniformly small in comparison with the size range of Hawaiian one-piece hooks generally. The most complete specimens have shank heights of 1.7 and 1.2 cm; shank height on a third, nearly complete shank probably did not exceed 1.4 cm. Shank thickness ranges from 0.1-0.3 cm. Line-lashing devices are present on three specimens, all of which are of type HT4 (Sinoto 1962), consisting of an outside knob perpendicular to the shank (fig. 8.1). The finished specimens are all carefully manufactured, evincing considerable skill in the ability to work friable pearl shell at such a diminutive scale.

One unfinished pearlshell one-piece hook tab was excavated from Site 60. This specimen indicates the use of the filling-and-notching manufacture technique described by Sinoto (1967).

Two-Piece Fishhooks

Two two-piece fishhook points were excavated, from Sites 36 and 58. The complete specimen from Site 36 (fig. 8.1) appears to be a small octopus lure point (Emory, Bonk, and Sinoto 1959:28-29) with two prominent notches for lashing on its outer face (fig. 8.4,d). The point is manufactured from the caudal tang of a large acanthurid fish, possibly *Naso* sp. The basal flanges of the tang have been filed down but not entirely erased. I am not aware of any other two-piece points made from such an acanthurid tang in other excavated Hawaiian assemblages. The hook has a point height of 3.0 cm. The specimen from Site 58 consists only of the tip of what is probably a typical two-piece hook. The point, with a strongly incurved tip, is of mammal bone, and has a width of 0.6 cm and a thickness of 0.35 cm.

TABLE 8.1

INDIGENOUS HAWAIIAN PORTABLE ARTIFACTS FROM THE ANAHULU ROCKSHELTERS

ARTIFACT CLASS	D6-60	D6-58	D6-36	TOTALS
Fishhooks	5	4	6	15
Line Sinkers	3			3
Adz		1		1
Adz Preform	1			1
Adz Fragments	1		1	2
Adz Flakes/Chips	35	39	15	89
Grindstones	3		1	4
Whetstones	4	1		5
Basalt Files	2	1		3
Polishing Stones	3			3
Coral Abraders	3	7	6	16
Hammerstones	10	2	2	14
Bone Awls	6	2	3	11
Cone-shell Beads	52	4	5	61
Tattooing Needle		1		1
Dog-Tooth Ornaments	1	2		3
Gaming Stone		1		1
Worked Bone	3	1		4
Worked Shell	8	3	2	13
Basalt Flakes	52	60	11	123
Volcanic Glass Cores/Flakes	1,407	336	213	1,956
Coral Manuports	37	13	9	59
TOTALS	1,636	478	274	2,388

Line Sinkers

Three small line sinkers were excavated at Site 60. All of these are made from naturally rounded, ovoid stream pebbles of basalt, and have a single narrow, incised groove extending longitudinally around the pebble to facilitate lashing onto a fishing line. The pebbles range in length from 1.4-2.2 cm, and in width from 1.2-1.5 cm. It is probable that these line weights were used in conjunction with the small one-piece fishhooks.

Stratigraphic Distribution

In Site 36, all of the hooks were recovered from depths between 20 and 35 cm. The three one-piece hooks from Site 58 were recovered from depths below 35 cm in Unit O11 only. The two-piece point was recovered from 45-50 cm in Unit D9. In Site 60, however, the hooks were found in the upper 10 cm of deposit, with the exception of one fragment from 15-20 cm in Unit M25. Two of the three line sinkers were recovered from the upper 5 cm of Site 60, while the third specimen was found between 50-55 cm in Unit D20.

Comparisons

The one-piece fishhooks from the Anahulu rockshelters are relatively small in comparison with the general size range of one-piece hooks in Hawaiian archaeological sites. Emory, Bonk, and Sinoto (1959:14-5) give a mean shank height of 1.98 cm for Hawaiian jabbing hooks; the Anahulu specimens are all somewhat smaller that this mean value. In a comparative study of three fishing sites (Kirch 1982) I demonstrated that hook size is directly related to certain local environmental conditions, such as the presence of an inshore fringing reef. For example, hooks from two coastal sites in which small inshore reef fish predominated had mean shank lengths of 1.83 and 1.94 cm respectively (1982, table III). These contrast with another site associated with benthic bottom fishing, in which shank length averaged 3.4 cm.

Were the Anahulu rockshelters situated near the coast, there would be no question that the small fishhooks were intended for taking small inshore reef fish. Their presence in three inland shelters 6 km from the coast, however, leaves this interpretation open to question. Furthermore, since the quantity of manufacture detritus and abrading tools in these sites is very limited, it appears that these hooks were not being produced at the shelters, but were brought to them in finished form. One possible function of these diminutive hooks may have been angling for the prized freshwater fish called *'o'opu* in Hawaiian, and including several endemic species in the families Eleotridae and Gobiidae (Titcomb 1952:122). I have been unable, however, to find any ethnohistoric references to the use of hooks in catching *'o'opu*, the usual reference being to nets. Certainly, though, the small size of the one-piece hooks from the Anahulu shelters would be appropriate to the *'o'opu* which generally range between 15-30 cm in length.

On the three one-piece hooks where the line-lashing device is present this is of type HT4 (Sinoto 1962), a distinctive protruding knob at right angles to the shank. As Sinoto (1962) originally suggested, the dominance of the HT4 type in the "late period" (after about A.D. 1200) has been confirmed by subsequent excavations at a variety of sites. The Anahulu sample is thus consistent with this general pattern.

TOOLS

Adzes

One complete adz, several diagnostic fragments, one preform, and 89 flakes or chips from polished adzes are included in the rockshelter assemblages. The whole specimen, from Unit K10 of Site 58, is a typical late prehistoric Hawaiian "quadrangular" adz (the cross-section is actually slightly trapezoidal), with a well-ground face and bevel, and only partially ground tang and sides, leaving considerable evidence of the direct percussion flaking process. Although the adz is relatively small, it has a pronounced tang. It has a total length of 6.1 cm, a cutting edge width of 2.4 cm, shoulder width of 2.35 cm, and shoulder thickness of 1.8 cm; it weighs 46 grams.

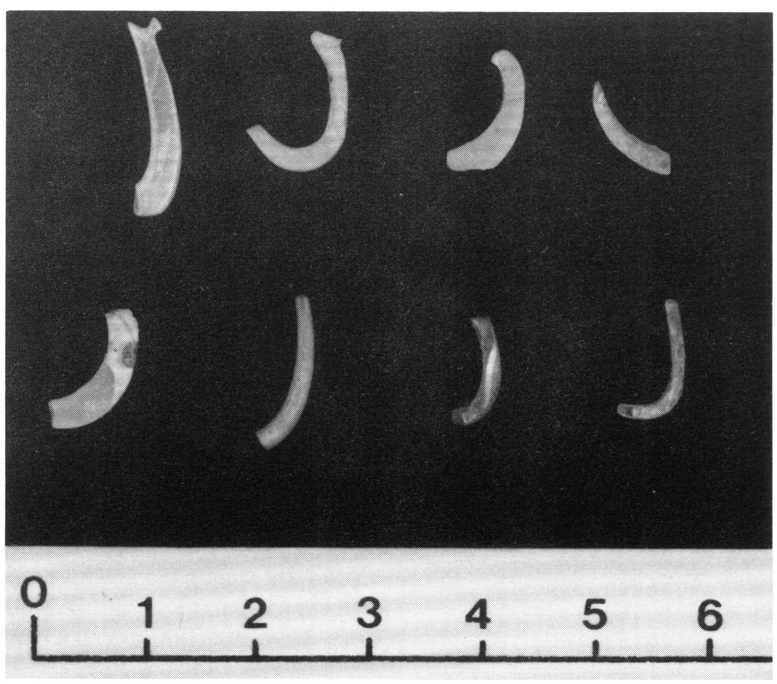

Figure 8.1. One-piece fishhook fragments from the Anahulu rockshelters.

The two larger adz fragments, from Sites 36 and 60, are both shoulder fragments from what must have been relatively large quadrangular adzes with pronounced tangs. In both cases grinding did not obliterate the original flaked surface. Both adzes, when complete, were probably in the size range of 10-18 cm.

On the surface of Site 60 we collected a small adz preform consisting of a retouched basalt flake. The flake was bifacially trimmed to form a rectangular preform, but was not ground. It has a maximum length of 6.5 cm, width of 2.5 cm, and maximum thickness of 0.95 cm. While larger adzes in Hawaii were generally made from core-type preforms, small, thin adzes are known to have been manufactured from retouched flakes such as this.

Relatively little can be said of the 89 adz flakes and chips, as these are largely non-diagnostic and diminutive; their presence in the rockshelters does, however, indicate adz use and/or reworking (such as bevel rejuvination) at these sites. In the few cases where more than one polished surface is present, right angles clearly indicate that most if not all of these flakes were detached from quadrangular sectioned adzes, the dominant form in late Hawaiian prehistory. The size ranges of these flakes, based on the sample of 15 specimens from Site 36, is as follows: length, $\overline{x}$=2.17 cm, s.d.=1.22; width, $\overline{x}$=1.45 cm, s.d.=0.66 cm; thickness, $\overline{x}$=0.58 cm, s.d.=0.20 cm.

Stratigraphic Distribution. Adz fragments or flakes were recovered from virtually every excavated level in all three rockshelters. Nonetheless, adz specimens tend to be more frequent in the upper levels of each site. This tendency is most pronounced in Site 60, where two-thirds of all adz flakes were recovered from the upper 20 cm of deposit. In Site 36, 13 of the total of 15 excavated specimens came from the upper 20 cm. This pattern is not so pronounced, however, at Site 58.

Comparisons. A marked change in adz variation appears in Hawaiian archaeological assemblages between the end of the Developmental and beginning of the Expansion Periods, ca. A.D. 900-1100 (Kirch 1985:184, 304). Earlier assemblages are notable for their range of variation in cross-sectional form and other attributes, whereas later assemblages are highly uniform. Cleghorn (1982) has commented on the virtually monotonous and stereotypic form of late prehistoric Hawaiian adz, with its distinct tang and quadrangular cross-section. The adzes from Anahulu conform perfectly with expectations from this general sequence. Dating to the Expansion and Proto-Historic Periods, they are all of classic quadrangular form.

Hammerstones

Fourteen hammerstones are included in the collection, with ten of these coming from Site 60. There is considerable variation in these artifacts, which are individually described in table 8.2. Most specimens consist of medium sized, ovoid or slightly elongated waterworn river cobbles of vesicular basalt, identifiable as hammerstones because they display battering, crushing, or pitting on ends, sides, or flat surfaces. Some specimens, however, deviate from this "typical" form. One hammerstone, for example (D6-60-M22-89) is markedly discoidal and of more vesicular stone than most. Two artifacts are pebbles rather than cobbles.

While the term "hammerstone" has been used to categorize all of these artifacts, it seems likely that this class includes a number of objects with differing functions. In many cases, the amount of crushing or bruising on the cobble edges is relatively slight, and certainly would not be sufficient to suggest use as a hammer used in the direct percussion flaking of dense basalt. More plausible would be the use of these cobbles for flaking the volcanic glass found in substantial quantities throughout all rockshelters. Furthermore, the presence of pitting on the flat sides of some of these stones hints that they may have been used as "anvils" rather than "hammers." Schousboe, Riford, and Kirch (1983) suggest that the reduction of Hawaiian volcanic glass assemblages was accomplished using a bipolar technique, requiring both anvils and hammerstones, which would be consistent with this interpretation. The discoidal hammerstone mentioned earlier stands out from the other specimens in this class, and may well have functioned as a hammer for direct percussion of fine-grained basalt adzes; certainly, it is similar to hammerstones from the Mauna Kea adz quarry site (Cleghorn 1982).

Stratigraphic Distribution. Hammerstones were recovered both on the surface of sites, and in a variety of stratigraphic contexts throughout the sites. No particular pattern of stratigraphic distribution can be detected, and it seems likely that these artifacts were utilized throughout the period during which the shelters were occupied.

Comparisons. Hammerstones have long been an analytically neglected artifact class in Hawaiian archaeological studies. Soehren (1966, ms.) and Tuohy (1965) were among the few investigators to devote some attention to these multipurpose tools. Soehren (1966, Appendix C) proposed a classification of hammerstones with a primary distinction between

TABLE 8.2

HAMMERSTONES

CATALOG NO.	L (cm)	W (cm)	Th (cm)	REMARKS
D6-36-SA-1	11.5	7.0	4.7	pecked finger grips on slides; pitting/abrasion around perimeter
D6-36-K19-7	9.1	8.9	5.9	minor pitting on one side; possibly an anvil rather than hammerstone
D6-58-K10-361	3.4	2.4	—	pebble; battering on one end
D6-58-O11-21	12.3	7.7	—	ovoid cobble with battering and flake scars on two ends
D6-60-M22-89	8.5	8.5	4.0	discoidal shape; highly vesicular; battering/crushing around perimeter
D6-60-M24-30	8.7	5.4	—	ovoid cobble; faint battering and flake scars—one end only
D6-60-M24-53	10.8	6.8	—	heavily battered/crushed around perimeter
D6-60-M24-93	10.8	4.3	2.7	elongate, pointed cobble; substantial battering/crushing on pointed end
D6-60-M24-94	8.0	5.5	4.2	small cobble; pitted one side
D6-60-M24-162	2.9	1.7	—	very small; problematic
D6-60-P24-1	10.8	—	—	slightly battered on one end
D6-60-P25-12	9.3	3.4	—	elongate cobble pitted on two ends
D6-60-P25-194	10.0	7.8	—	ovoid cobble pitted on two sides
D6-60-Q25-100	—	—	—	cobble; one side pitted
	$\bar{x}$ = 8.93 s.d. = 2.85	$\bar{x}$ = 5.78 s.d. = 2.40	$\bar{x}$ = 4.30 s.d. = 1.16	

natural stones "selected for their convenience and suitability" and "artifically shaped stones, either made expressly for use as hammers, or other artifact types converted to hammerstones" (1966:56). According to Soehren's schema, most of the Anahulu specimens would fall into Type IA, general discoidal or ovoid stones, although there are also examples of IB, elongate or cylindrical stones. Since these artifacts were clearly utilized for a variety of "hammering" functions, however, I believe that a more productive approach will be to focus on the nature of the damage or use patterns, including the type of damage (crushing, flake scars, pitting, etc.), its position and extent on the stone. The material itself, including properties of density and porosity, would also seem to be relevant. For example, most of the hammers identified from the Mauna Kea adz quarry are of highly vesicular, low density basalt, much "softer" than the fine-grained adz basalt being worked. This observation alone might suggest that the hammerstones of relatively dense, waterworn cobbles such as those from Anahulu, were not used in adz manufacture or retouching but for some other purpose. Certainly, a great deal more attention needs to be paid to this artifact class and its functional attributes in the future.

Coral Abraders

Sixteen pieces of *Porites* sp. coral displaying one or more clearly abraded facets or surfaces have been classified here as abraders. These include small, often elongate and tapering artifacts commonly termed coral "files" (cf. Emory and Sinoto 1961:53-54), as well as larger pieces with one or two flat, abraded surfaces sometimes termed "rubbing stones." The latter type predominate in the Anahulu assemblages, with only five artifacts which could be termed "files." There are as well a substantial number of apparently unworked coral fragments from all sites (see below); a number of these may be fragments of coral abraders which, however, lack worked surfaces. Some are chemically weathered (with "chalky" surface textures) making it difficult to determine whether they were once used as abraders.

Stratigraphic Distribution. Abraders were recovered at different levels in all sites, and no apparent temporal pattern is evident.

Basalt Files

Two basalt file fragments were excavated from Site 60, and a complete specimen from Site 58. The latter, of dense, fine-grained basalt is a slightly tapering object, with broad surfaces worn nearly flat through abrasion. The edges also show evidence of wear. The file measures 6.9 cm long, 2.1 cm wide, and 0.6 cm thick. This artifact was found at a depth of 45 cm in Unit K10 of Site 58. The pieces from Site 60, both tip fragments, also consist of dense basalt. They were recovered from depths of 35-40 cm in Unit M22 and from 9 cm in Unit P26.

Comparisons. Files of dense basalt are not common occurences at Hawaiian archaeological sites, but they have been previously reported, for example, from the leeward O'ahu rockshelters (Emory and Sinoto 1961:56), from the Halawa Dune Site on Moloka'i (Kirch 1975:40), and from the Nualolo sites on Kaua'i (Soehren ms.). On Hawai'i Island, most files or abraders of stone are made from the vesicular, scoriaceous lava which is readily available from recent volcanic eruptions. The use of dense basalt, as in the Anahulu specimens and those cited above, may be restricted to the westerly islands, although further distribution studies would be necessary to confirm this.

Grindstones and Whetstones

Grindstones are here defined as relatively large stones with one or more grinding surfaces, on which other stone implements (and particularly basalt adzes) are worked and sharpened. In contrast, whetstones are smaller, hand-held tools and frequently have concave grinding surfaces on opposing sides of a tabular stone.

Grindstone fragments were excavated from Site 36 (1 specimen) and from Site 60 (3 specimens). The fragment from Site 36 was used secondarily as a core for the removal of basalt flakes. A specimen from Unit M22 of Site 60, of coarse-grained basalt with olivine phenocrysts, is fractured and blackened from secondary use as an oven stone.

Five whetstone fragments were excavated, one from Site 58 and four from Site 60. A basalt whetstone fragment from Site 60 is thoroughly ground on two parallel sides as well as along the adjoining edge. The three other specimens from Site 60 are of a fine-grained andesite with numerous feldspars; these tabular stones have slightly concave grinding surfaces on both sides. The specimen from Site 58 has been fractured by heat, suggesting secondary use as an oven stone.

Stratigraphic Distribution. The grindstones in Site 60 were recovered at depths ranging from 3 to 25 cm; the Site 36 specimen came from a depth of 18 cm. Three of the whetstones from Site 60 came from the upper 5 cm of deposit; the other was excavated at 23 cm in Unit D20. That from Site 58 was found at 15 cm depth in Unit O11. In general, these proveniences suggest the use of grindstones and whetstones only in the later occupation phases of these sites. This pattern may well correlate with the increased frequency of adz use in the upper levels of the rockshelters, as noted earlier, since a primary use of both grindstones and whetstones was probably the sharpening of adz bevels.

Comparisons. The Anahulu grindstones and whetstones are comparable to many examples excavated from a variety of sites throughout the archipelago (e.g., Kalahuipua'a, Kirch 1979:167; Honaunau, Tuohy 1965:57; Halawa, Kirch 1975:40; West Moloka'i, Bonk 1954:78-9; O'ahu rockshelters, Emory and Sinoto 1961:64; Nualolo, Soehren ms.).

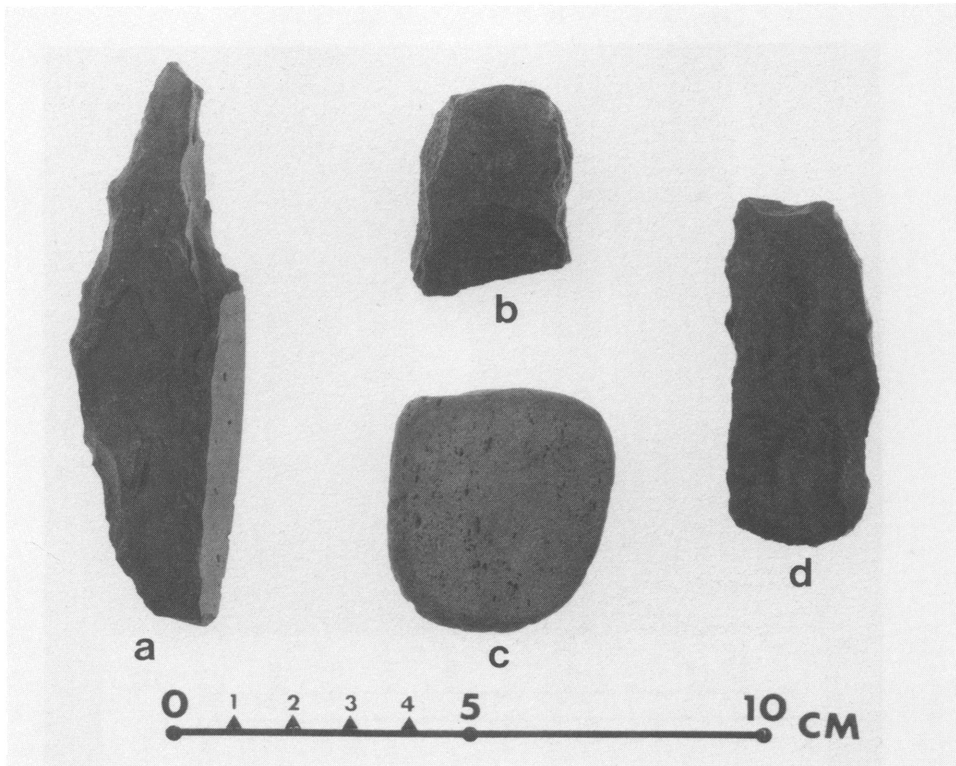

Figure 8.2. Artifacts from Site D6-60: a, retouched adz fragment; b, adz flake; c, polishing stone; d, adz preform.

Polishing Stones

Three small waterworn stream pebbles of basalt, all from Site 60, have abraded and polished facets and are classified here as "polishing stones." The largest of these measures 4.4 by 3.9 cm, and is 1.3 cm thick; it has been worked on two faces (fig. 8.2,c). An ovoid pebble 4.2 cm long and 1.5 cm thick shows artificial polish along part of its edge. The third specimen, also an ovoid pebble, 3.7 cm long and 1.0 cm thick, has polish on part of one side. The probable use of these artifacts was in polishing or burnishing, possibly of wooden artifacts.

Stratigraphic Distribution. The polishing stones were recovered from the following proveniences: 5-10 cm depth in Unit O25, 10-15 cm depth in Unit Q25, and 55-76 cm depth in Unit M22. This sample is too small to speak meaningfully about temporal patterns.

Comparisons. Polishing stones have not been widely reported in the Hawaiian archaeological literature, and it is conceivable that these nondescript tools have often been overlooked and discarded during excavations. Bonk (1954:82) notes that many of the West Moloka'i sites contained "smooth water worn stones...utilized for burnishing." Tuohy (1965:56) also distinguished 8 stone pebbles from his Honaunau excavations which show "some degree of polish" and which he separated from "stone rubbers." Somewhat surprisingly, Soehren (ms.) does not note the presence of polishing stones in the Nualolo terraces.

Awls or "Picks"

This category consists of all slender, artificially-pointed objects of bone, which some archaeologists in Hawai'i have separated into "awls" and "picks" (e.g., Emory and Sinoto 1961). This distinction appears to be arbitrary and functionally meaningless and therefore is not maintained here. Awls were recovered from all three rockshelters. Five of them are of bird bone with one condyle removed and the shaft beveled so as to produce a sharp working end (fig. 8.3,a-b). The other specimens appear to be of mammal bone, possibly dog or pig; four of the six mammal bone awls are only fragments. These objects probably served multiple functions, including the removal of meat from shellfish, the preparation of *Pandanus* leaves for mat making, and for perforation of various kinds of material.

Stratigraphic Distribution. With the exception of one bird bone awl from the lower fill (40-95 cm depth) in Unit K17 of Site 36, all awls were recovered from the upper 15 cm of deposit in each site. Their use was thus largely confined to the later occupation phases.

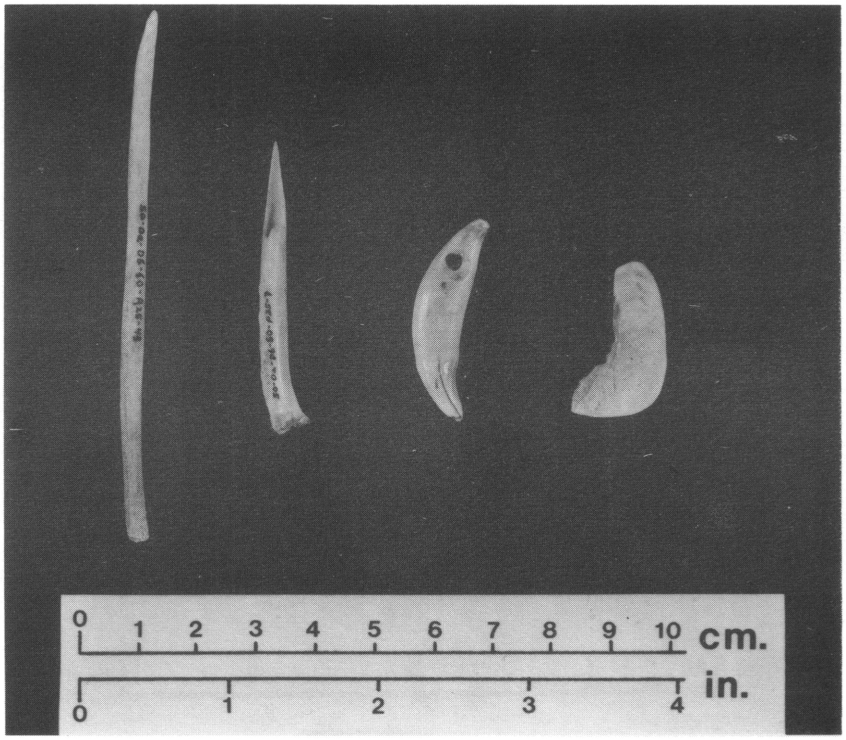

Figure 8.3. Artifacts from Site D6-60: a,b, awls of bird bone; c, dog tooth ornament; d, unfinished one-piece fishhook.

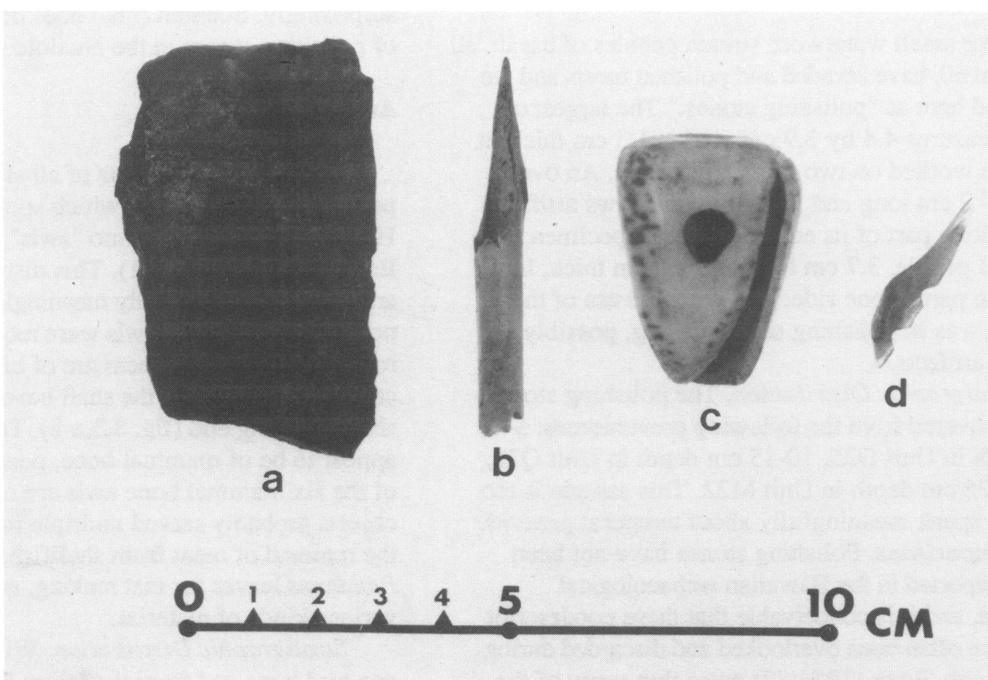

Figure 8.4. Artifacts from Site D6-36: a, basalt flake with use wear; b, bird bone awl; c, modified cone shell; d, octopus lure point.

Comparisons. "Bone pickers" were first described by Bonk (1954:109) from his West Moloka'i excavations, who interpreted them as instruments for "extracting the soft parts of mollusks for food." Emory and Sinoto (1961:39) described "picks" from their O'ahu sites, but distinguished them from awls. In assemblages from Halawa, Moloka'i and Kalahuipua'a, Hawai'i, analyzed by the author, the distinction between "picks" and "awls" appeared to be arbitrary and funtionally meaningless, and the term "awls" was applied to all such pointed bone objects (Kirch 1975:40; Kirch 1979:171).

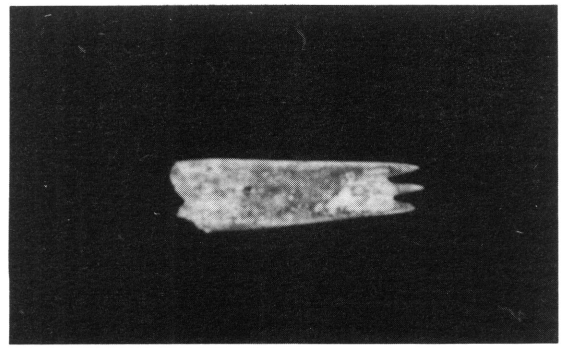

Figure 8.5. Tattooing needle from Site D6-58.

ORNAMENTATION

Tattooing Needle

Like other Polynesians, the Hawaiians decorated their bodies with finely-executed geometric tattoos, frequently depicted in the sketches and engravings made by the first European artists to visit the islands (Emory 1946). Tattoo needles are, however, a rare occurrence in Hawaiian archaeological sites. The tip of a small tattoo needle was recovered from the uppermost 1 cm of deposit in Unit K10 of Site 58 (fig. 8.5). Made from a bird bone shaft, the needle is slightly tapering and has three very sharp teeth defined by notches filed between them. The needle is distinctly blackened over its entire surface, presumably ink stained. The length of this incomplete needle is 1.3 cm; width measures 0.38 cm, thickness 0.05 cm.

Comparisons. Tattoo needles have been recovered from a few excavations, including those at Makaniolu Shelter on O'ahu (Site O2; Emory and Sinoto 1961), and the K3 and K5 house terraces at Nualolo on Kaua'i (Soehren ms.). The Makaniolu needles are of a compound type quite different from the Anahulu specimen. The latter is, however, very similar to the tattooing combs from Nualolo described by Soehren (ms.). The Anahulu and Nualolo needles also closely match a specimen in the Salem Peabody Museum described and illustrated by Emory (1946:263, fig. 13).

Perforated Dog's Teeth

Canine teeth of *Canis familiaris*, with a single perforation through the root end, are frequently found in Hawaiian archaeological sites, and three examples are included in the rockshelter assemblages (two from Site 58 and one from Site 60). Such teeth were used in the distinctive dance anklets (Hawaiian *kupe'e niho 'ilio*) worn by men, and illustrated in the famous engraving of a Sandwich Islands man dancing by Webber made during Cook's third voyage. Buck (1957:553-561) has described these anklets in detail. Dog teeth were also strung on a cord to be used as necklaces (Buck 1957:545), although Buck regards such a use as temporary: "they were so strung until a sufficient number had been collected to make the dog-tooth leg ornament characteristic of Hawaii."

The Anahulu specimens are typical, with a single perforation drilled through the root from both sides. The drill holes are funnel-shaped and slightly irregular, indicating the use of the indigenous pump drill with a shell or stone tip. On one specimen from Site 58 the area of the root adjacent to the perforation has been abraded smooth on one side only. This is a modification not previously observed on specimens from a large number of other Hawaiian sites.

Stratigraphic Distribution. The Site 60 specimen is a surface find, as is one from Site 58. The single excavated example was recovered at a depth of 20-25 cm in Unit K10 of Site 58.

Cone Shell Disks

One of the most common finds in all of the rockshelters were small, beach-worn disks of the spire portion of *Conus* shell, many of which have natural perforations in the center (such disks, easily collected on Hawaiian beaches, are popularly called "puka shells" and necklaces strung from them became something of a fad in the mid-1970s). Five of these disks were found at Site 36, four at Site 58, and 52 at Site 60. None of the specimens shows evidence of artificial modification, but it seems likely that they were collected in order to be strung as necklaces, in the manner described by Buck (1957:543, fig. 334). The diameters of these disks range from 0.45 to 1.7 cm.

Stratigraphic Distribution. The large sample of cone-shell disks from Site 60 provides the best indication of their temporal distribution. Six specimens are distributed at depths of between 20-60 cm, but the majority were recovered between 0-20 cm, and especially in the upper 10 cm of deposit.

Comparisons. Cone shell disks are frequent occurrences in Hawaiian archaeological sites, although they have at times not been distinguished from molluscan midden material. Emory and Sinoto observed that in the leeward O'ahu rockshelters "the commonest beads found are cone spires or cone-shell tops, which are plentiful on the beaches" (1961:70). Such beads were also common finds at the Honaunau sites excavated by Tuohy (1965:80).

MANUFACTURE DETRITUS

Worked Shell

Twelve pieces of pearl shell (*Pinctada* and *Isognomon* spp.) with evidence of working were excavated from the rockshelters. Most of these are small fragments with one or two abraded or cut edges. A roughly rectangular piece (1.5 by 1.4 cm, 0.1 cm thick) from Site 58 may be a small fishhook tab. Another specimen from the same site is circular in outline (diameter 0.9 cm, thickness 0.1 cm) and could have been used as an inlay, possibly for the eye of a small wooden figure (cf. Buck 1957:469-478). With the exception of these two pieces, the worked shell material is non-diagnostic.

Stratigraphic Distribution. Two pieces of worked shell were recovered at depths of 23 and 45 cm in Site 58 (both in Unit K10). Otherwise, worked shell was recovered from depths of less than 20 cm in all sites.

Worked Bone

One fragment of worked bone was found at Site 58, three at Site 60; all of these display abrading or cut marks, and probably represent detritus from the manufacture of bone artifacts. All fragments are of mammal bone, of indeterminate species. The specimen from Site 58 was recovered from a depth of 78 cm in Unit O11; of the Site 60 specimens, one was found at 15 cm, while the other two came from the 0-5 cm level.

MISCELLANEOUS OBJECTS

Gaming Stone ('Ulumaika)

A beautifully made example of a bowling disk for the Hawaiian *maika* game (Buck 1957:372-3) was excavated from Unit K10 of Site 58, at a depth of 28-35 cm. The disk is of fine-grained basalt, and has been highly polished over all surfaces. Its sides have the characteristic convex shape, and are well balanced. This *'ulumaika* has a diameter of 7.15 cm, and maximum thickness at the center of 4.35 cm. It weighs 318.5 grams.

Modified Cone Shell

From a depth of 5 cm in Unit K20 of Site 36 we excavated a *Conus* shell which has been ground flat on the spire and along the longitudinal surface adjacent to the aperture (fig. 8.4,c). The shell as modified measures 4.1 cm long. Its function cannot be ascertained, although one might presume that it was intended as an item of ornamentation.

Comparisons. Soehren (ms.) describes and figures several cone shells worked in precisely the same manner as the specimen described above, from sites K3 and K5 at Nualolo, Kaua'i. Based on the flat, ground surface, Soehren interprets these artifacts as "bracelet components," but notes that in the absence of ethnographic confirmation, this interpretation is "arbitrary."

Oven Stones

Four vesicular basalt cobbles with fracturing and fire-blackening are presumed to have been oven stones for use in the indigenous *imu* or underground oven. The stone from Site 36 was excavated at a depth of 10 cm, while the three from Site 60 were recovered at depths between 20-40 cm.

Coral Manuports

Small pieces and fragments of coral, including both *Porites* type and branch coral, were common finds in all sites, with 9 from Site 36, 13 from Site 58, and 37 from Site 60. Some of the *Porites* fragments may have derived from the fracturing of larger abraders, although they do not bear traces of abraded surfaces. A number of water-rolled branch coral pebbles could have been used as playing pieces in the *konane* game (cf. Buck 1957:369-372). There is no clear pattern of stratigraphic distribution of these objects, which were recovered at virtually all levels.

LITHICS

The most frequently recovered items in all three sites were flaked basalt and volcanic glass, totalling 2,079 specimens.

Basalt Flakes

A total of 123 flakes of basalt were excavated, 11 from Site 36, 60 from Site 58, and 52 from Site 60.

TABLE 8.3

VOLCANIC GLASS CORES AND FLAKES

SITE	CORES	FLAKES	TOTAL	RATIO
D6-36	6	207	213	1:34
D6-58	28	308	336	1:11
D6-60	87	1,320	1,407	1:15
TOTAL	121	1,835	1,956	

These range from flakes of fine-grained basalt of adz quality (but lacking polished or ground facets) to flakes of rather coarse-grained, vesicular basalt. A number of these can be classified as decortication flakes, and exhibit cortex from waterworn stream cobbles. For the most part, the flakes are small, as indicated by the following summary statistics: length, $\overline{x}$=3.59 cm, s.d.=2.2 cm; width, $\overline{x}$=2.59 cm, s.d.=1.75 cm; thickness, $\overline{x}$=0.88 cm, s.d.=0.56 cm. A small number of flakes have either been retouched or have evidence of use wear; these are individually described below.

OA-D6-36-K17-2. Parallel sided blade of basalt with almost glassy texture (6.7 by 3.9 cm). Unifacial use wear in the form of micro flake scars is evident along half of one edge. The flake would be classified as a scraper (fig. 8.4,a).

0A-D6-36-K17-4. Roughly rectangular flake of fine-grained basalt (3.9 cm long, 3.0 cm wide, 0.8 cm thick). Both edges along the long axis show use wear in the form of rounding and smoothing.

OA-D6-36-K17-44. A rectangular flake of fine basalt (3.65 cm long, 2.85 cm wide, 0.95 cm thick). Micro flake scars along half of one edge suggest use, possibly as a scraper.

OA-D6-36-K19-1. Roughly square flake of fine-grained basalt (1.8 by 1.7 cm). Utilization suggested by rounding and polish along the right lateral edge. There is also a small area of polish toward the distal end of the flake scar.

OA-D6-58-SA-7. A roughly rectangular flake of vesicular, coarse-grained basalt with some cortex (6.6 cm long, 4.3 cm wide, 1.7 cm thick). Micro flake scars along part of the longest edge suggest use, possibly as a scraper.

OA-D6-58-O11-45. A large rectangular blade of basalt (8.4 by 5.7 cm), with step flake scars along one edge.

OA-D6-60-D20-53. A small flake of basalt (5.0 by 1.9 cm) with possible modification in the form of the three secondary flakes removed from one end.

OA-D6-60-Q25-99. Medium-sized flake of basalt (6.0 by 3.8 cm), with weathered cortex on the dorsal surface. Minor modification or retouch indicated by the secondary removal of three flakes from the dorsal surface, one from the ventral surface. No evidence, however, of use wear.

Stratigraphic Distribution. In Site 58, there is fairly consistent distribution of basalt flakes from top to bottom throughout the deposit. In Site 36, most of the flakes were recovered in the upper 10 cm, although specimens occurred also in the 10-20 and 30-40 cm levels. In Site 60, flakes were distributed throughout the stratigraphic section, but were most prevalent in the 0-10 and 10-20 cm levels.

Comparisons. Flaked basalt, though ubiquitous in Hawaiian archaeological sites, has long been a neglected artifact category, which renders inter-assemblage comparisons virtually impossible.

Volcanic Glass

As is the case in most prehistoric Hawaiian sites, the most abundant artifact class consisted of small cores and flakes of volcanic glass, a low-silica form of obsidian (Barrera and Kirch 1973; Schousboe, Riford, and Kirch 1983). A total of 1,956 of these artifacts were recovered from the excavations (table 8.3). The majority of these consist of flakes, with only about 3-8% of each site assemblage comprising cores.

The flake assemblage from Site D6-58 was analyzed for five metric attributes, and the results are reported in table 8.4. The diminutive size of this lithic assemblage is clearly evident in these statistics. Observations were also made on a series of morphological attributes (following the protocol developed by Schousboe et al. 1983), permitting the following general characterization of the assemblage: (1) prepared platforms are extremely rare (1%); (2) bulbs of percussion are dominantly diffuse (81%), with low frequencies of salient, sheared, or acuminate bulbs; (3)

TABLE 8.4

METRIC ATTRIBUTES OF VOLCANIC GLASS FLAKES FROM SITE D6-58

ATTRIBUTE*	$\bar{x}$	s.d.	Range	N
Length	6.55	2.74	2.0-17.5	280
Width	5.41	2.26	1.1-13.4	275
Thickness	1.47	1.07	1.0-6.8	308
Platform thickness	.79	.70	0.1-4.8	283
Platform breadth	2.13	1.55	0.1-9.0	272

* All measurements in mm.

most flakes have a single dorsal ridge (41%), although up to 4 dorsal ridges may be present; (4) cortex is absent from fully 65% of flakes, and where present tends to be located on the dorsal surface; (5) flake edges are usually divergent (36%) or irregular (26%), with lesser frequencies of parallel, convergent, ovate, or diamond edges; and (6) flake terminations are dominantly feather (52%), with lesser frequencies of hinge, step, snap, and bibulbar types.

All flakes from all three sites were also closely examined (under 10X binocular microscope) for evident signs of use wear. Only nine flakes clearly displayed evidence of use, in the form of micro flake scars, in all instances along a single edge. Eight of these flakes came from Site D6-60, and one flake from D6-58.

HISTORIC ARTIFACTS

All three rockshelters yielded artifacts of Euro-American manufacture from the upper 5-10 cm of cultural deposit, and from the site surfaces. The most frequent items in these assemblages of exotic artifacts are small glass beads of several types, gun flints (some of which have been reworked), and small sherds of bottle glass. A detailed analysis of these historic artifacts will form part of a larger work on the Anahulu Valley Project (Sahlins and Kirch, in prep.).

REFERENCES CITED

Barrerra, W., Jr., and P.V. Kirch. 1973. Basaltic glass artifacts from Hawaii: their dating and prehistoric uses. *Journal of the Polynesian Society* 82(2):176-87.

Bonk, William J. 1954. "Archaeological Excavations on West Molokai," M.A. thesis, University of Hawaii.

Buck, P.H. (Te Rangi Hiroa). 1957. *Arts and Crafts of Hawaii.* B.P. Bishop Museum Special Publication 45. Honolulu.

Cleghorn, P.L. 1982. "The Mauna Kea Adze Quarry: Technological Analyses and Experimental Tests." Ph.D. Dissertation, University of Hawaii. (University Microfilms, Ann Arbor).

Emory, K.P. 1946. Hawaiian tattooing. *B.P. Bishop Museum Occasional Papers* 18:235-270.

Emory, K.P., W.J. Bonk, and Y.H. Sinoto. 1959. *Hawaiian Archaeology: Fishhooks.* B.P. Bishop Museum Special Publication 47. Honolulu.

Emory, K.P., and Y.H. Sinoto. 1961. *Hawaiian Archaeology: Oahu Excavations.* B.P. Bishop Museum Spec. Publ. 49. Honolulu.

Kirch, P.V. 1975. Excavations at Sites A1-3 and A1-4: early settlement and ecology in Halawa Valley. In P.V. Kirch and M. Kelly, eds., *Prehistory and Ecology in a Windward Hawaiian Valley,* pp. 17-70. Pacific Anthropological Records No. 24. Department of Anthropology, Bishop Museum. Honolulu.

_____. 1979. *Marine Exploitation in Prehistoric Hawai'i: Archaeological Excavations at Kalahuipua'a, Hawai'i Island.* Pacific Anthropological Records 29. Dept. of Anthropology, B.P. Bishop Museum. Honolulu.

_____. 1982. The ecology of marine exploitation in prehistoric Hawaii. *Human Ecology* 10(4):455-76.

_____. 1985. *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory.* University of Hawaii Press. Honolulu.

Sahlins, M. and P.V. Kirch. in prep. *Anahulu: The Archaeology of History in the Early Sandwich Islands Kingdom.*

Schousboe, R., M.F. Riford, and P.V. Kirch. 1983. Volcanic-glass flaked stone artifacts. In J. Clark and P. Kirch, eds., *Archaeological Investigations of the*

Mudlane-Waimea-Kawaihoe Road Corridor, Island of Hawaii, pp. 348-70. Dept. Anthropology Report 83-1. B.P. Bishop Museum. Honolulu.

Sinoto, Y.H. 1962. Chronology of Hawaiian fish-hooks. *Journal of the Polynesian Society* 71(2):162-66.

_____. 1967. Artifacts from excavated sites in the Hawaiian, Marquesas, and Society Islands. In G.A. Highland et al., eds., *Polynesian Culture History*, pp. 341-61. B.P. Bishop Museum Special Publication 56. Honolulu.

Soehren, L.J. 1966. "Hawaii excavations, 1965." Typescript in Dept. Anthropology, B.P. Bishop Museum. Honolulu.

_____. ms. "Archaeological excavations at Nualolo, Kauai." Incomplete typescript report in Dept. of Anthropology, B.P. Bishop Museum. Honolulu.

Titcomb, M. 1952. *Native Use of Fish in Hawaii.* Polynesian Society Memoir 29. Wellington.

Tuohy, D.R. 1965. "Salvage excavations at City of Refuge National Historical Park, Honaunau, Kona, Hawaii." Mimeo. B.P. Bishop Museum. Honolulu.

CHAPTER NINE

CONCLUSIONS

by Patrick V. Kirch

THE THREE ANAHULU ROCKSHELTERS reported in this volume have yielded one of the largest samples yet available of prehistoric occupations in a truly *interior* valley setting in the Hawaiian Islands. They thus provide an opportunity to investigate the chronology and sequence of prehistoric human penetration and use of the interior regions of O'ahu Island, and to compare this sequence with that from coastal or lowland areas. The shelters likewise offer evidence for the course of local environmental change in the inland parts of the Anahulu Valley over the past six to seven centuries, and of the probable role of humans in initiating such change. These are the principal themes to be summarized in this concluding discussion.

The perspective on Anahulu and Waialua prehistory contributed by the rockshelter evidence is a view *from the periphery*, that is, from an interior, hinterland region. Unfortuately, we as yet know little of the prehistory of coastal Waialua, much of which has been subject to major land use changes and disruptions in the historic period. Sporadic surface finds of early artifact types in the vicinity of Haleiwa (A. Anderson, pers. comm., 1982), however, hint that occupation in this area may date to the Colonization Period (A.D. 300-600) (Kirch 1985:298-302). Certainly the environmental setting and resources of coastal Waialua—its sheltered bays, rich marine life, and especially its well-watered fertile alluvial plains—would have been attractive to early Polynesian settlers. There can be little doubt that this part of O'ahu must have been settled relatively early, although an effective archaeological research program to locate and excavate sites dating to the Colonization and Developmental Periods has yet to be mounted. Nonetheless, there is no reason to doubt that the occupation sequence revealed in the Anahulu rockshelters reflects the gradual expansion into a peripheral, hinterland zone some centuries (and perhaps as long as a millennium) after initial human colonization of the region.

The large Ke'eke'e Nui rockshelter (D6-58) encapsulates the longest occupation sequence for the interior valley. Feature 9, a lens-like deposit of ash and charcoal immediately overlying the sterile alluvial base in Unit O11, and probably representing burning of vegetation on the site prior to first use, yielded a calibrated calendar age range of A.D. 1280-1430. The shelter appears to have been used, more-or-less continuously, from the fourteenth century up through the early historic period (ca. A.D. 1810). Although our excavated sample from the site is relatively small, limited to 3 m^2, we were able to identify major differences between lower and upper cultural deposits. These deposits were first observed during excavation as depositional units with contrasting color differences, representing varying quantities of included ash and charcoal (see chapter 2). The hypothesis was raised that a major shift in the intensity of occupation in the shelter might be represented by the transition from lower to upper cultural deposit. Additional support for this hypothesis comes largely from the analysis of both vertebrate and invertebrate faunal assemblages (see chapter 4.) With almost equivalent excavated volumes, the upper cultural deposit contains more than three times the number of vertebrate faunal specimens (NISP), especially of pig and dog, domestic animals likely to have been raised in the interior valley. This pattern is replicated by the invertebrate fauna, particularly marine shell, which displays a roughly three-fold increase in density from lower to upper cultural deposit. Thus, assuming that the physical conditions of sedimentation and deposition within the rockshelter remained constant (and there is nothing from the geoarchaeological analysis of sediments to suggest otherwise, see chapter 3), these significant increases in the density of faunal remains (as of charcoal and ash content of the sediments), can only signal a shift to greater intensity of human occupation. The question remains, howerver, whether the *functional activities* carried out in the shelter actually changed, or whether the same range of activities was merely carried out more frequently, leading to a higher density of cultural materials in the upper deposit.

The portable artifact assemblage from Ke'eke'e Nui shelter helps to discriminate between these alternative explanations for the differences between lower and upper cultural deposits. In terms of the presence/absence of discrete artifact classes represented, the upper cultural deposit contains a significantly more diverse array than the lower cultural deposit. The latter contains primarily flakes of both basalt and volcanic glass, some adz flakes, small one-piece fishhook fragments, a few possible coral abraders, and one piece of worked bone. The upper cultural deposit contains not only all of these classes present in the lower deposit, but in addition a grindstone, bone awls, dog tooth ornament, tattooing needle, polished basalt file, complete quadrangular adz, and an *ulumaika* gaming stone. The awls suggest some kind of domestic activity not carried out earlier in the shelter, while the basalt file and grindstone may indicate new kinds of tool manufacturing activity. More telling may be presence of the dog tooth ornament and tattooing needle, as well as of the gaming stone. These classes of artifact are generally regarded as associated only with permanent residential sites.

Based on the results of both the faunal and artifactual analyses, the interpretation of a change in the nature of occupation in the D6-58 shelter, first generated on the basis of field observations, can not only be confirmed but further elaborated. While the lower cultural deposit was accumulating, a relatively restricted range of activities was taking place in the site, including the flaking of volcanic glass and basalt (probably also adz bevel re-sharpening), bone working, and use of one-piece fishhooks (in the nearby stream, for freshwater fish?). During the period when the upper cultural deposit was accumulating, this range of activities expanded to include other domestic work (using awls and other tools), bodily ornamentation, and leisure activities. Further, the frequency or intensity with which fires were lit in the shelter (for light and cooking) increased substantially, indicated by the differences in ash/charcoal content of the sediments. These changes would be most parsimoniously explained by a change in the use of the shelter from a temporary camp to a permanent residential site. The pattern evidenced by the lower cultural deposit would fit well with the model outlined by Kirch (1979:51), and summarized in chapter 1, in which the shelter would have been visited periodically by small groups residing in the interior valley for periods of a few days. Presumably during such visits, these groups would have exploited particular interior resources, such as nesting seabirds (in the cliffs above the shelters) or native landbirds (both of which are indicated in the vertebrate faunal assemblages), and the endemic gobiid fish. Clearing of small shifting cultivations on the alluvial flats adjacent to the shelter may also have been initiated during this early phase. During the later phase, represented by the upper cultural deposit, one household group evidently took possession of the shelter as its permanent place of residence. Exploitation of wild resources continued, evidenced in the faunal assemblages, but in addition the substantial increases in domestic pig and dog bone are highly suggestive of animal husbandry in the vicinity of the site. Based on ethnographic descriptions of Hawaiian pig and dog husbandry, which document the regular feeding of these animals on vegetable crops (such as taro and sweet potato), the existence of permanent gardens can also be inferred.

The timing of this shift in the use of Ke'eke'e Nui rockshelter from temporary to permanent residence is approximately indicated by the radiocarbon sample from Feature 5, which was cut from near the base of the upper cultural deposit (see chapter 2, table 2.4). This sample yielded two calibrated calendar age ranges, but most likely dates to the first half of the 17th century (ca. A.D. 1600-1650). It is probably significant that this age is only slightly younger than the date from Feature 4 in nearby Site D6-36, which was presumably first used at about the same time that Site D6-58 became permanently occupied.

The archeological record itself is mute as to the cause(s) that may have precipitated the shift from temporary use to permanent occupation of Ke'eke'e Nui shelter, but it may be instructive to briefly consider some possibilities. The most deterministic explanation would be to invoke the pressure of a burgeoning lowland Waialua population on coastal lands and resources, thus forcing certain members of society (those without access to prime lands ?) to move inland. Alternatively, we might suppose that a group which had been regularly exploiting the interior valley on a seasonal or periodic basis chose to specialize fulltime on exploitation of the valley's interior resources (such as the opportunitites presented by development of pig and dog husbandry). This might be labelled the "ecological opportunism" scenario. Yet a third possibility would invoke force and chiefly control, by means of the forced dispossession of a group or household of its coastal lands, perhaps occasioned by conquest of Waialua and redistribution of its lands, as is known to have occurred repeatedly in late prehistoric Hawaiian society (Kamakau 1961; Sahlins 1958; Goldman 1970). Indeed, none of these scenarios need be mutually exclusive, and all three factors could have played a role in the decision of a particular group to take up permanent residence some 6-7 km inland. Significantly, this removal of a group of people from lowlands to interior, indicated by the Ke'eke'e Nui rockshelter sequence, appears to have been repeated later, especially in the early historic period following the conquest and occupation of O'ahu in 1804 by Kamehameha I. Interior, hinterland areas such as the middle and upper reaches of the Anahulu Valley offered opportunities for agricultural expansion to individuals and groups dispossessed of, or for other reasons without access to, more desirable coastal land and resources. This is a theme which forms a dominant subject of a longer work on Anahulu ethnohistory and archaeology (Sahlins and Kirch, in prep.).

Having pressed the interpretation of the evidence from Site D6-58 to its limits, how does the sequence compare or contrast with that from Kuolulo shelter? Initial use of Site D6-60 is indicated by the radiocarbon date from the base of excavation Unit D20, of the mid 15th century A.D., about one hundred years after the first use of Ke'eke'e Nui shelter. The relatively deep and continuous stratigraphic sequence provided by Unit D20 does not evidence a significant shift in the intensity or nature of use/occupation in this site. The vertebrate fauna, for example, shows no major shifts, although sample size is admittedly small (chapter 4, table 2.5). Nor do the deposits in Site D6-60 show the same density of vertebrate or invertebrate faunal remains as in the upper cultural deposit at D6-58 (chapter 4, tables 4.2, 4.6).

While the deep stratigraphic column from Unit D20 does not indicate a shift in the intensity of occupation or changes in the density of faunal remains, other evidence from Site D6-60 can be adduced to suggest a rather late change in the nature of human occupation at this site. Most important is the construction of both the inner and outer terraces in the western part of the site, which indicate the subdivision of the shelter floor into discrete activity spaces (probably domestic activity and sleeping on the inner terrace, certainly earth oven cooking on the outer terrace). Two radiocarbon dates (B-5170 and B-5168, see chapter 2, table 2.4) reveal that the construction of these formal activity areas took place fairly late in the site's occupation sequence, probably not prior to A.D. 1700, and possibly quite late in the eighteenth century. As in Site D6-58, the range of portable artifact classes recovered from excavation of these late, formalized constructions is suggestive of a broad range of activities, most likely to have resulted from permanent residence in the site. These include several classes of tools (adzes, grindstones, whetstones, files, polishing stones, abraders, hammerstones, and awls), fishhooks and line sinkers, a dog tooth ornament, and a large number of cone-shell beads, as well as the more ubitiquous basalt and volcanic glass flakes present in the deeper D20 sequence as well. Although their density was less than in D6-58, the inner and outer terrace deposits also yielded 61 dog and pig bones, again suggestive of the local husbandry of these animals, probably in conjunction with permanent gardening on the alluvial flats.

This evidence suggests that there was also a shift from temporary to permanent occupation at Kuolulo Shelter, but that this shift occurred quite a bit later than that at Ke'eke'e Nui shelter. Indeed, the radiocarbon evidence would not mitigate against the permanent occupation of D6-60 having been confined to a few decades immediately prior to the Historic Period (i.e., the latter part of the eighteenth century). Such a short phase of permanent occupation would readily account for a lack of accumulation of deposits with a high density of faunal materials, as in Site D6-58.

Turning lastly to the evidence from Site D6-36, Ke'eke'e Iki shelter, it will also be recalled that this site is so close to the larger Ke'eke'e Nui shelter that the two may well have been utilized by the same social group. The radiocarbon age determination from Feature 4 indicates that the shelter was first used no earlier than the mid-seventeenth century, and possibly not until the later half of the eighteenth century. (The multiple calendar ages produced by radiocarbon age calibration in this time period make a more precise temporal placement impossible; see Stuiver and Becker 1986.) Thus, D6-36 was not utilized until after the shift from temporary to permanent residence in D6-58, and quite possibly not until sometime late in the final century prior to European contact.

As with D6-60, the Ke'eke'e Iki cultural deposit has densities of vertebrate and invertebrate faunal materials somewhat lower than in D6-58. However, D6-36 did yield 39 pig and dog bones, again fitting well with a pattern of late prehistoric animal husbandry in the interior valley. The portable artifact array (chapter 8, table 8.1) is the least diverse of the three rockshelter assemblages, but does contain several classes of stone tools (adz flakes, grindstone, polishing stones, coral abraders, and hammerstones), as well as bone awls, fishhooks, and the ubiquitous volcanic glass and basalt flakes. The most likely interpretation of this evidence is that Ke'eke'e Iki rockshelter was utilized permanently for a relatively short period of time, most probably by the same social group occupying nearby Ke'eke'e Nui rockshelter.

The individual occupation sequences of the three rockshelters are depicted graphically in figure 9.1. Human penetration of the interior Anahulu Valley must be understood, not as a sudden event, but as a gradual process of increasingly intensive use occuring over at least four centuries. The earlier phases at D6-58 and -60 appear to represent only intermittent use of the shelters, associated with a pattern of exploitation of inland resources by groups still residing permanently in the lowlands. By the early seventeenth century, at least one group had shifted permanently inland to reside at D6-58, but the permanent occupation of D6-60 did not take place until sometime in the eighteenth century. In both sites, the shift to permanent occupation appears to be associated with a greater emphasis on husbandry of pig and dog, arguably a reflection of some form of agricultural expansion or intensification in the interior valley.

This prehistoric sequence from the inland Anahulu Valley may be briefly compared with my proposed archipelago-wide phase sequence (Kirch 1985:298-308), and also with Hommon's (1976, 1986) model of "inland expansion" in Hawaiian prehistory. The inland Anahulu sequence coincides with the Expansion Period (A.D. 1100-1650) and Proto-Historic Period (A.D. 1650-1795) of the sequence proposed on the basis of an archipelago wide synthesis of the several hundreds of excavated and dated sites. The Expansion Period was "the most significant period of cultural change in the entire sequence of Hawaiian prehistory" (Kirch 1985:303), witnessing explosive population growth, expansion of population into previously uninhabited ecological zones (especially leeward valleys and slopes), intensification of production, and reorganization of socio-political structure. The dating of initial human penetration into the Anahulu interior coincides well with the time span of the Expansion Period, and documents yet another case of movement into a new ecological zone, at first on a low-intensity, intermittent basis, and later through permanent occupation. By the Proto-Historic Period, the interior valley seems to have been permanently occupied by resident inland groups (probably not only at the

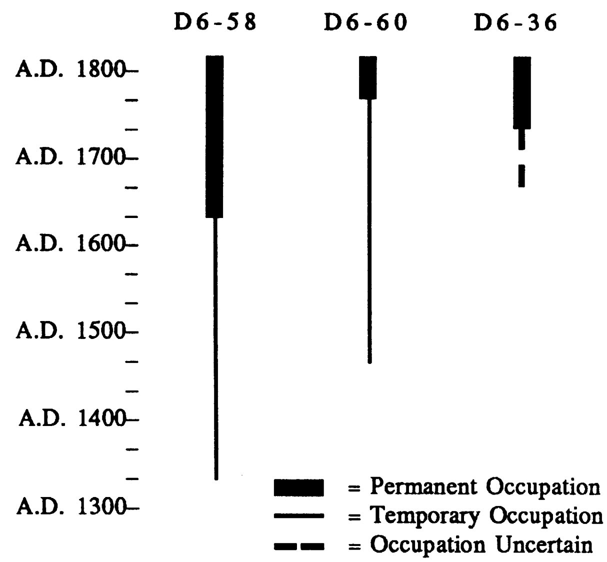

Figure 9.1. Occupation sequences of the Anahulu Valley rockshelters.

rockshelters excavated by our project, but at other, as yet untested sites as well). Hommon (1976, 1986) has put forward a slightly different, although fundamentally similar model in which the major phase of "inland expansion" is dated to ca. A.D. 1400-1600 (his Phase II, Hommon 1986:61-65). This phase coincides well with the initial use of both Sites D6-58 and -60.

The process of increasingly intensive human use, and eventual permanent occupation of the inland Anahulu Valley was reflected by a parallel sequence of changes and modifications to the natural environment, both physical and biotic. A major objective of the rockshelter excavations was to track this sequence of environmental change, as recorded in the rockshelter sediments, and in the floral and faunal materials contained within those sediments. Application of a range of interdisciplinary techniques for investigating prehistoric environmental change in Hawai'i—such as palynology, phytolith analysis, landsnail analysis, charcoal identification, geoarchaeological analysis of sediments, and archaeobotanical studies—has been largely a development of the 1980s, building upon the earlier settlement pattern-ecological approaches of the 1970s. Thus, at the time of the Anahulu Project fieldwork in 1982, most of the approaches which we planned to bring to bear on the retrodiction of environmental change in the valley were still experimental, and in some cases (especially with the identification of charcoal) hampered by a lack of adequate reference collections.

A further limitation to our objective of investigating environmental change is that the rockshelters themselves can be expected to yield evidence of a particularly local sort. The physical sediments and landsnails derive from very localized catchments in the immediate vicinity of the shelters. Carbonized seeds and charcoal probably reflect somewhat larger catchments, but cannot be expected to provide a comprehensive picture of valley vegetation patterns. The faunal assemblages reflect the broadest spatial range (extending indeed to the coastal and marine sections of the valley), but are biased by the filter of cultural patterns of food choice, as well as of processing and disposal. The varying spatial scales of these catchments from which particular sets of archaeological materials derive must be taken into account in any interpretation of the evidence from the rockshelters. Ideally, a comprehensive study of environmental change in the Anahulu Valley would incorporate evidence from a variety of other depositional contexts aside from the rockshelters, such as alluvial stream sections (for both geoarchaeological sediment analysis and identification of incorporated charcoal), agricultural features (both dryland and irrigation systems), open habitation sites, and bottom sediments from the large coastal ponds (Ukoa and Loko'ea). Such a comprehensive project, however, was well beyond either the objectives or resources of the Anahulu Project.

Hunt's study (chapter 3) is, to our knowledge, the first effort to analyze in detail the sedimentological characteristics of any Hawaiian rockshelter deposits. The lack of comparable data from other sites makes interpretation of his results difficult, as we cannot yet know whether the Anahulu shelter sediments differ from those of other sites in similar, or different, geomorphological contexts. This is a situation that will hopefully be remedied as geoarchaeological analyses become accepted as a standard part of excavation programs. The sediment profiles from D6-60 and -36, and individual unit samples from D6-58, certainly do not display any radical changes in sediment characteristics that would imply major shifts in the geomorphological regimes of which the shelters were a part. This evidence thus argues for a relatively low degree of human impact on the slopes surrounding the shelters, the primary source environment for sediment influx to the sites. However, the valley walls in the vicinity of all three sites are quite steep (incorporating substantial cliffs), and were thus unlikely to have been the focus of any agricultural activities. It is rather on the alluvial terraces immediately *below* the shelters (and thus lying outside of the source catchment for sediments) that any forest clearing and agricultural activities would have been focussed.

The landsnail sequences from D6-60 and -36 (chapter 5) present a clear and consistent picture of microenvironmental changes in the immediate vicinities of these sites. The deep D20 column from D6-60 displays three temporal zones or phases, as discussed in detail in chapter 5. The earliest zone represents an undisturbed mesic native forest containing several endemic, arboreal and terrestrial landsnail taxa, such as *Auriculella*, *Achatinella*, and *Amastra*. Initial clearance of this vegetation is reflected by the change to Zone 2, marked by the absence of arboreal taxa and other species requiring relatively wet micro-habitats. Also significant is the appearance, in Zone 2 and also in the D6-36 column, of the anthropophilic snail *Lamellaxis gracilis*. This species very likely reflects gardening activity in the vicinity of these sites. Finally, Zone 3, which corresponds with the Historic Period (after European contact), represents a new phase of microenvironmental changes, with the disappearance of additional native land taxa, and the introduction of exotics such as *Gastrocopta* and *Hawaiia*. In sum, the landsnail evidence is consistent with our interpretation that the occupants of the rockshelters also opened up the pre-human mesic forest canopy through clearing for agricultural activity. Truly radical changes in the local vegetation that supported these endemic snail populations did not occur, however, until the Historic Period.

Allen (chapter 6) has thoroughly discussed the problems and limitations of the archaeobotanical evidence obtained by flotation of column sediment samples and from features. Her cautious interpretation of these data is that they reflect disturbed conditions in the valley's vegetation throughout the period that the shelters were occupied, and that such disturbance was most likely due to agricultural activity. The archaeobotanical evidence thus meshes well with that of the landsnail analysis. It is also worth remarking that the absence of seeds of hydrophilic taxa (especially *Ludwigia octovalvis*, *Scirpus juncoides*, or *Cyperus* spp.), even though negative evidence, supports the archaeological field evidence that pondfield irrigation systems were not constructed in the upper valley until early in the nineteenth century (Kirch and Sahlins, in prep.).

The analysis of charcoal from the Site D6-60 column, by Murakami (chapter 7), was substantially limited by the incomplete state of available reference collections, thus requiring the use of "surrogate taxa" for which actual taxonomic identifications are not available. Certainly the charcoal data do not support a picture of radical environmental changes in the interior valley during the period of prehistoric human occupation. Neither are they inconsistent with our interpretation of agricultural activities on the valley floor and lower slopes, based on the landsnail and archaeobotanical data. Perhaps the most significant result of the charcoal analysis is the demonstration that two species of cultivated trees, breadfruit *(Artocarpus altilis)* and the Malay apple *(Eugenia malaccensis)*, were present in the valley throughout the period of prehistoric occupation of D6-60, and presumably in the interior valley itself, as it seems unlikely that firewood would have been carried 6 km from the coast to these shelters. The potential of charcoal identification to yield significant evidence on the nature of prehistoric Hawaiian cultivation systems, as well as on changes in the native vegetation communities, is clearly considerable, once problems of adequate reference materials have been overcome.

The marine fauna in the rockshelters tells us nothing of environmental change within the inland part of the valley, but the presence of the diadromous snail *Neritina granosa* is significant, as this species would have required permanent flow of the Anahulu Stream to survive. Historic Period changes in the valley's hydrologic regime (particularly the use of streamflow for sugarcane irrigation) have led to the extirpation of *N. granosa* from the watercourse.

Finally, there is the evidence of the culturally-deposited faunal assemblages (both vertebrate and invertebrate) which, as we have noted, were certainly derived from an extensive catchment area, and may therefore not necessarily reflect conditions in the interior valley per se. Of great interest is the range of indigenous and endemic birds represented in all rockshelter deposits. No less than five species of procellarids are present, and surely indicate that nesting populations of these seabirds were present within the Anahulu Valley environment until quite late in the prehistoric period. Also notable is the Bonin Petrel *(Pterodroma hypoleuca)*, whose historically-documented range does not even extend to the main Hawaiian Ishlands. Thus, the Anahulu rockshelter evidence reinforces the interpretations of Olson and James (1982) that there were massive reductions in the resident populations of seabirds in the main Hawaiian Islands during the period of Hawaiian occupation. Also of note are the several species of native land birds represented in the rockshelter assemblages, most of which are today either extinct on O'ahu, or threatened with extinction. It would appear that exploitation of these forest birds was one activity of the rockshelter occupants throughout the prehistoric period.

REFERENCES CITED

Goldman, I. 1970. *Ancient Polynesian Society.* University of Chicago Press. Chicago.

Hommon, R.J. 1976. "The Formation of Primitive States in Pre-Contact Hawaii." Ph.D. Dissertation, Univ. of Arizona. (University Microfilms.)

_____. 1986. Social evolution in ancient Hawaii. In P.V. Kirch, ed., *Island Societies: Archaeological Approaches to Evolution and Transformation*, pp. 55-68. Cambridge University Press.

Kamakau, S. 1961. *Ruling Chiefs of Hawaii.* Kamehameha Schools Press. Honolulu.

Kirch, P.V. 1979. *Late Prehistoric and Early Historic Settlement-Subsistence Systems in the Anahulu Valley, O'ahu.* Anthropology Dept. Report 79-2. B.P. Bishop Museum. Honolulu.

_____. 1985. *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory.* University of Hawaii Press. Honolulu.

Olson, S., and H. James. 1982. *Prodromus of the Fossil Avaifauna of the Hawaiian Islands.* Smithsonian Contributions to Zoology 365. Washington, D.C.

Sahlins, M. 1958. *Social Stratification in Polynesia.* American Ethnological Society. Seattle.

Sahlins, M., and P.V. Kirch. in prep. *Anahulu: The Archaeology of History in the Early Sandwich Islands Kingdom.*

Stuiver, M., and B. Becker. 1986. High-precision decadal calibration of the radiocarbon time scale, A.D. 1950-2500 B.C. *Radiocarbon* 28(2B):863-910.