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MAKAI--MAUKA:

FISHING AND FARMING ON THE ISLAND OF HAWAII

IN A.D. 1778

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN ANTHROPOLOGY

AUGUST 1970

By

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Dissertation Committee:

Richard Pearson, Chairman
Bion Griffin
Samuel Elbert
John Maciolek
Yosihiko Sinoto
Roger Green

PREFACE

This study is not a traditional archaeological site report, but rather a multi-discipline synthesis of native Hawaiian fishing and farming practices on Hawaii Island. Data from archaeology, historical sources, marine biology, geophysics, botany, and general ecology have been brought together to reconstruct the interaction of the Hawaiian with his environment prior to the influence of European culture. No raw data are included but data summaries appear as appendices.

Every attempt was made to present this report in a fashion understandable to all interested people; specialized terminology was consciously avoided wherever possible owing to the multi-disciplinary approach used. If a particular shade of meaning required the use of a technical term, every attempt was made to define the term when introduced. Hawaiian place names are spelled according to current local practice; all other Hawaiian words are spelled with glottals and macrons according to Pukui and Elbert (1965).

The basic archaeological data stemmed from field work during the 1968 Lapakahi Project, funded by the Division of State Parks, a National Science Foundation Undergraduate Research Participation Grant, and the University of Hawaii Summer School. A National Science Foundation Doctoral

Dissertation Improvement grant and support by the Division of State Parks ensured adequate funding for laboratory analyses.

This report rests upon the labors of many individuals and organizations, working in concert to further the knowledge of our Hawaiian heritage. It would be nearly impossible to acknowledge the contributions of all who took part in the field work and analyses of the 1968 Project and only a few may be mentioned.

Foremost would be the field crew of students, volunteers, and supervisors who carefully extracted the basic archaeological information from the sites at Koaie and Apaapaa 1 during the summer of 1968. Special thanks must go to Mike Seelye who competently supervised major portions of the field excavations; Paul Rosendahl for excellent mapping and tending to logistic details; Rob Hommon for help in designing the recording system used to log the field work information; Madge Schwede for her constant records checking for completeness and accuracy; and Ginger Newman for supervising the Field Laboratory with competence.

The people of North Kohala supported the field work with their interest and sustaining help; particularly Yoshio Kawamoto of Parker Ranch, who devoted much of his time to guiding us through the area; Charlie Christensen who gave valuable help in identifying midden remains and artifacts as well as guiding us through the area; and

Richard Smart of Parker Ranch who supported the Lapakahi research by kindly granting permission to excavate and cross his land. Librarians, hotel owners, storekeepers, and garage owners all contributed to the success of the project by their continual support.

Francis Ching and Mr. J. Souza of the Division of State Parks maintained a close liaison with the field crew and were immensely helpful in accelerating shipments of equipment and supplies from Honolulu. Peter Miles of the R. M. Towill Corporation supervised the preparation of aerial photogrammetry and the construction of the excellent base maps used extensively in the field. Ed Norum arranged for the Kohala Sugar Company to donate the use of a diesel back-hoe to excavate in the field section of Lapakahi and, with his daughters and Carol Sugiyama, spent many hours in the driving rain helping to analyze the trench profiles. Mr. Edwin Murabayashi made two field trips to Lapakahi to develop his very thorough analysis of the field system and Don Kelso spent three days investigating the marine resources of Koaie.

The efficiency and competence with which the laboratory analyses of midden components were completed is due to a number of specialists who worked on them: Don Kelso aided in identifying sea urchin remains; Hank Snider methodically identified some one hundred pounds of shell fragments; Stan Swerdloff identified all fish remains; and Alan Ziegler identified all mammal, bird, and turtle bones.

Special thanks must go to John Belshe who unsparingly gave of his time in designing and debugging computer programs used to process the data. Likewise, Lorraine Wu and Shirley Imamoto aided in the computer work by key-punching immense numbers of cards and carrying them back and forth from the computing center.

A very special role, and one often forgotten in acknowledgements, was played by Donald Kong, the Fiscal Officer with the University who unraveled snarled accounts and cut through administrative red tape to ensure the success of the project.

A vast number of people and organizations contributed to the completion of this work by providing access to library materials, and sending copies of articles needed for the analyses: The Hawaii and Pacific Room librarians of Sinclair Library, Margaret Titcomb of the Bishop Museum Library, Agnes Conrad of the State Archives, the Bureau of Commercial Fisheries, the Institute of Marine Biology, the National Archives, and the Department of Geophysics.

Gerald Holland who courageously read the entire manuscript and acted as Devil's Advocate must be given special recognition and heartfelt thanks. Peggy Recania, Diane Arakawa, Dayna Shimabukuro, and Jackie Marquard all spent many hours typing the manuscript. Rodney Shimabukuro carefully and competently produced the maps, tables, profiles, and artifact drawings. His excellent graphics greatly aid in understanding this report.

The one person who consistently provided the most help throughout the laboratory analyses and during the writing was Lena Sekido, my assistant; without her help this report would have been shorter, less detailed, and much less thorough.

Finally, the continued support and understanding of my family provided me with both the reason and drive to complete this project.

ABSTRACT

Hawaiian fishing and farming practices, demography, and the limiting factors of the Hawaiian ecosystem are reconstructed for the post-European contact period of Hawaii Island. The historical approach is used to differentiate between native and introduced patterns of land and sea exploitation while an ecological approach indicates the environmental limiting factors. All are correlated with archaeological data from the Lapakahi Project in an application of the direct historical approach in archaeology to reconstruct Hawaiian land and sea exploitation patterns truly native and pre-European. The interaction of man and nature in early Hawaii is illustrated through this analysis.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

CHAPTER I

INTRODUCTION

Scholars have attempted to trace the origin of the Hawaiians for at least the past one hundred years. Only within the last decade has there been general agreement that Marquesan settlers became the first human inhabitants of the Hawaiian Islands, probably between the seventh and ninth centuries A.D. This concept, that a group of voyaging Polynesians could become the first humans in an entire island chain, raises some intriguing questions:

(1) What were the Islands like before man arrived?

(2) How did the first settlers and their later descendants exploit the Hawaiian flora and fauna for food?

(3) How might the Hawaiian and his culture affect (and be affected by) the nature of the Hawaiian environment?

A concern with these last two questions led to this attempt to outline the relationship between man and nature in aboriginal Hawaii, as shown by a study of fishing and farming practices. Available summaries in this field are inadequate for reconstruction of native Hawaiian subsistence techniques as they present a mix of native and European exploitation patterns. The extent to which historic European diffusion changed Hawaiian culture has only been appreciated in the last few decades, primarily through the writings of Kelly (1956, 1967), Barrere (1961, 1967, 1969), Rohsenow (1967), and Davenport (1969). With mounting evidence of widespread historic change in many aspects of native Hawaiian culture, it is necessary to analyze the historic literature on fishing and farming in the Islands.

The use of the historical approach to develop a series of reconstructions for Hawaiian exploitation patterns at particular periods in the historic era makes it possible to detect traits which result from European diffusion. Only when the truly native traits have been determined is it possible to correlate these with the archaeological data. Then reconstructions of prehistoric patterns may be generated through applications of the direct historical approach in archaeology (cf. Hawkes 1959).

The historical literature must also be studied to detect changes in the environment due to European influences in order to separate these from any environmental change caused by native exploitation practices. A major goal of this paper is the delineation of man-nature relationships in aboriginal Hawaii. This is to be accomplished by following an ecological approach to show the characteristics of nature in Hawaii that both influenced and were influenced by native culture. This paper, therefore, concerns itself with:

(1) reconstructing the native exploitation practices for extracting subsistence from the land and the sea in Hawaii at or just before the time of European contact;

(2) the character of those parts of nature being exploited, and

(3) especially the factors lying behind the development of particular interaction patterns between man and nature in Hawaii.

Such a theme is truly ecological for "ecology" is the study of relationships in nature; of living organisms to one another and to their non-living, or abiotic, environment. Ecological analysis is as applicable to the study of man as to the study of birds or snails, for man is a part of nature despite his feeling that culture makes him something special.

Cultural Ecology

There is a distinction, however, between ecology as practiced by biologists and that traditionally practiced by social scientists; the latter have tended to view the interrelationships of man and nature primarily in terms of the articulation of culture and environment. In particular, the cultural ecologist has approached the study of man and nature in this fashion; he disregards the fact that man, as a living creature, interacts with his environment in other than cultural ways. This restrictive viewpoint initially split the ecology of the social sciences from that of the biological sciences; sustaining a whole series of debates between "determinists," "possibilists," advocates of specific cultural history or historical particularism, and "cultural ecologists" (cf. Vayda 1965; Vayda and Rappaport 1968; and Geertz 1968 for critical summaries of these arguments). After this split, biological ecologists progressed through a series of conceptual levels to the development of very powerful interpretive models; unfortunately these were generally ignored by social scientists who held that man is unique in having culture and hence is not subject to the generalizations developed in general ecology.

Even if man does react to nature primarily through the vehicle of culture, the stimulus to react is based in his biology. Man can thus be studied within the framework of general ecology, especially if his culture is considered a biological adaptation, albeit unique (cf. Spuhler 1959:12). Acceptance of this theory has resulted in a recent trend in the social sciences to apply the generalizations of general ecology to the study of man. This study is a continuation of such efforts.

General Ecology

The Ecosystem Concept

Perhaps the most important interpretive model to have been developed in general ecology that is now being applied to studies of man in nature is that of the "ecosystem." The ecosystem concept provides a conceptual scheme for studying the patterns of interaction between a number of interrelated variables, really a forerunner to the much discussed "systems analysis" technique. Odum defines the ecosystem as:

> Any area of nature that includes living organisms and nonliving substances interacting to produce an exchange of materials between the living and nonliving parts . . . (1959:10).

He further says that:

> The ecosystem is the basic functional unit in ecology, since it includes both organisms (biotic communities) and abiotic environment, each influencing the properties of the other . . . (1959:11).

The concept of the ecosystem is applicable at many levels of interpretation: from the ecosystem of the universe to the ecosystem of a drop of pond water on a microscope slide; from the interactions of all living organisms within a particular geographical province with their abiotic environment, to the ecosystem of the human skin (Marples 1969). This concept embraces four basic ideas:

(1) a definition of provenience, geographical or otherwise (e.g., the human skin);

(2) living organisms of all levels, from microbe to whale;

(3) the non-living or abiotic environment which includes, but is not limited to, such factors as water, gases, geological formations of soil, rock and minerals, rainfall patterns, temperature and insolation; and

(4) patterned relationships within and between all components.

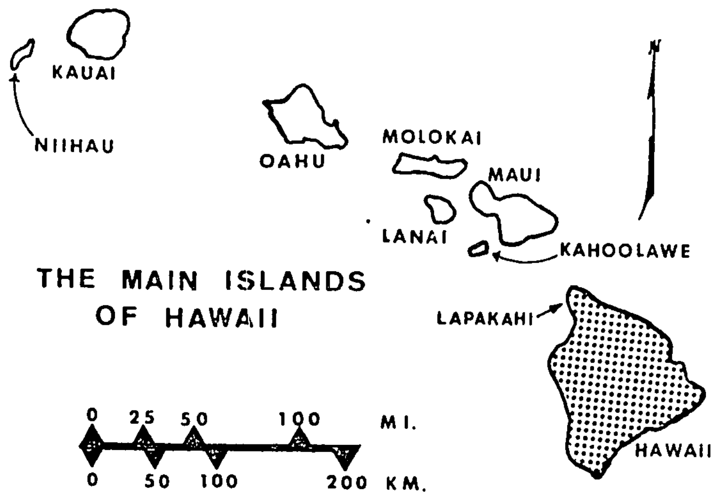
Fosberg says that the goal of describing an ecosystem may be approached through a study of its:

> . . . spatial relations; inventories of its physical features, its habitats and ecological niches, its organisms, and its basic resources of matter and energy; the nature of its losses of matter and energy; and the behavior or trend of its entropy level (1963:2).

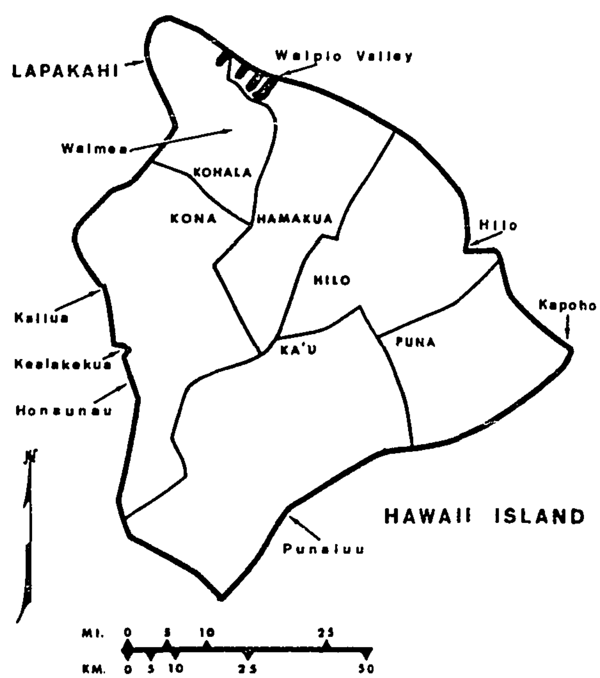
Only with a careful analysis of these factors and their relation to Hawaiian and Hawaiian culture comes an accurate understanding of the interaction between man and nature there. It then becomes possible to illustrate some of the ways in which the Hawaiian both affected and was affected by the Hawaiian ecosystem, of which he and his culture were a part.

Approach to be Used

Chapter II, therefore, begins with a discussion of salient, and presumably regulating factors within the general Hawaiian ecosystem (Map 1) before focusing on


KAUAI
NIIHAU
OAHU
MOLOKAI
MAUI
LANAI
KAHOOLAWE
THE MAIN ISLANDS OF HAWAII
LAPAKAHI
HAWAII
0 25 50 100 MI.
0 50 100 200 KM.
N

MAP 1

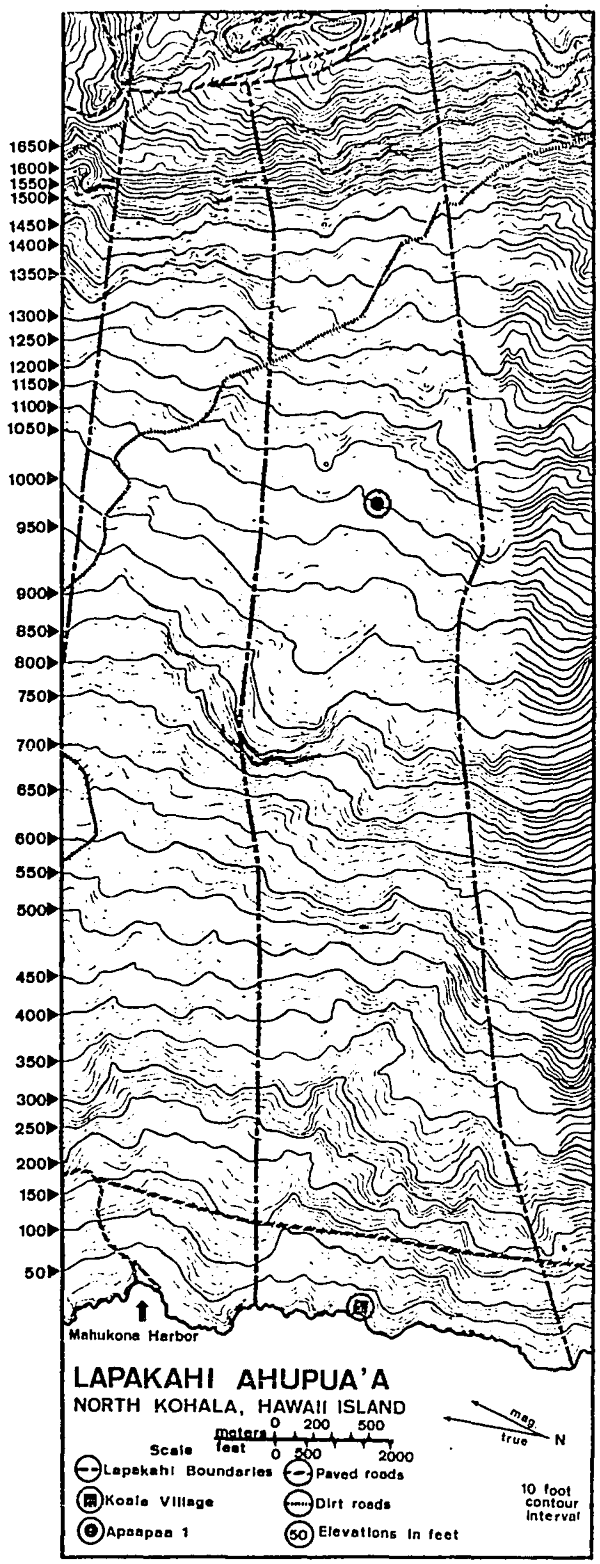

LAPAKAHI
Waipio Valley
Waimea
KOHALA
KONA
HAMAKUA
Hilo
HILO
Kapoho
Kailua
KA'U
PUNA
Kealakekua
Honaunau
HAWAII ISLAND
Punaluu
N
MI. 0 5 10 25
KM. 0 5 10 25 50

MAP 2

Hawaii Island (Map 2) and the Lapakahi area of North Kohala where field research was conducted (Maps 3 and 4). Only those factors are covered that appear to have affected Hawaiian fishing and farming to a major degree. This chapter provides the basic environmental information for the general ecological approach taken throughout the rest of the discussions.

Chapter III begins the historical approach to a study of Hawaiian maritime adaptations by reconstructing exploitation patterns at different post-European periods on the basis of the historical literature. This allows the isolation of exploitation practices and devices that were imported to Hawaii after European contact. The remaining patterns are seen to be authentically Hawaiian and these are correlated with the environmental factors of Chapter II in an application of the ecological approach. The last portion of Chapter III deals with specific functions of Hawaiian fishhooks within the broad picture of Hawaiian maritime exploitation.

Chapter IV is an application of the direct historical approach in archaeology where the archaeological data from the Koaie and Apaapaa 1 sites (Maps 3 and 4) are correlated with the general Hawaiian sea exploitation patterns developed in Chapter III. A reconstruction of maritime exploitation patterns at Koaie is then made on the basis of these correlations.



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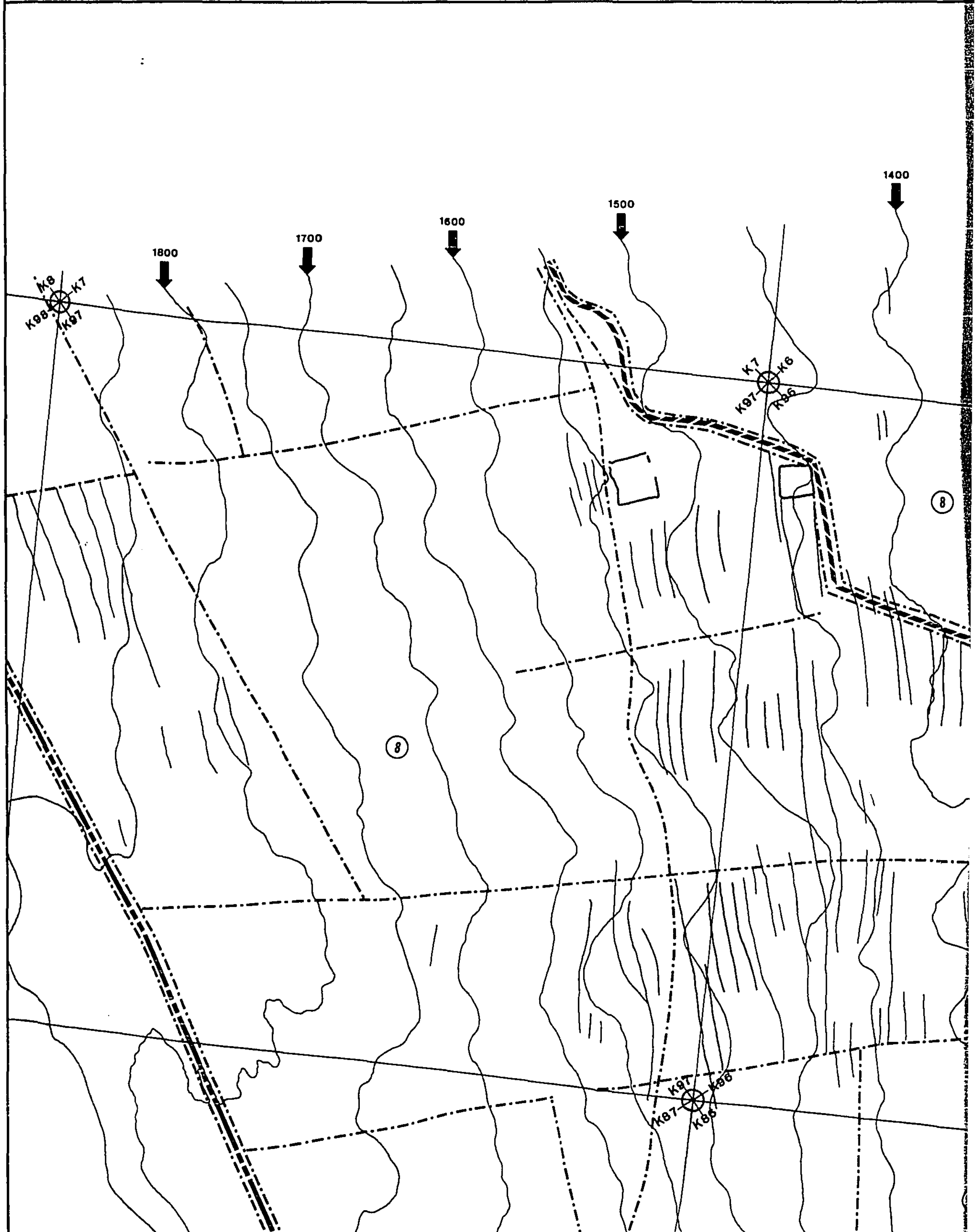
Mahukona Harbor
LAPAKAHI AHUPUA'A
NORTH KOHALA, HAWAII ISLAND
mag.
true
N
Scale
meters 0 200 500
feet 0 500 2000
Lapakahi Boundaries
Paved roads
Koaie Village
Dirt roads
Apaapaa 1
50 Elevations in feet
10 foot contour interval

MAP 3

ARCHAEOLOG

NO

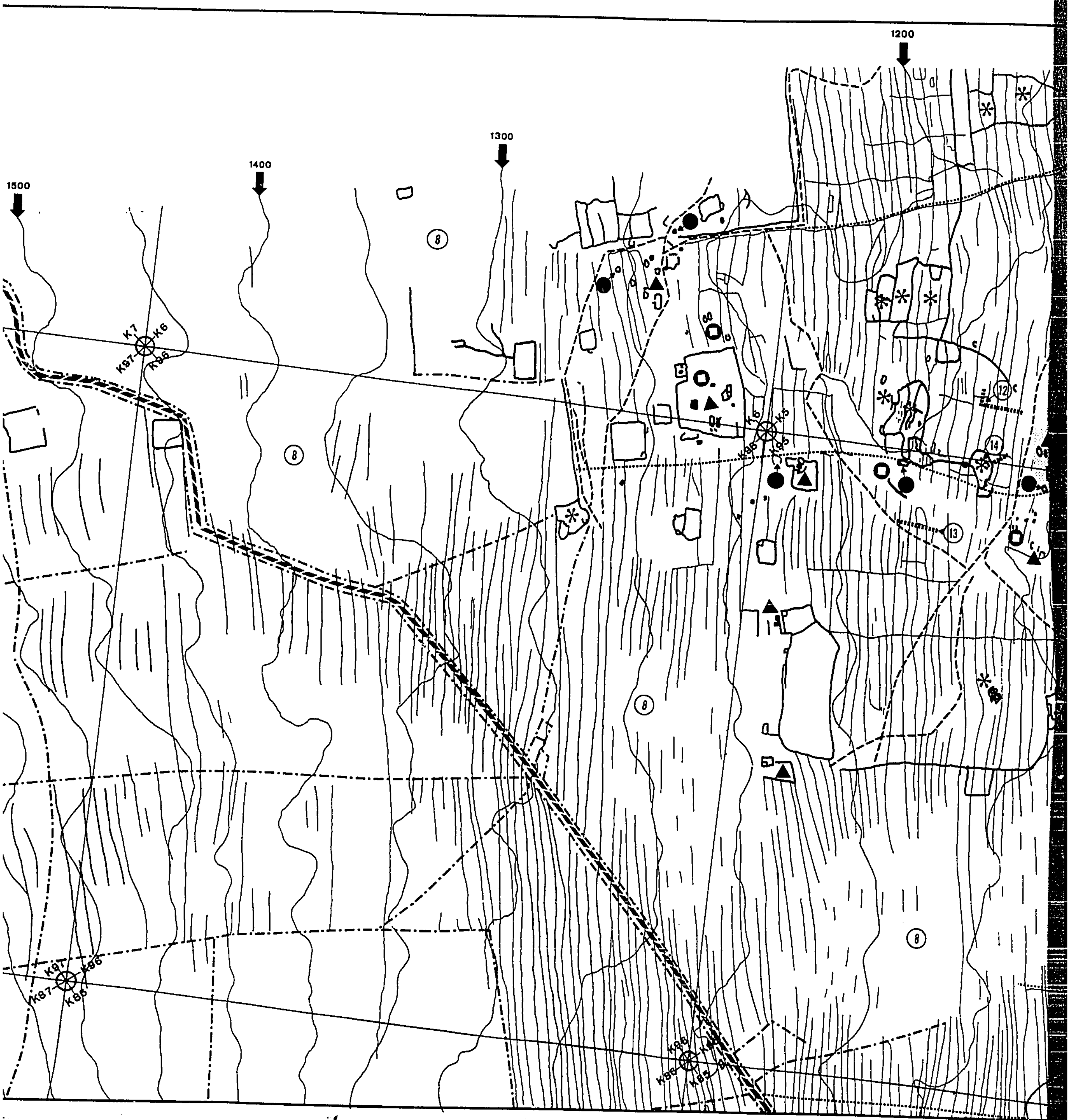
MAP



ARCHAEOLOGICAL FEATURES OF LA

NORTH KOHALA DISTRICT, ISLAND

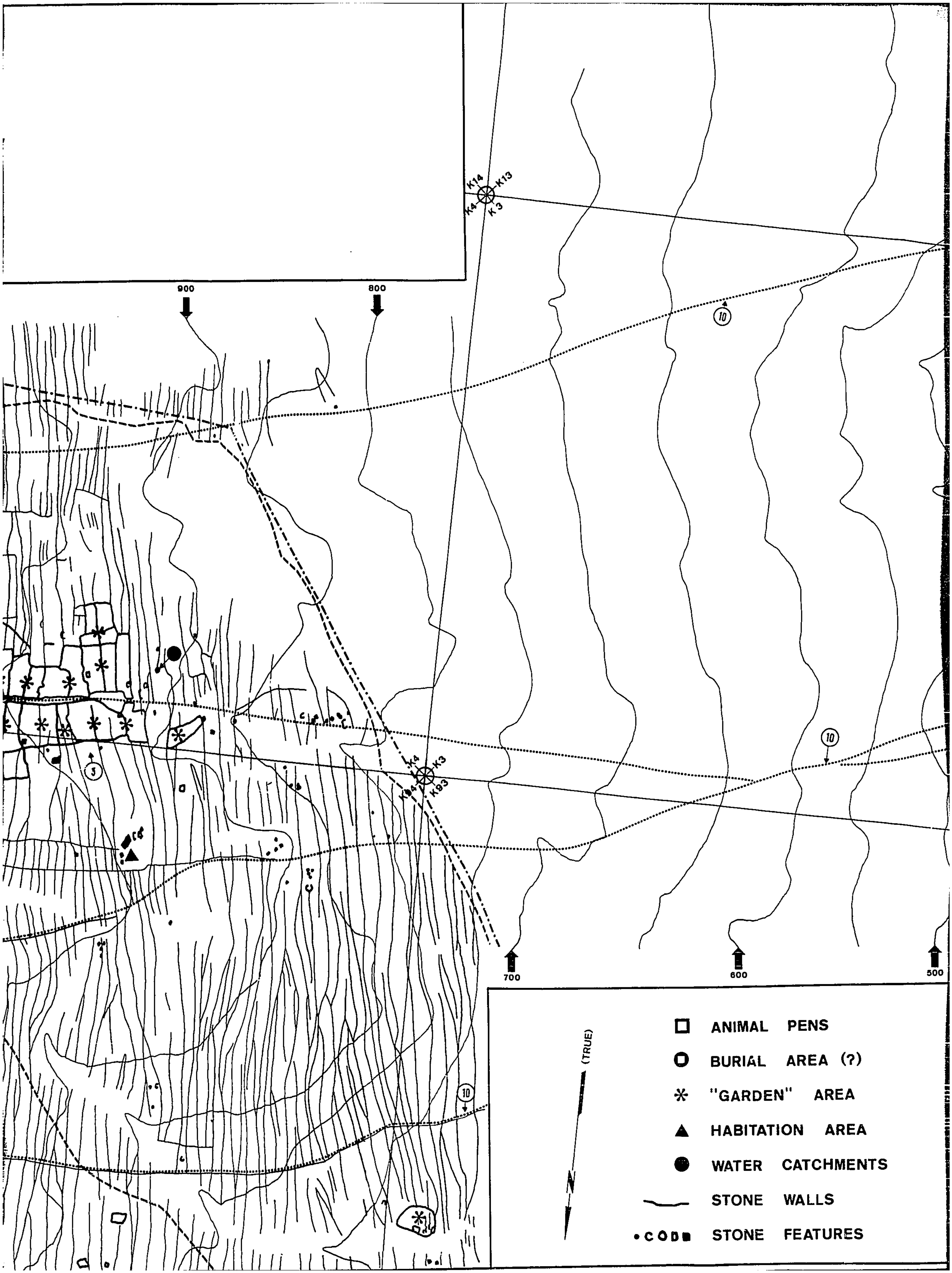
MAP BASED ON AERIAL PHOTOGRAMMETRY AND GR



OF LAPAKAHI AHUPUA'A

CT, ISLAND OF HAWAII

RAMMETRY AND GROUND SURVEYS



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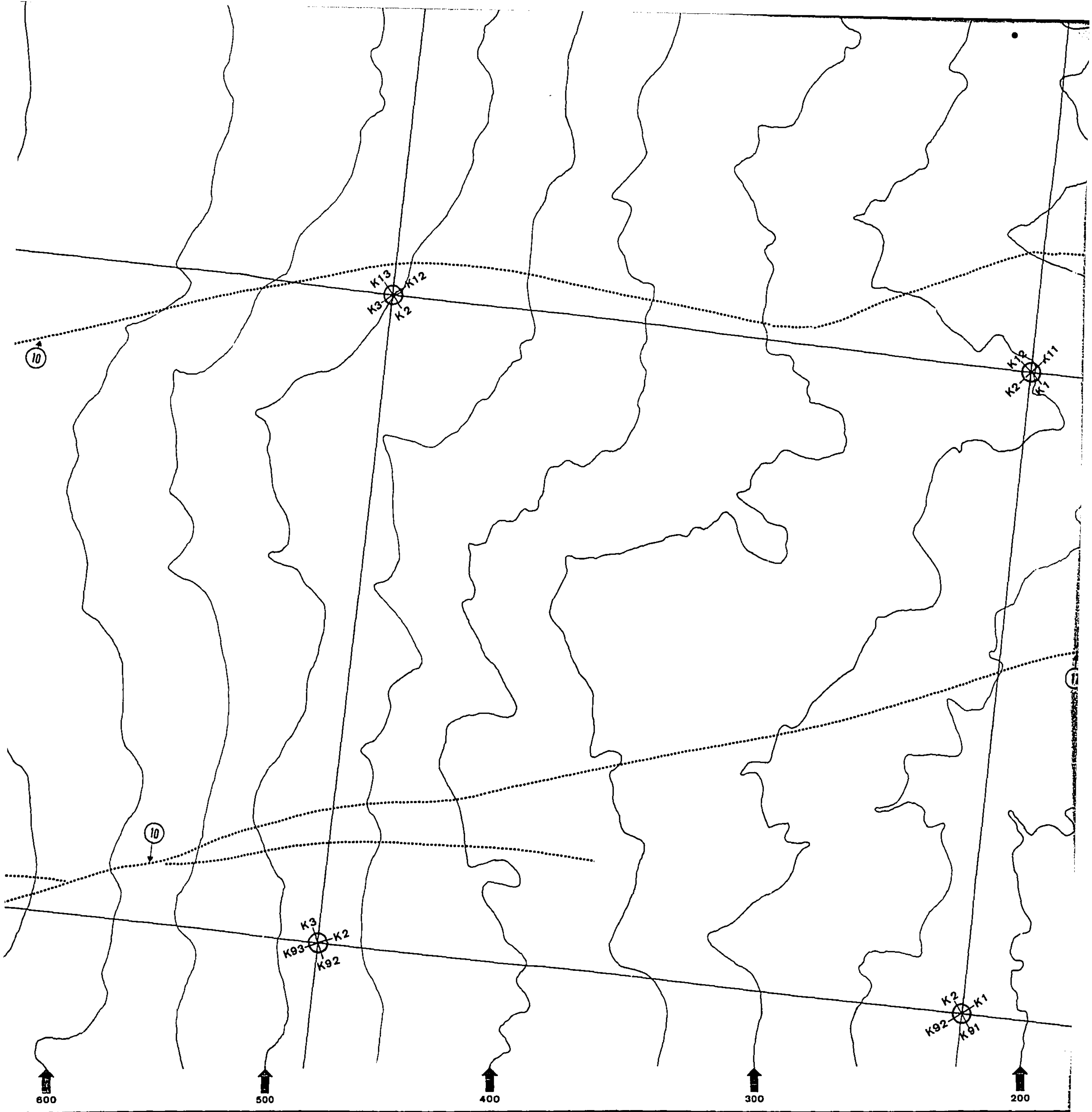
ANIMAL PENS
BURIAL AREA (?)
"GARDEN" AREA
HABITATION AREA
WATER CATCHMENTS
STONE WALLS
STONE FEATURES



ANIMAL PENS
BURIAL AREA (?)
"GARDEN" AREA
HABITATION AREA
WATER CATCHMENTS
STONE WALLS
STONE FEATURES

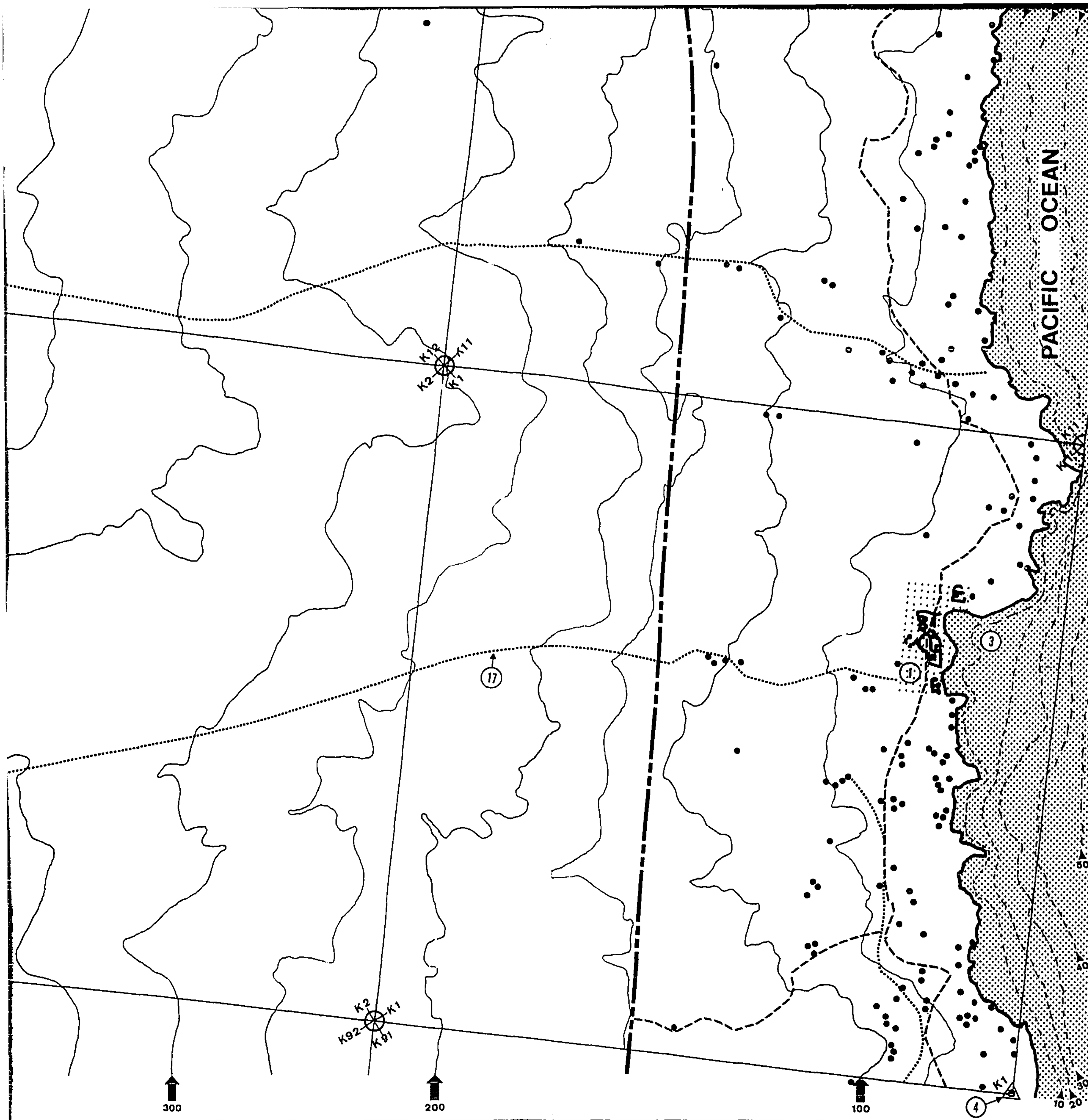
PAVED HIGHWAYS
DIRT ROADS
BULLDOZED JEEP ROADS

OLD WAGON / HORSE TRAILS
FENCES
FIELD TRENCHES

FIELD BORDERS

SCALE METERS 0 100 200 300 400 500
YARDS 0 100 200 300 400 500

MAP SIZE IS APPROXIMATELY 1 BY 4 MILES



OLD WAGON / HORSE TRAILS (?)

FENCES

DS

FIELD TRENCHES

ELD BORDERS

100 200 300 400 500

100 200 300 400 500

PROXIMATELY 1 BY 4 MILES

APAAPAA 1 SITE

KOAIE SITE

FEATURES DISCUSSED IN TEXT

KILOMETER GRID

MAHUKONA LIGHTHOUSE

CONTOUR LINES (FEET)

UNDERWATER CONTOUR LINES (FEET)

Chapter V begins the historical approach to an analysis of Hawaiian farming by reconstructing land use on Hawaii Island on the basis of observer accounts. These reconstructions are then correlated with environmental information to outline the interaction between Hawaiian farming techniques and particular facets of the Hawaii Island environment; again an application of the ecological approach. Archaeological data from Kealakekua Bay and the Lapakahi area are then interpreted in terms of this overall picture of native farming on the Island of Hawaii.

The general approach of this paper is to correlate historical, ecological, and archaeological data into a reconstruction of native Hawaiian sea and land exploitation at the time of first European contact. The overall goal is to illuminate the interaction of man and nature in Hawaii under native culture.

CHAPTER II

THE GENERAL HAWAIIAN ECOSYSTEM

An encyclopedia will give a multitude of geographical statistics for the Hawaiian Islands but this discussion is closely limited to those which regulate man's exploitation practices. The atolls and pinnacles northwest of Niihau are excluded for they were uninhabited except for meager settlements at Nihoa and Necker (Emory 1928), and present a more specialized problem. This limits the geographical coverage to the major islands of Niihau, Kauai, Oahu, Molokai, Lanai, Maui, Kahoolawe, and Hawaii; all larger Islands comprising the southeastern one-third of the whole Hawaiian chain. To facilitate focusing upon salient environmental factors, this general Hawaiian ecosystem will be discussed first in terms of its marine component and second in terms of the land component.

The Hawaiian Marine Ecosystem

Topography

A geographical parameter of major import is the volcanic building process by which these Islands were built up from the ocean bottom. Underwater volcanic lava flows consolidated to form relatively steep-sided Island bases for all of the Hawaiian Islands, bases built up through some 15,000 feet (4,572 meters) of water. These Island bases are less than 150 miles (240 kilometers) in width at the bottom, yielding an average underwater slope of 2,000 feet per mile (380 meters per kilometer). This steep underwater gradient creates a very narrow band of shallow water surrounding each Island, a factor of major importance to Hawaiian fishing.

Data presented in Chapter III indicate that the maximum depth to which the Hawaiians were able to fish was 1,200 feet (366 meters) below the surface; the water area of the Hawaiian Islands of depths less than this figure is extremely limited. An example of this may be seen in Map 14 where the 1,200 foot (366 meter) underwater contour is plotted for Hawaii Island. There are only about 500 square miles (810 square kilometers) of inshore waters surrounding Hawaii Island less than 600 feet (183 meters) in depth (Bryan 1954:4). If the slope from the 600 to the 1,200 foot contour is about the same as from 0 to 600 feet the maximum ocean area usable for sub-surface angling around Hawaii Island is roughly 1,000 square miles (1,600 square kilometers). The actual area exploited by native fishermen would undoubtedly have been greatly less because of bottom conditions, water currents, swell systems, and inadequate habitat conditions to support the types of marine life normally exploited by the Hawaiians.

Basic Marine Habitats

The effect of this geological feature on the marine biota is seen in the division of the waters surrounding the Hawaiian Islands into three basic habitat types: the pelagic, benthic, and inshore or reef area, each with its characteristic fauna. The pelagic habitat, quite uniform in temperature and salinity, ranges from the surface to perhaps 600 feet (183 meters) in depth and is located in the open sea offshore from the Islands (Gosline and Brock 1965:6). Comparatively few species of fish are found in the pelagic habitat and those exploited by the Hawaiians were surface feeding carnivores such as mālolo, 'ahi, aku, ono, mahimahi, and kākū (see Appendix A for the scientific names for these and all other marine biota). There is also an inshore pelagic (neritic) zone, defined by Gosline and Brock (1965:7) as the upper water layers where the total depth is less than 600 feet (183 meters) in depth. In this sub zone are often found the usual pelagic species as well as others restricted to this zone, such as the akule, 'ōpelu, and kawakawa.

The benthic, or bottom habitat, is the sea floor at depths from 180 to 900 feet (55 to 274 meters) in which the fish fauna is only poorly known (Gosline and Brock 1965:7).

The inshore or reef habitat extends from the above surface splash and surge pools to a depth of about 180 feet (55 meters) (Gosline and Brock 1965:5). As noted above, this area is quite limited in extent in the Hawaiian Islands because of the steepness of the underwater base. Only in embayed areas such as Kaneohe Bay on Oahu does the horizontal extent of the zone exceed one-half mile (.8 kilometers). The largest marine biomass is found in this inshore habitat and it was the habitat most extensively exploited by Hawaiians, as will be shown in Chapter III.

Reefs

A second factor of great importance is that reef-protected areas are not common in Hawaiian waters. Shallow water areas where coral is dominant were found in only about one-third of the areas surveyed by the Hawaiian Fish and Game Division during submarine fish transects (Gosline and Brock 1965:8). The only barrier reef found in the Islands is a small one in Kaneohe Bay, Oahu, while the rest are of a discontinuous fringing type, varying in presence, size, and depth by geographic position (Moberly and Chamberlain 1964:10-11). Yet, as will be pointed out in Chapter III, reefs were areas of major maritime exploitation. Since the distribution and physical characteristics of reefs largely control the types of marine fauna in an area, the Hawaiian exploitation practices were closely linked to the type and location of reefs.

Wave Action and Habitats

Another major abiotic factor affecting Hawaiian exploitation practices was wave action, a primary habitat parameter for much of the Hawaiian marine biota (cf. Gosline and Brock 1965:10-13; Gosline 1965). Four vertical habitats may be delimited in the inshore area on the basis of wave action: the supra-surge zone, the surge zone, the reef protected zone, and the sub-surge zone (Gosline and Brock 1965:10-15).

The supra-surge zone lies above mean water level and consists of pools filled by spray or intermittent wave action. Few fish exploited by the Hawaiians live in this supra-surge zone although it was probably a major shellfish exploitation zone, particularly for 'opihi. The surge zone itself is an area with much horizontal water movement through wave action. Most of the fish in this zone are herbivores such as surgeonfish and parrot fish, with the most usual predator a species of wrasse. The surge zone extends from the surface to some 10 to 25 feet (3 to 8 meters) in depth in protected areas and down to over 65 feet (20 meters) in exposed areas. The calm sub-surge zone has the largest fish population; the distinction between the surge zone and the top of the sub-surge zone is quite marked on a populational basis. The reef-protected zone is likewise a calm water area of great fish biomass distinct from the sub-surge zone primarily on the basis of depth.

Swell Systems

These zones vary in size and distribution on the basis of the swell system involved for the swell systems striking the islands differ in azimuth, intensity, and periodicity.

Swells in Hawaii consist of four broad types:

(1) the northeast trade waves,

(2) the southern swell,

(3) the North Pacific swell, and

(4) the Kona storm waves (Moberly, Baver, and Morrison 1965:590).

These wave systems are primarily caused by surface wind patterns which in turn are controlled on a seasonal basis by meterological pressure cycles. Various combinations of these wave systems may be present at any one time, but generally the dominant system during the months of April to November is the northeast trade swell. This system is present from 90 to 95 percent of the time from April to November and from 55 to 65 percent of the time from December to March (Chamberlain 1968:181). It impinges on the northeast or windward coastline, producing strong and consistent wave action resulting in a windward enlargement of the supra-surge and surge biotic zones. For example, the 'opihi is a shellfish particularly adapted to the supra-surge zone (cf. Kay 1969); it is noticeably more prevalent along rocky windward coastlines.

The southern swell is felt in the Islands about 53 percent of the time from April through October, striking exposed southern and southwestern coasts. Kona storm waves are short-term waves generated by low pressure storm systems near Hawaii; they roll in from the south and southwest some 9 percent of the year, usually during the winter months. The North Pacific swell is produced by storms in the northern Pacific and are often the largest waves to reach Hawaii. They occur primarily from October to May along northeast to northwest exposures (Chamberlain 1968: 181-182). These last three wave systems are not as constant and have less effect than the northeast tradewind swell system in producing large and consistent supra-surge and surge habitats. They are important because they transform inshore bottom habitats by a periodic movement of sand deposits (Chamberlain 1968).

These different swell systems cause a horizontal zonation around the Islands on the basis of swell action. The largest, most consistent, and generally highest energy packed waves flow against the windward (eastern) coastline while swell action is much less pronounced along leeward (western) shores.

Upwelling

Wind action over the leeward shore probably also results in the production of minor upwelling, generating vertical water currents by surface friction, bringing up the colder and nutrient-laden lower waters. Although this phenomenon is most pronounced along the leeward coasts of continental land masses (Ryther 1969:73), it quite likely occurs along the leeward coast of the Hawaiian Islands as a "micro-upwelling" condition and makes a horizontal differential in available marine nutrients between the leeward and windward areas.

Biomass Differential Between Leeward and Windward Sides

There is a distinct possibility that a biomass differential exists between the windward and leeward sides of the Islands which may be explained in part by upwelling. Direct support for this thesis, moreover, comes from the observation of Gosline (1965:829) that relatively few carnivores are to be found in areas affected by wave or surge action; rather they are found in the deeper, unaffected waters where they presumably have a larger trophic-level biomass upon which to feed. Since more of the relatively short shallow-water slope of the Island base is taken up with supra-surge and surge zones on the windward sides, it would seem reasonable to assume that a larger sub-surge zone exists on the leeward side, and hence more carnivores. Obviously, where more predators are present there must be a larger supporting lower trophic level upon which they feed.

Secondly, the total number of species present is greater in the sub-surge zone than in the surge zone, and although this is not a direct measure of biomass, it is indicative. The long-term pounding of the trade wind swell system against the windward coast results in a further reduction of the windward total shallow water zone causing a lower marine biomass to windward. Finally, the leeward waters of Molokai and Maui lie over a shallow water area, for Molokai, Maui, Lanai, and Kahoolawe are remnants of a once contiguous Island mass, since submerged, leaving relatively shallow water saddles between these Islands. This shallow area is to windward of Lanai and Kahoolawe, but these Islands are relatively well sheltered from trade wind effects by the mountains of Molokai and Maui. Historical studies also show that most fishing tended to take place along the leeward coastlines although this may have also been due, in part, to the difficulties of fishing in the rough waters of the windward shores. For example, little fishing was described by Ellis (1963) for the windward coastline of Hawaii Island in 1823 while it was very important in leeward areas.

Bottom Conditions

Other biotic marine zonation occurs in Hawaii on the basis of underwater topography and bottom conditions. Each type of bottom, such as sandy, muddy, silty, coralline, or rocky, will support a distinctive assemblage of both fish and invertebrates. This is most pronounced with shellfish where gastropods are generally found under clear, unsilted conditions while Lamellibranchia [bivalves or pelecypods] are primarily adapted to silty and more polluted conditions (Doty 1968:15). The gastropod/lamellibranch ratio is quite important for it is a direct indication of habitat characteristics and might be used as an indication of land conditions, which generally are the cause of silting. This could help measure the degree of land degradation from aboriginal agriculture. Erosion and land degradation may be indicated if the ratio varies from the typical 82 percent gastropods to 18 percent lamellibranchs (Kay 1967:98) toward a higher percentage of lamellibranchs. Unfortunately, if archaeological midden deposits are used to determine this ratio it is necessary to interpret the ratio of a living assemblage from what is essentially a death assemblage (Boucot 1953), where the ratio may be skewed by human cultural preferences.

Summary

Distributions of marine biota, and hence Hawaiian sea exploitation practices, appear to be regulated by a combination of water depth, bottom morphology, and wave action generated by surface wind patterns.

The Hawaiian Land Ecosystem

Geology

Topography

A number of the same abiotic factors affecting marine biota and man's exploitation patterns are important environmental parameters of the land ecosystem. In particular, the nature of Island genesis and the resulting steep underwater slope of the Island base is a major factor in the land ecosystem, for the general terrain slope continues to be quite steep. This is indicated by the fact that over 50 percent of the land in the Islands lies at elevations in excess of 2,000 feet (610 meters) above mean sea level (Blumenstock and Price 1967:2) and it will be shown in Chapter V that 2,000 to 2,500 feet (ca. 600 to 750 meters) was in general the upper elevation limit for aboriginal agriculture. This single factor made half of the land area in Hawaii unsuitable for Hawaiian farming techniques.

Landscape Age

The age of the landscape is another major limiting factor in Hawaiian subsistence exploitation. Although the particular processes are of a long-range nature and beyond the present scope, the cumulative results do have a bearing of some consequence upon the distribution of Hawaiian irrigation systems. Irrigated taro agriculture is dependent upon an adequate and predictable source of surface water, normally from streams and rivers; such surface streams are commonly restricted to the heavily eroded valleys along high rainfall coasts. There are leeward (western) valleys with surface water and broad windward (eastern) valleys only on the older islands such as Kauai, Oahu, and West Maui. On young Islands, for example Hawaii Island, and newer portions of older Islands such as East Maui, valleys tend to have been formed only along the heavy rainfall areas of the windward coasts. On very young Islands, or young portions of old Islands, if there are irrigated agricultural systems at all they will be along the windward coasts. In particular, irrigated agriculture was found along the windward coast of Haleakala, Maui but not on its leeward side; the valleys of windward Kohala, Hawaii Island, had irrigated agriculture but not the leeward side. The lower windward flanks of Mauna Kea, Mauna Loa, and Haleakala have only small valleys (an indicator of geologic youthfulness) and probably had some irrigation, but size of the valleys alone would mitigate against any major population-carrying capacity for irrigated crops.

Similarly the soils of very young land areas are usually quite porous and virtually no surface water is present except in areas above the 100-inch isohyet. Thus, although rainfall is quite prevalent just to leeward of the summit in the high regions of Kohala, the surface waters percolate into the soil long before they reach the agricultural areas. Young terrain, therefore, can only support dry-land agriculture along slope or plateau lands.

Climate

Topography and landscape age are important in limiting the nature of Hawaiian land exploitation, but climate is of at least equal importance. The geological processes have provided the raw materials upon which Hawaiian agriculture is based, but it has been climatic factors that have molded and changed these raw volcanic materials into soil and provided adequate moisture, proper temperatures, and suitable sunlight levels to support plant life. These various factors, working in concert, limit the flora by determining the nature of the vegetation that can flourish under these conditions.

Hawaii owes its climate to its location in the northern portion of the Pacific Ocean tropics, in the northeast trade wind belt. This geographical location insures a fairly uniform day length which provides a dependable level of sunlight for agriculture and a relatively long, not particularly seasonal, growing period. Relatively constant day length contributes to the generally mild temperature regime at sea level for Hawaii and the lack of great seasonal temperature change. It is the combination of generally uniform solar energy levels and the geographical position of the Hawaiian Islands in mid-ocean that results in a lack of definite seasonality on the basis of sunlight levels and temperature; both of these factors are adequate for year-round crop growth for most types of plants in Hawaii. The Hawaiian Islands do have seasons but these are primarily dependent upon influences other than temperature and solar energy levels.

Seasons

Blumenstock and Price (1967:4) recognize two broad seasons in Hawaii: (1) winter, which consists of the months of October through April and (2) summer, consisting of the months of May through September. This division of the year places the warmer weather, period of predominant trade winds, and time of a general lack of storms in the summer. The windward areas tend to be cloudier in the summer because of the trade wind pattern while the leeward areas tend to be cloudier in the winter months owing to periodic storms (Kona storms) which tend to reverse the wind regime, and hence, the rainfall patterns (Blumenstock and Price 1967:8).

The agricultural seasons of the Hawaiians were slightly different, but were most likely dependent upon a combination of these factors and quite variable by geographical area. Thus, in the Kona area of Hawaii Island, the primary growing season would have been the winter months when adequate rainfall from frontal action and Kona storms tends to occur. Sunlight levels are not a problem for this area since it is well protected from trade wind generated clouds except at the higher elevations, generally above the agricultural zones.

Wind Action and Rainfall

Wave action caused by surface wind was of major importance in establishing biotic habitats in the sea. Likewise, wind is of paramount importance in establishing parameters for Hawaiian exploitation of the land ecosystem. Surface wind patterns greatly influenced Hawaiian agriculture by delimiting suitable crop habitats through regulating the amount, duration, periodicity, and type of moisture available to land areas.

The dominant wind pattern is that of the northeast trade wind which flows across this portion of the Pacific for 80 to 95 percent of the time during the months from May through September and some 50 to 80 percent of the time from October through April. The seasonal shift in trade wind frequencies is correlated with the North Pacific Low Pressure Area which is controlled by insolation, and, hence, shifts its position on a seasonal basis. Wind velocities over the ocean are highest in the summer trade wind period of May through September when they exceed 12 miles (19.3 kilometers) per hour some 50 percent of the time; from October through April the wind velocities are this high only 40 percent of the time. (Blumenstock and Price 1967:6).

The trade winds are usually less than about 10,000 feet (3,048 meters) in thickness, resulting in a sheet of wind moving across the ocean with relatively calm air above. A temperature inversion commonly occurs at an altitude of 5,000 to 7,000 feet (1,524 to 2,134 meters) and acts to hold the moisture laden lower portion of the trade wind sheet below that altitude. Cloud development in the Islands is normally restricted to altitudes below 7,000 feet over the ocean.

This dominant trade wind regime produces a rather brisk flow of air across the ocean surface which strikes the coastal areas along the northeastern shore at a direct azimuth and the north to northeast and southeast to south coasts somewhat obliquely. This moisture-laden air flows onto these coastlines, but the land mass shelters the opposite leeward coastline from the moist air. It is the interaction of wind and topography which induces most rainfall, which naturally falls on the windward areas.

Orographic Flow

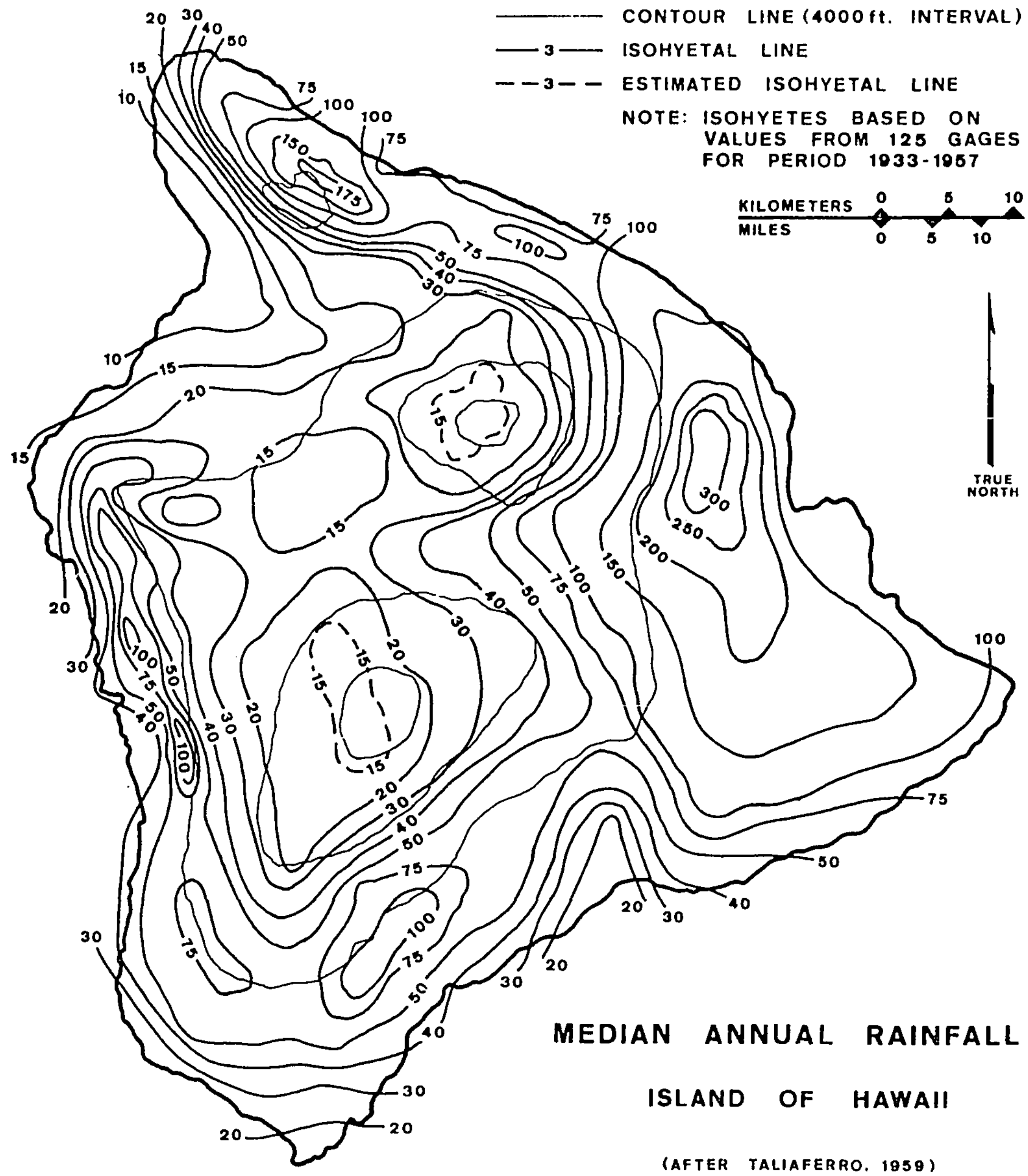
After flowing onto the land masses along their windward sides, the trade wind sheet is lifted through orographic action to higher altitudes where the wind mass either moves over the top of the land terrain in the case of low altitude land masses, or splits and flows around the flanks of the higher masses such as Mauna Kea and Mauna Loa on Hawaii Island and Haleakala on Maui. This action varies with the velocity and thickness of the trade wind sheet which sometimes splits around the lower masses or even goes over the tops of Mauna Kea, Mauna Loa, and Haleakala.

As the moist air is lifted and its temperature decreases, the relative humidity increases to the point of saturation and rainfall results. If the trade wind normally flows up and over the tops of the high terrain, rainfall is deposited up the entire slope to the summit and then a distance to leeward, this latter usually in the form of wind-blown shower activity. If the trade wind splits to flow around the high mountain masses, the rainfall increases rapidly with elevation to approximately 4,000 to 6,000 feet (1,220 to 1,829 meters) and then begins to decrease to extremely arid conditions in the area above the major trade wind flow. This latter phenomenon is restricted to Mauna Kea, Mauna Loa and Haleakala, for everywhere else in the Islands the trade winds generally flow over the summits of the land masses. The rainfall patterns for Hawaii Island may be seen on Map 5.

In terms of rainfall there is great variation in amount, nature, periodicity, and duration with respect to geographical location in relation to the trade wind and elevation. Hawaiian agriculture was in turn limited by these factors of moisture.

Rainfall and Soil

The type of soil was evidently not a very important limiting factor in Hawaiian agriculture for historical records show crops to have been grown on everything from



MEDIAN ANNUAL RAINFALL

ISLAND OF HAWAII

(AFTER TALIAFERRO, 1959)

MAP 5

lava to the finest of alluvial soils. The limiting nature of the soil seems to have been associated with its nutrient levels and these are directly correlated with rainfall. Continuous rains along windward areas produce leached soils poor in plant nutrients. This would certainly have been a major contributing factor, for example, to the marginal agriculture reported by Ellis (1963) during his journey of 1823 along the windward coast of Hawaii Island (Appendix H, points 21 to 30). The exception to poor windward soils would be where alluvial deposits are constantly incremented, or where flowing surface streams are used to irrigate taro paddy soils. Both of these conditions continually replace plant nutrients, allowing intensive agriculture.

Vegetation

The nature and distribution of vegetation depends upon the generative history of each plant type and upon the selective factors of climate, elevation, and soils. A basic distinction must be made between Polynesian and Post-contact period vegetation in Hawaii; the species composition and distribution patterns changed after European contact.

All vegetation, however, is governed by the basic interrelationships between moisture, temperature, sunlight, soils, and elevation. A series of vegetation zones synthesized by Ripperton and Hosaka (1942) on the basis of these interrelationships is shown in Table I and for Hawaii Island on Map 6.

TABLE I

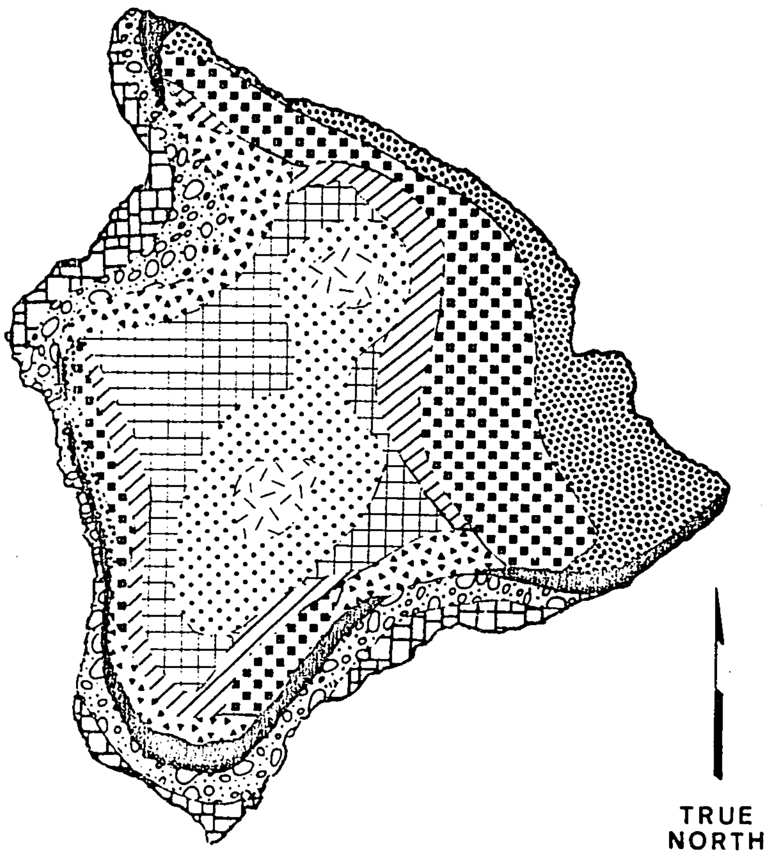
VEGETATION ZONES IN HAWAII[a]

Vegetation Zone	Elevation (feet)	Average Annual Rainfall (inches)	Great Soils Group	Indicator Plants
A	0-1000	20	Red Desert, Reddish Brown Low Humic Latosol, Lithosol	Kiawe, Feather Fingergrass, Swollen Fingergrass, Bristly Foxtail
B	0-3000	20-40	Low Humic Latosol, Reddish Brown, Reddish Prairie, Lithosol	Ekoa, Cactus, Guineagrass, Lantana, 'Ilima, Natal redtop
C_1	0-3000	40-60	Low Humic Latosol, Reddish Brown, Humic Latosol, Lithosol	Guava, Guineagrass, Yellow Foxtail, Lantana, Molasses grass
C_2	2500-4000	30-60	Latosolic Brown Forest, Reddish Brown, Reddish Prairie, Regosol, Lithosol	Kikuyu, White Clover, Puakeawe, Plantain, 'Ohelo, Koa
D_1	0-2000	60	Humic Latosol, Hydrol Humic Latosol, Lithosol	'Ōhi'a-lehua, Guava, Tree fern, Hilo Grass

TABLE I (continued) VEGETATION ZONES IN HAWAII

Vegetation zone	Elevation (feet)	Average Annual Rainfall (inches)	Great Soils Group	Indicator Plants
D_2	1000-2000	100	Hydrol Humic Latosol, Bog, Lithosol	Lobelia, 'Ohi'a-lehua, 'Ama'uma'u fern, Uluhe
D_3	2000-7000	60	Latosolic Brown Forest, Lithosol	Koa, 'Ōhi'a-lehua, Bracken fern
E_1	2000-4000	40	Latosolic Brown Forest, Lithosol, Regosol	Koa, Māmane, Puakeawe, Lovegrass
E_2	4000-9000	25-50	Lithosol, Latosolic Brown Forest	Māmane, Puakeawe, Kukainene, Naio
E_3	8000	25	Regosol, Lithosol	Lichen, Moss

[a]Table from Baker, Sahara, Ryan, Murabayashi, Ching, Fujimura, and Kuwahara (1965:3), but Hawaiian spellings have been corrected.



VEGETATION ZONES OF HAWAII ISLAND

KILOMETERS 0 15 30 45

MILES 0 10 20 30

ZONE A

ZONE B

ZONE C1

ZONE C2

ZONE D1

ZONE D2

ZONE D3

ZONE E1

ZONE E2

ZONE E3

(AFTER RIPPERTON AND HOSAKA, 1942)

MAP 6

Many of the indicator plants were introduced in the post-contact period. This illustrates the need to review the vegetational history of Hawaii, which is done in Chapter V.

Summary

In summary, the land parameters affecting Hawaiian agriculture are age of landscape, topography, geographical position of the Islands in the Pacific, geographic position in relation to the trade winds, and most importantly, the amount, periodicity and type of moisture. These and the marine factors affect Hawaii in general and the particular conditions at Lapakahi, Hawaii Island.

Kohala Land Ecosystem, Hawaii Island

Topography

Before one may discuss the land ecosystem of Lapakahi itself, it is necessary to understand some pervasive factors of the general Kohala area that are regulating parameters for Lapakahi. Important among these is the differential availability of soil moisture which is directly related to the general Kohala topography and its effect upon the north-east trade wind.

The Kohala area is dominated by Kohala mountain which is the remnant of an old volcano, the first to erupt above the ocean surface to begin the building of Hawaii Island. Today Kohala mountain is a long ridge lying along a

310/130° true axis, or roughly northwest to southeast. Although not particularly high by Hawaii Island standards (5,500 feet, 1676 meters) it is sufficient to cause very important orographic rainfall. The windward slope of the Kohala mountain extends some 4.5 miles (7 kilometers) from the 4,000 foot (1,219 meter) contour to terminate in a vertical sea cliff, dissected by the eroded valleys of Waipio, Honokane, Pololu, and Waimanu. The slope from the 4,000 foot (1,219 meter) leeward contour line to the coast is approximately 6.2 miles (10 kilometers) long, or about 1.9 miles (3 kilometers) longer than the comparable slope to windward. The leeward slope is more gentle than that to windward and is not cut by eroded valleys, although some small gullies are present. The Kohala ridge is approximately at right angles to the predominant trade wind and this has a great effect upon the local climate.

Climate

Weather conditions were observed by this author over a three-year period while piloting commercial aircraft through the area and this section is primarily based upon this information because little specific meterological information is available for Kohala.

A level of cumulus clouds is normally found over the ocean to the windward of the Kohala coastline at an altitude of one to two thousand feet (305 to 610 meters) above sea level. The typical pattern during trade wind conditions is for this cumulus layer to be scattered at daybreak and to gradually change to broken conditions (.6 to .9 cloud cover) by noon, and then to become nearly solid by mid-afternoon before gradually becoming scattered during the night.

Under low pressure conditions resulting from frontal passage or storms, the clouds often form a series of layers at about three-thousand-foot (914 meter) intervals. This cloudiness is relatively constant throughout all periods of the day, although it tends to become less dense during the night. Occasionally, the pattern is one of clear skies under certain high pressure conditions or a series of dense stratiform cloud decks from as low as 100 feet (30 meters) to in excess of 20,000 feet (6,096 meters) during very low pressure periods.

The average surface wind conditions over the ocean to windward of the Kohala coast are estimated on the basis of spray patterns to be a Beaufort force 4 to 6 wind (11 to 27 knots or 20 to 50 kilometers per hour) from a direction of 060 to 080° true. The wind velocity increases slightly from sea level to 3,000 feet (914 meters) and then remains fairly constant to an altitude of 5,000 to 7,000 feet (1,524 to 2,134 meters) where it begins to decrease; the winds are light and often from non-tradewind directions above 10,000 feet (3,048 meters).

Orographic Rainfall

The trade wind blowing from 060 to 080° true strikes the windward coastline of the Kohala ridge at an angle of about 110° to 130°. Orographic lifting occurs along the windward face of the Kohala range and rarely, if ever, does the trade wind split and flow around its ends; instead the main trade wind flow is up and over the summit area resulting in high rainfall areas to windward up to the summit and then rapidly decreasing rainfall as the wind begins to flow back to lower and warmer elevations. The wind velocity does not substantially decrease over the land mass on its way to the summit and probably increases slightly just below the summit on its downward flow to leeward because the Kohala mountain ridge acts as a single side of a venturi or airfoil and forms a low pressure area.

The heavy windward rainfall area has been observed from low altitude flights to consist of widespread swampy areas with many surface streams. Although few areas of swampy conditions are visible along the ridge summit, vegetation patterns indicate heavy rainfall and this rain evidently continues for up to one-half mile (1 kilometer) down the leeward slope before beginning to lessen substantially. Throughout a typical day there the spill-over of the moisture-laden clouds will gradually increase, but rarely do broken to overcast conditions extend more than about 2 to 4 kilometers (1.2 to 2.5 miles) beyond the summit. Scattered cloud conditions normally occur from the 4 kilometer (2.5 miles) point below the ridge top all the way out to sea as the cloud cover breaks up.

Lapakahi Land Ecosystem

Lapakahi is thus characterized by a great diversity in available surface moisture for it is a long and narrow strip of land extending from the 2,000 foot (610 meter) summit of the ridge down the leeward Kohala flank to the coast, oriented parallel to the trade wind vector.

The Lapakahi area *per se*, is composed of the old native land divisions of Lapakahi, Puukole, Koaie, Koaeae, and Koea (Map 11), and lies along the leeward flank of the Kohala ridge toward its northwest end. The area is just south of Mahukona Harbor on the coast and runs inland to the top of the ridge, just to the northwest of Puu Hue ranch headquarters. Lapakahi has a width of 1.5 miles at the coast and gradually narrows to about one mile in width at the summit of the ridge, some 4.5 miles inland (coastal width of 2 kilometers; ridge width of 1.5 kilometers; length of 7 to 8 kilometers). The general orientation of the land division is along an axis of 070°/250° true and runs almost perpendicular to the general contour of the leeward Kohala slope (Map 3).

Geology

The basic geology of the area is covered in detail by Murabayashi (1969) and can be summarized with some additions as follows:

(1) the land formation is composed of basaltic lava flows from the Kohala volcano;

(2) ash beds overlie this lava base at depths of two to five feet (.6 to 1.5 meters) and form the parent soil material;

(3) the topography is relatively smooth with some undulation and follows the general sloping contours of the underlying basaltic flows with an overall average slope of about 10 percent;

(4) this slope may be divided into a steeper upland section where the slope ranges from 11 to 20 percent for the first mile (1.6 kilometers) below the ridgeline before leveling out slightly to a slope of 0 to 10 percent with a few local areas of from 7 to 25 percent (Baker, et al. 1965: 9, 11);

(5) little erosion is evidenced beyond a few gullies of apparently recent origin; and

(6) sub-surface ground water resources probably come from a few subterranean inland lenses to a brackish water discharge at the coast, although the data are not specific for the area (Davis and Yamanaga 1963:17, 25).

Climate

Climatological data have explained why great differences in rainfall occur over the Lapakahi area and these changes are seen to be closely correlated with changes in elevation and distance to leeward. Long-term mean annual rainfall varied from 57.8 inches (1.5 meters) at 1900 feet (579 meters; Puu Hue) to 12.6 inches (0.32 meters) at 11 feet (3.4 meters; Mahukona).

The trade wind flows over the Lapakahi area at an average direction of 075° true based upon 1968 summer field observations and decreases only slightly in velocity between the upland and coastal areas. This azimuth is parallel to the length of the land division, and perpendicular to the contour lines and Hawaiian field boundaries. The wind velocity at Apaapaa 1 (Map 4) averaged a Beaufort 5 (17-21 knots or 32 to 39 kilometers per hour) during the summer of 1968 and during subsequent winter return trips. The coastal wind was judged to be a Beaufort 3 to 4 (7-16 knots or 13 to 30 kilometers per hour) based on wind action in the upper portions of the dense coastal kiawe forest.

The trade wind clouds and rain showers begin to disperse rapidly to leeward over Lapakahi. Usually the cloud cover is scattered to broken by Kilometer 6 (See Appendix B for a description of the grid coordinate system) and most shower activity stops completely by Kilometer 4 (Map 4).

This decrease in moisture falling upon the surface has resulted in fairly obvious differences correlated with both elevation and isohyets.

Present Flora

In general, the present vegetation gradates from vegetation zone C in Kilometers 87, 97, and 7, through zone B in Kilometers 94-96 and 4-6, to zone A for Kilometers 91-93, and 1-3 (Murabayashi 1969:17-21). The bulk of the field area is in zone B with the upper portions of the agricultural area lying in zone C. No visible fields were within the area of zone A vegetation. Murabayashi puts the transition from zone A to B at about the 800 foot (244 meter) contour line (1969:19).

The present vegetation is well described by Murabayashi where he records finding Kikuyu grass and lantana in zone C with redtop and Bermuda grass, lantana, Christmas berry in the gullies, a few kiawe trees, 'ilima, 'uha-loa, and haole koa in zone B. Zone A illustrated the disappearance of lantana, the gradual replacement of redtop and Bermuda grass by pili grass, finger grass, Japanese tea, and indigo, and a gradual increase in kiawe tree cover (Murabayashi 1969:17-21). Beyond a species difference by vegetation zonation, there was also an increase in the height and density of the characteristic plants from zone B through zone C (Murabayashi 1969:19).

Most of these plants were introduced to Hawaii in historic times and this would again indicate the need to reconstruct the vegetation history of the Lapakahi area. This will be done in the later section on Hawaiian farming so that the discussion can be closely focused upon those patterns of early vegetation that were closely associated with agriculture in the Lapakahi area. Other than floral cover and the suggestion of late erosion, all other environment variables were present throughout the human occupation of Lapakahi.

Summary

The physical setting at Lapakahi shows a great diversity in amount of available moisture owing to geographic position in relation to the northeastern trade wind. The upper portion of the sloping land receives adequate moisture for good agriculture while the coastal lowlands are characterized by near-desert aridity. The moisture differential is reflected in the present floral distribution patterns, the location of particular plant types, and the nature of their growth.

Lapakahi Marine Ecosystem

There is little evidence of change in the nature of the sea ecosystem during the human occupation of the Hawaiian Islands. At Lapakahi a description of the present marine environment is also a description of both historic and pre-historic conditions. A possible exception is the collapse of some coral caverns during the late nineteenth century which resulted from the use of dynamite in fishing. (Cartlidge 1968).

Geology and Substrate

Lapakahi has a rugged coastline where numerous lava flows have been eroded by wave action, creating a profusion of alternating basalt tongues and low sheer cliffs which are interspersed with an occasional small rocky or coral-strewn beach. No sandy beaches occur along the Lapakahi coastline because of the lack of a strong swell system and the general youthfulness of the area, although localized sandy bottom areas do exist in the shallow offshore areas. The underwater substrate is predominately smooth bare lava, jumbled small boulders, and coral. Some sand occurs in narrow bands arranged parallel to the coastline and perpendicular to the normal swell azimuth.

A detailed description of the bottom conditions and biotic distributions is to be found in a report by Don Kelso, a marine biologist from the University of Hawaii who spent several days surveying the area immediately offshore of Koaie (Kelso 1969). He found that the coral growth is predominately *Pocillopora meandrina*, *Porites lobata*, and *Porites compressa* (Kelso 1969:3-4). The data of Kelso also show that the bottom slopes gradually to a depth of about

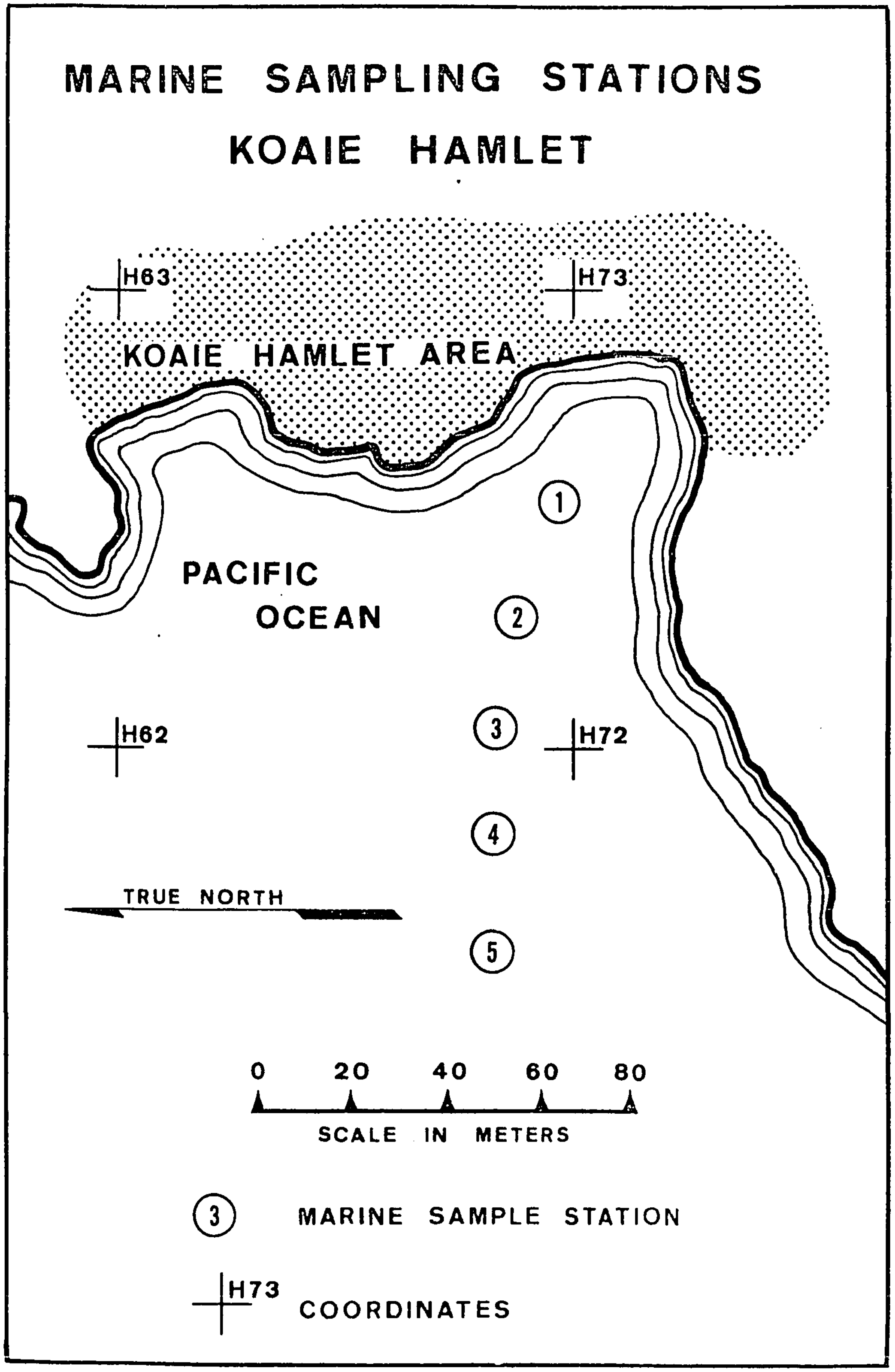
25 feet (7.6 meters) at a distance of some 328 feet (100 meters) offshore (1969:2).

This gradual slope continues and nautical charts show the 180 foot (55 meter) underwater contour line used to define the lower limit of the sub-surge zone by Gosline and Brock at a distance of over one-half mile (800 meters) offshore. This is indicative of the enlarged shallow water inshore area found on the leeward side of Kohala, the largest shallow water area around Hawaii Island.

> The broad shelf 30 miles wide extending westward to a depth of 5,000 feet from Kohala Mountain is an anomalous geomorphic feature, as everywhere else the sub-marine contours closely parallel the shore (Stearns and MacDonald 1946:56).

Habitat Zonation

The western exposure of the Lapakahi coastline avoids the northeast trade wind swell system. Wave action comes only from the less energy-laden and less consistent southern swell. This swell system, combined with the shallowness of the water in the area, creates a very large sub-surge zone with a high fish biomass. The supra-surge and surge zones are relatively small and this is empirically supported by the work of Kelso (1969:2) who found a high concentration of the surge zone sea urchin, *Echinometra mathaei* only in the shallow water of Station 1 (Map 7).


MARINE SAMPLING STATIONS
KOAIE HAMLET
H63
H73
KOAIE HAMLET AREA
1
PACIFIC
OCEAN
2
H62
3
H72
4
TRUE NORTH
5
0 20 40 60 80
SCALE IN METERS
3 MARINE SAMPLE STATION
H73 COORDINATES

MAP 7

Biota

Underwater observations off Koaie revealed a reasonably large fish population, primarily uhu, kole, pūhi, 'o'opu-hue, and various wrasses, tangs, and needlefish, but only one large carnivore, an ulua, was noted in the area (see Appendix A for Hawaiian, common, and scientific names of marine biota). Most of the fish seemed concentrated along the rubble choked vertical shoreline to the south of the main portion of Koaie in Hectare 72 (Map 7).

These observations of fish types at Lapakahi are corroborated by a student paper for the 1968 Field School which reports on a special project of collecting fish from the waters near Koaie and preparing type skeletons. Fish speared or otherwise caught for this collection included kala, uhu, 'ū'ū, 'o'opu-hue, nenue, uku, 'āweoweo, pāku'iku'i, palani, kūmū, and hīnālea (Fox 1968:3-4).

Summary

The underwater habitat zones and biotic distribution at Lapakahi appear to fit the classification system of Gosline and Brock. They show a diminution of the suprasurge and surge zones because of the leeward location, resulting in a larger sub-surge zone. This sub-surge zone is further enlarged because of the gradual underwater slope of western Kohala which also increases the distance offshore at which the inshore area transitions into the pelagic zone.

How did the Hawaiians take advantage of these environmental factors at Lapakahi? Before this question may be answered it is necessary to first develop a broad knowledge of Hawaiian maritime exploitation practices and authenticate them through the use of historic references. This general body of information may then be correlated with the ecological data from this chapter; finally both will be keyed to the archaeological data from Lapakahi to reconstruct the Hawaiian use of the sea in this area. Chapter III begins this by providing an analysis of historic Hawaiian sea exploitation.

CHAPTER III

HAWAIIAN EXPLOITATION OF THE SEA

Marine fauna were termed i'a by the Hawaiians and this name was applied, for example, to fish, sea mammals, and invertebrates such as shellfish, octopi, sea urchins, and sea cucumbers. Hawaiian taxonomy was not the same as Linnean taxonomy and native classifications are often difficult to convert to current scientific names; however, Appendix A has been compiled to provide correlations between most Hawaiian names used in the text and their scientific taxonomy.

Historic Approach

An attempt was made to describe historical exploitation of the sea by compiling and analyzing bibliographic sources. It quickly became apparent that twentieth century literature on Hawaiian sea exploitation was the result of a self-nurturing process whereby each succeeding source merely quoted an earlier one, often without acknowledgement, and without questioning the authority or validity of the earlier work. Virtually all recent sources are based on the reports by Beckley (1886) and Cobb (1902). Absolutely no source took into account the possibility of culture change during the historic period, including the otherwise excellent coverage by Titcomb (1952) and Buck (1957).

Twentieth century sources could not be used for the purposes of this study because these late summaries failed to meet two important criteria of analytical historiography: (1) demonstrable authority on the subject and (2) a careful delineation of the time period reflected in the descriptions. This made it necessary in this study to reconstruct sea exploitation practices for specific time periods on the basis of authoritative accounts by contemporary observers. The historic periods chosen were the late eighteenth century; and the early, middle, and late nineteenth century. Literature from these periods was searched for sources meeting the criteria listed above and acceptable materials were then synthesized into a composite picture of exploitation practices for the applicable time period.

Late Nineteenth Century

Data Sources

Only two sources were located that authoritatively recorded late nineteenth century exploitation practices; these were the work of Beckley (1886) and Cobb (1902). Cobb's material provides the core of the present synthesis because his work is much more detailed than that of Beckley and also includes some highly significant quantitative data. Cobb was a professional statistician working for the United States Fish Commission and gathered comprehensive quantitative data on commercial fishery operations in Hawaii for the year 1900. The exploitative techniques of the 1900 commercial fisheries will be seen in the course of this analysis to be based, for the most part, upon native techniques that were but little changed from at least the beginning of the nineteenth century. By historically validating portions of this 1900 commercial fishery as representative of much earlier native techniques, it is possible to apply the detailed quantitative data of Cobb to these earlier practices.

Cobb spent three months researching the commercial fisheries of Hawaii during 1901; he observed fishing and collecting operations, interviewed local fishermen, analyzed government documents, records, and newspapers. Although Cobb's work was done in 1901 and his statistical base was 1900, it is reasonable to accept his data as illustrating sea-exploitation practices at the very end of the nineteenth century. Beckley's materials were used to validate the synthesis for the beginning of the late nineteenth century period.

These two authors described basic exploitation patterns of hand collection, snaring, spearing, poisoning, and the use of nets, basket traps, fishhooks, and lures. Although both authors included brief descriptions of the use of fish ponds for the raising and storage of fish, this topic has been excluded from the present research.

Hand Collection

Collecting by hand was practiced in shallow water, both on the surface and by diving. Some types of fish were caught by hand in shallow pools as well as by divers in underwater caves while other food items collected by hand included crabs, lobsters, eels, sea urchins, sea cucumbers, shellfish, octopi, shrimp, and seaweed. Much of this type of exploitation was practiced at night, particularly for mobile fauna. No items of material culture were used except for fiber containers in which the organisms were placed, and perhaps the torches used at night to mesmerize fish.

Poisoning

Although fish poisoning was made a misdemeanor by legislation in 1850 (Jordan and Evermann 1902:365), it was still reported by Cobb in 1902. Poisons used were of plant origin and made of pounded ahuhu (*Tephrosia purpurea*) and 'ākia (*Diplomorpha sandwicensis*) to be inserted into underwater caves; the fish were not affected as a human food by it. For obvious reasons there are no data available on poisoned fish in the 1900 commercial market.

Snaring

Cobb notes that he only saw snares being used on Hawaii Island and not on any of the other major islands. He says that eels and lobsters were the primary objects of snaring. A noose on a pole was placed in front of an eel hole, bait placed outside and when the eel stuck its head outside the hole to get the bait, the noose was drawn tight and the eel brought to the surface with the pole. A noose attached to a long pole with a forked end was also lowered near bait and the line slipped under the tail of a lobster.

Spearing

Fish spears were about six feet long (2 meters), made of a very hard wood tipped with an iron point, and used underwater by a diver who positioned himself on the bottom and impaled fish on the spear as they came close. It was possible to spear more than one fish per dive by allowing them to slip down the spear after they were pierced. Above surface use of spears was restricted to spearing turtles, octopi, 'o'opu-hue, and fish mesmerized by torchlight at night in shallow water. No mention was made of spears propelled by slings or elastic bands, such as the "Hawaiian sling," and these are undoubtedly of twentieth century origin.

Basket Traps

Relatively few basket traps were made and most were used by women to catch 'ōpae, hīnālea, kala, and 'uī'uī. The traps were woven from fresh vines or flexible branches into box-shaped designs. In one common technique, a simple basket was lowered to the bottom in shallow water, often with a bait of pounded shrimp inside and when fish entered the trap, the woman watching nearby would dive to bring the trap to the surface. A more sophisticated version had a conical woven entry protruding into the interior where it terminated in an opening only large enough for a fish to squeeze through. The trap, baited with seaweed, ripe breadfruit or papayas, cooked pumpkins or sweet potatoes, was lowered to the bottom, and when the fish entered by the conical entry they were unable to find their way back again.

Nets

Gill Nets

Gill nets were designed to entangle the fish in a net with a fairly large mesh instead of merely trapping them within an encircling small mesh net wall as was done with seines and bag nets. Gill nets were manufactured in different sizes according to the type of fish to be caught and the habitat to be exploited, ranging in length from about 55 feet (17 meters) to over 1,200 feet (366 meters), in depth from seven feet (2 meters) to 25 feet (8 meters), with mesh size from one-half to seven inches (1.2 to 17.7 cm.). Three basic techniques were used in gill netting:

(1) letting the net remain stationary and allowing the fish to entangle themselves in the mesh;

(2) driving the fish into a stationary net; or

(3) moving the gill net to encircle the fish and then scaring them into the entangling mesh.

Stationary gill nets were often placed at high tide across shallow openings in the coral reef at night to entangle any fish navigating the fish run. Nets used in this fashion usually had a mesh of two to two and one-half inches (5 to 6 cm.).

Drawn gill nets were used to either completely encircle fish or to arc a half-circle around them before the fish were scared into the net by fishermen beating and splashing the water from within the circle or across the open end of the semi-circle. Sometimes, the nets were drawn up on the shore after the fish were meshed but at other times, the fish were taken out of the nets and put into canoes.

Lobsters were caught in a special gill net, with a seven-inch (18 cm.) mesh, by placing the net completely around a rock cluster and leaving it in place all night to entangle the lobsters as they came out of the rock cairn.

Gill nets used for specific fish included:

(1) a net measuring some 1,200 feet (366 meters) in length, 25 feet (8 meters) in depth, with a mesh of four inches (10 cm.) used to encircle a school of akule, and

(2) a gill net some 540 to 900 feet (165 to 275 meters) long, 12 to 18 feet (4 to 5 meters) deep with a three to four inch (8 to 10 cm.) mesh used just outside the reef or breakers to encircle larger fish such as the 'ō'io.

Cast Nets

Cast nets were circular and about 25 feet (8 meters) in circumference with lead weights arranged around the edge. A rope was attached to the center and the whole net was cast over fish in shallow water. Cobb says this type of net was a comparatively recent introduction from the Orient and it was not mentioned by Beckley or any other earlier source. The cast net and its associated techniques would appear to be a fairly clear illustration of historic diffusion in sea exploitation techniques.

Seine Nets

A Hawaiian seine was a net deployed in the water and moved horizontally, trapping fish by impounding them within a complete circle formed by the net, or between the net and the shoreline. The fish were not normally entangled in the mesh as with a gill net, but rather were kept within a small circle by the net wall where they could be scooped out with small bag nets or dragged bodily onshore, net and all. A bag net was often used in conjunction with a seine and this combination will be discussed later. Seines varied in length from about six to over 350 feet (2 to 107 meters) in length, with the common large net measuring some 150 to 350 feet (46 to 107 meters) in length, about 10 feet (3 meters) in depth, with a mesh width of several inches. The net size and mesh type seem to have been dependent upon the particular types of fish to be caught and the habitats to be exploited.

Bag Nets

Bag nets were made into an enclosed purse with only one open end; or alternately were flat pieces of netting that were closed into a self-contained bag by manipulating attached flexible sticks in a particular manner to seal it. Although bag nets were extensively used in conjunction with seines, there was a great diversity of bag nets used alone, and these seem to have been quite specialized by type of fish to be caught. An initial ordering of these different types may be made on the basis of use technique: (1) hand held, and (2) manipulated by attached ropes.

Hand Held Bag Nets:--The hand-held bag nets were fine meshed small nets fitted on a flexible wooden hoop which held the mouth open, used for dipping out fish trapped by an encircling sein net; for scooping up fish at night in very shallow water areas, usually by torchlight which mesmerized the fish; or by being held across the opening of an underwater hole by a diver while the fish hiding inside were herded into the net with a stick.

Rope Manipulated Bag Nets and Baits:--Bag nets manipulated by attached ropes were often used with some form of bait to draw the fish into the net. Common baits were cooked pumpkin, squash, sweet potatoes, kukui and coconut meat; raw mashed bananas, papaya, breadfruit or taro; pounded up fish, sea urchins, shrimp or eels; whole small fish such as nehu, 'iao, and akule; or a special mixture called palu which was based on the cooked ink bag of the octopus pounded into a paste with ingredients added such as the juices of various plants, salt, spices, kerosene, tobacco juice, liquor, or Perry Davis Pain Killer. These different baits were often mixed with sand, to make the bait sink, and then placed in the water near as well as inside the bag net to attract fish. Some of these baits are obviously the result of European diffusion. When the fish, usually 'ōpelu, were inside the bag, it was lifted to the surface by the attached ropes.

Decoy Fish:--Two slightly different baits were the decoy fish and the melomelo bait stick. In the use of decoy fish, live uhu or 'ōpule were caught and tied through the mouth and one gill opening to a line. A square bag net with its mouth held open by two diagonally crossed sticks was lowered into the water by a line and the decoy fish lowered in its vicinity. Fish of the same species as the decoy were attracted by its erratic behavior. The decoy was gradually manipulated by the line into a position over the submerged net; then the net was drawn vertically upward to trap the fish and the line attached to the cross-point of the two diagonal sticks was given a special jerk which caused the sticks to slip parallel to one another, closing the opening of the bag.

Melomelo Stick:--The melomelo stick was made of a hard wood, shaped like a small club 13 to about 36 inches in length (33 to 91 cm.) with a carved knob at one end. After incantations were said over it, the melomelo stick was slowly toasted over a small fire and rubbed with a mixture of cooked coconut and kukui meat. When used, a line was attached to the knobbed end of the stick, it was again rubbed with the bait mixture and lowered into the water to attract fish by its scent before being manipulated by the line into a submerged bag net. When the fish followed the stick into the bag, the mouth was closed by divers and the bag was lifted to the surface by lines attached to each side.

Bag Nets Used Without Bait:--Bag nets used without bait and manipulated by ropes were usually filled by frightening schools of fish into them. One small net used in this way was the kapuni nehu for catching the small nehu fish in shallow water while a larger net held open by flexible sticks tied into circles was used in deep water to catch the surface-schooling mālolo, puhiki'i, or iheihe. This latter net was carried by canoe and lowered into the water near the fish while other canoes formed a circle around the school to drive them toward the bag net by beating the water. The fish were driven inside the bag as the canoes gradually closed in toward the net, the net opening was closed, and the whole lifted to the surface.

Seine/Bag Net Combinations

When bag nets were used with seines, the bag was laced in the center between two seine net sections so that each seine net formed a long wing on each side of the bag and served to channel or direct the fish into the bag. Long ropes with dried ti or convolvulus leaves lashed to them by their stems were often tied to the ends of the seine nets. These bushy ropes, called lau, served to drive the fish ahead when the leaves swirled and waved in the water, creating threatening shadows that frightened the fish. Lau ropes were also used with seine nets without bags and with bag nets without seines for the same purpose.

Seine/Bag Net Techniques:--A very common bag and seine combination was described as having a conical bag measuring about 20 feet (6 meters) long, with a mouth some 12 feet (4 meters) wide. The seine portion was formed by two nets, each about 30 feet (9 meters) long, five feet (1.5 meters) deep, with a three-quarters to one-inch (1.7 to 2.5 cm.) mesh. During use, the two seine net sections were laced together and lengths of lau ropes, each measuring some 120 feet (37 meters), were tied together and then attached to each end of the seine nets. The net was taken to a likely spot where fishermen played out both ends of the lau rope in a long semi-circle while others came along behind to keep the lau near the bottom but clear of obstructions. The seine, held vertically by hau-wood floats and lead sinkers, formed the central section of the apparatus; the lau ropes were gradually moved into a circle until the fishermen on each end passed one another. The circle was gradually decreased in size and unneeded sections of the lau were untied and allowed to float to the surface. When the circle was small enough to be formed only by the mesh wall of the seine net, the bag was laced in the center between the two seine halves. The circle was then made smaller and smaller until all the fish in the center were forced into the bag, which was then closed and either lifted to the surface or dragged onto the shore.

The 'upena kolo was another combination seine and bag net and the largest net used in the Islands in the late nineteenth century. Because it was over 145 feet (45 meters) in length with a huge flaring mouth, it could only be used in a very few places, such as Honolulu harbor, but, although the bag was extremely large, it was made with a fine mesh. To the bag were attached seine wing nets measuring some 120 feet (37 meters) in length and the whole apparatus was towed behind canoes around the harbor, engulfing everything in its path, but principally akule and 'ama'ama.

In another technique, the seine net was laid and moved into a circle and then the bag net was placed inside the circle without attaching it to the seine, and the fish driven within it.

Hook and Line

Fishing with hook and line has been split into two divisions based upon type of habitat exploited:

(1) surface trolling with a lure and

(2) sub-surface angling with both bait and lure.

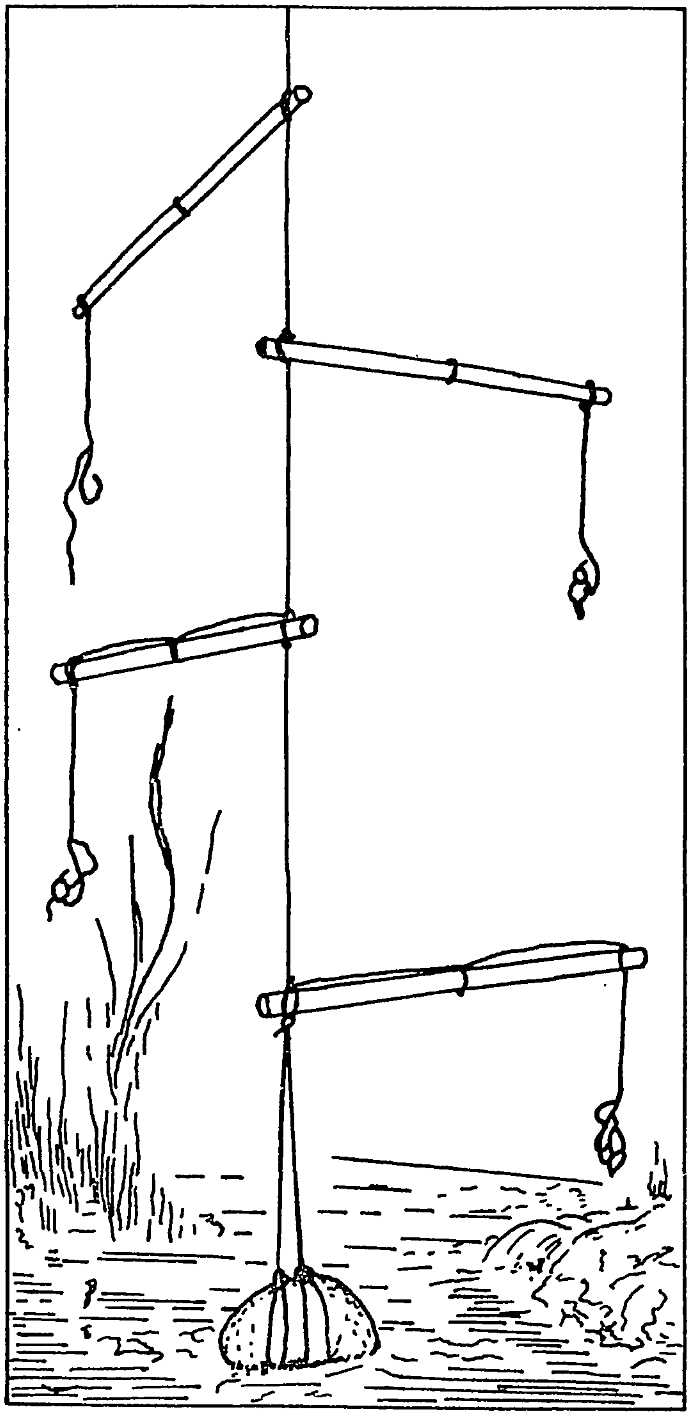
Surface Trolling with Lure

Surface trolling was carried out in offshore waters with a special pearlshell lure called pā, which had an attached hook of bone, tooth, ivory, turtle shell, iron, or brass and a distal skirt of pig bristles to keep the hook side of the lure pointing skyward on top of the water. This lure was attached by a twelve foot (4 meters) line to a bamboo pole and manipulated by a fisherman in a canoe. A school of offshore carnivorous surface feeding fish, usually aku, was first located and the canoe was carefully positioned ahead of the school in the direction the fish were feeding. Sometimes small live bait fish, such as nehu or 'iao, were taken from a special baitbox lashed to the canoe and thrown overboard to attract the fish. When the school of aku neared the canoe, the paddlers maintained the canoe in, or quite near the school while the fisherman stood erect in the stern and slapped the pā lure smartly on the water behind the canoe and then skittered it across the surface to imitate the small fish upon which the aku were feeding. When a fish struck the lure, the fisherman would jerk the pole to set the lure hook and lift the fish out of the water, catching it momentarily under his arm to extract the lure before dropping the fish into the canoe and casting again. This type of fishing had to be done quickly for the school was easily frightened.

Sub-surface Angling with Bait

Sub-surface angling was done with a pole and line in shallow water and with hand lines for deep-water bottom fishing. The baits used were the same as those listed under bag net baits except for decoy fish and the melomelo stick. Some were attached directly to the hook, while the palu bait was merely rubbed on the hook; often a bag of bait was lowered near the baited hooks and released underwater.

Kākā Technique:--Deep-water bottom fishing used a rig of multiple hooks attached by short leaders to the main 3/8th inch (1.7 cm.) fish line at intervals close to the bottom. Each short line with the hook attached was supported by a section of coconut midrib lashed perpendicular to the main fish line which served to keep the multiple hooks separated from one another and from the main line. Figure 1 shows an illustration of this technique that was copied from Cobb. The Hawaiian name, kākā, has been supplied from other sources because the technique was not identified by name in Cobb's article.



KAKA TECHNIQUE
(COBB 1902:419)
Fig. 1

The kākā rig was used in depths of up to 1,200 feet (366 meters) and the line was lowered with a stone weight attached to the end, just below the hooks. After the stone hit bottom, the line was given a jerk which released the weight and allowed the baited hooks to drift freely near the bottom. When a sufficient number of fish were felt to have hooked themselves, the line was hauled up by hand. Note that the illustration by Cobb shows what are probably rotating hooks used with this technique.

Sub-surface Angling with a Lure for Octopus

This technique was practiced only to catch the octopus. A special octopus lure was made by opposing a Mauritania or Tiger cowry shell with a shaped stone weight; the two were lashed to a short wooden shank which had a bone hook tied to its distal end, covered with a skirt of ti leaves. The cowry shell was carefully selected for small red spots and a reddish background and could be slightly steamed over a fire of sugar-cane husks if the background color was not quite right. The lure was lowered to the bottom and jiggled up and down to attract an octopus; when the octopus wrapped his tentacles around the cowry shell, the line was hauled up to bring the octopus to the surface where it was killed with a club. A more modern version was a cowry shell attached to a line with a metal hook embedded in lead in its ventral side, used in the same way as the more traditional lure.

Summary

The quantitative data from Cobb for the Hawaii Island 1900 commercial fishery are given in Table V in Appendix C. A summary of these data is given below in Table II.

TABLE II

HAWAII ISLAND COMMERCIAL CATCH: 1900

Technique		Poundage	Percent
Hook and Line		995,952	78.3
Seine/Bag Nets		65,893	5.1
Gill Nets		60,042	4.7
Cast Nets		49,852	3.9
Bag Nets Only		49,000	3.8
Basket Traps		4,737	.3
Snares		600	.04
Spears		18,246	1.4
Hands		26,579	2.0
	Total	1,270,901	100. (rounded)

Middle Nineteenth Century

Data Source

Middle nineteenth century sea exploitation has been well and authoritatively described by A. D. Kahaulelio in the Hawaiian-language newspaper, Ka Nūpepa Kū'oko'a (1902 *et seq*.). These articles have since been translated by Mary Pukui and the translation manuscript is to be found in the Bishop Museum library (Kahaulelio, 1902). Kahaulelio was born in 1837 and began fishing intensively with his father and grandfather in 1848, continued to fish with them until their deaths some 16 years later, and then fished for another 25 years by himself. Kahaulelio seems to have quit extensive fishing sometime around 1880 although he makes several references to fishing in the 1890's. This account of Kahaulelio is quite full and detailed, providing an excellent source on Hawaiian sea exploitation for the middle nineteenth century, the period of his major fishing endeavors. It will be seen that many of the techniques described by Beckley and Cobb for the late nineteenth century are also described by Kahaulelio for this earlier period and Kahaulelio greatly amplifies our knowledge of exploitation practices through the wealth of first-hand details and personal experiences given in his manuscript. The account by Kahaulelio covers exploitation by means of hand collection, spearing, basket traps, nets, and hook and line.

Spearing, Hand Collection and Basket Traps

These categories were described by Kahaulelio in terms quite similar to those of the late nineteenth century authors, making it certain that the same general techniques were in use throughout these two time periods.

Nets

Gill Nets

Kahaulelio described only one net that might have been a gill net and this in only a few sentences. This possible gill net was used in ho'omoemoe fishing which was done by two fishermen at night with a net some 360 feet (110 meters) in length with a mesh of "two-fingers width." Stokes (1906:107) gives the English equivalent of "two fingers" as a mesh width of two inches (5 cm.). The net was laid in the evening and left alone until midnight or later when the fishermen returned and raised it to remove the fish. The net was then put back in place and left until morning. The major fish types caught included kala, ulua, mullet, and nenue. Kahaulelio failed to state exactly how the net functioned but a likely explanation is that it was a gill net.

The lack of detail on definite gill nets by Kahaulelio and all other earlier writers could mean any of several things:

(1) gill nets were present but just not mentioned;

(2) gill nets were recognized as a separate technique by the Hawaiians but were not particularly important in sea exploitation;

(3) the distinction between "gill nets" and other nets such as seines and bag nets was not one made by Hawaiian fishermen; or

(4) gill nets and the associated use techniques were the result of diffusion in historic times and were not authentically part of the native exploitation inventory.

No definitive answer can be offered here for everything is based on negative evidence, but it is likely that gill nets were indigenous and were not mentioned because they represented a relatively minor technique. This is entirely subjective, and it is possible that gill nets came in through historic diffusion.

Seine Nets

Seine nets were called pāloa by Kahaulelio when they were used alone without accompanying bag nets. Evidently Kahaulelio did not consider seine nets as important as the seine and bag net combination which he described in great and varied detail. Descriptions of seine nets by Kahaulelio are not complete as he consistently failed to give any dimensions other than a "two-finger mesh." He did, however, describe the technique of their use as being based upon the principle of surrounding a school of fish with an encircling net wall, and did not mention that the fish became entangled in the mesh as they do in a gill net. The seines were laid in a long arc either by swimmers or by being played out from canoes, and were drawn into an ever-tightening circle around the fish.

Fish Caught:--Fish types caught with the pāloa included weke, kala, pīhā, and moi. The definite impression was given that the use of a pāloa without an accompanying bag net was a technique secondary in importance to the seine/bag net combination but still more widely used than gill nets.

Bag Nets

Bag nets used alone were evidently more important than either gill nets or seines used alone, to judge from the relative emphasis in descriptions by Kahaulelio. At least with the hano net for catching mālolo, iheike, puhiki'i, and a'ua'u, the use of seine wing nets with the hano bag was optional. The hano had a mouth some 30 feet (9 meters) in diameter and was about 75 feet (23 meters) long. Its use as described by Kahaulelio is substantially the same as the description by Cobb for the mālolo net, evidently the same thing.

Nets completely without seine wings included the 'ōpelu net which was some 18 feet (5 meters) long, 36 feet (11 meters) in circumference; it was held open by flexible sticks encircling the mouth. This net was first lowered into the water by ropes attached to the mouth and a bait of pumpkin, papaya, taro, shrimp, or dragon fly pupa was placed in the water in and near the bag to attract the fish inside before the net was raised.

Fish Caught:--Uhu, kūmū, 'āhuluhulu and maomao were listed by Kahaulelio as being caught with decoy fish and a vertically used bag net such as described by Cobb.

A net described by Kahaulelio but not by Beckley or Cobb, was the luelue which was small, rounded, and bordered by a flexible stick to which four ropes were attached. A bait of pounded lobster was put inside before the bag was lowered, and the net was drawn up by the ropes when lau-hau and uhu were attracted inside.

The melomelo stick and palu were also used for bait in net fishing with bag nets. Kahaulelio described a melomelo stick owned by his father and indicated that these were highly prized possessions.

The lau'apo'apo technique was also not described by the late nineteenth century writers. This involved a bag net lowered below the surface and then drawn vertically upward, engulfing any fish in its path, principally 'ōpule, 'ōmalemale, uhu, mā'i'i'i, and kolepala.

The lauahi technique was to lower a bag net in the water just beyond the breakers after dark and then draw it horizontally through the breakers into shallow water, catching kūmū, pā'ū'ū, nenue, and weke.

In still another technique in which a bag was used alone, piles of stone or coral were arranged underwater to provide shelter for fish. A net about six feet (2 meters) in diameter was put entirely over the cairn and the stones were removed one by one, leaving the hiding i'a without shelter. The net was then closed and drawn up with small fish, shrimp, and lobsters inside.

Seine/Bag Combination Nets

This combination was generally referred to by Kahaulelio as a laulima net. He said that the fibers of the wauke plant were made into a net called pūhi iki; another was made of olonā with a mesh of about one inch (2.5 cm.) and called pūpū; and a third net with a two inch mesh (5 cm.) was made and this was called pūhi nui. These three were joined together to form a bag called the 'upena with the pūhi nui forming the mouth, the pūhi iki the middle, and the fine meshed pūpū the rear. Yellowed and dried ti leaves were next fashioned into lau ropes. The 'upena papa, or papa net, was then used in a number of different ways.

Laulele Technique:--In this technique the lau ropes and the net were taken to where the water was about 90 feet (27 meters) deep. The lau ropes were tied together and two canoes began to play them out in a long line, evidently gradually incurving toward shallow water, or stretching the lau in a straight line all the way across a small bay. Each end of the lau was finally anchored in about 6 feet (2 meters) of water and arranged so that it lay near the bottom in the shallow water areas and at a depth of about 50 feet (15 meters) in the deep water section. Fishermen then took each end of the lau and began hauling it toward the shallows causing the waving ti leaves on the lau to frighten the fish and drive them ahead, while divers followed to keep the lau clear of underwater obstructions. When the lau was drawn into a depth of about 25 feet (8 meters), divers stuffed the holes lying between it and the beach with leaves and rubbish. Then the 'upena papa bag net was inserted between the two seine wings that each measured some 60 feet (18 meters) in length; these in turn were tied to the ends of the lau ropes on either side. The 'upena papa bag net had an opening in the pūhi nui section that measured some 12 to 18 feet (4 to 5 meters) in diameter and tapered down to about 6 feet (2 meters) in diameter where the pūhi iki was attached, and then on down to the end of the cone formed by the pūpū. There were sticks in the pūhi nui and pūhi iki to keep the net open and the sides from collapsing into one another. The lau ropes were then drawn in such a way as to force the fish between the seine wings and toward the papa bag. When the encircling lau was drawn toward the bag tightly enough the fish were driven into it by fishermen who beat the water; the bag was then drawn up and the fish removed. Fish commonly caught through this technique included 'ōpule, moi-li'i, palapala, kūmū, weke, kala, manini, moano, uhu, 'ō'io, hilu, 'a'awa, kakakī, and 'anae.

Lau Kapaliki Technique:--A variation of laulima fishing called lau kapalili was practiced in calm waters over sandy areas. The lau was laid in the same way as with the laulele technique and then drawn shoreward until a depth of about 15 feet (5 meters) was reached, when a small bag net about

20 to 25 feet (6 to 8 meters) in length was lowered and arranged to face the arc of the lau which terminated at each side of the bag. The lau was then drawn onto the shore as men and women beat the water behind it, driving the fish into the papa bag. When the fish were inside, the bag net was closed and dragged ashore instead of being emptied into canoes. This technique was used in shallower areas than the laulele, and was quite effective in catching 'ō'io.

Seine and bag combination nets were also used to catch many other types of fish such as palani, pahuhunuhu, kawa-kawa, 'ōmaka, nenue, akule, moi, kalanoho, pīhā, and nehu.

Hook and Line

Surface Trolling with Lure

Kahaulelio's pearlshell lure description resembles Cobb's except that Kahaulelio gives names designating the particular shell color: 'onihilehua and uhipa'a lures were rainbow colored while the kuala lure was a plain white. Different-colored lures were used for different conditions or times of day. The actual fishing technique was the same as described by Cobb but Kahaulelio provides a more detailed description of the use of live bait fish.

Use of Bait Fish:--Live bait fish were caught near the shore in small mesh nets and kept alive in a special bait container called the malau. The malau was two fathoms long, one ha'ilima high, and one half of an iwilei wide;

these measurements translate to about 12 feet (4 meters) long, 6 inches (5 cm.) high, and 18 inches (46 cm.) wide (Mattimoe and Nagao 1967:12). The bait fish, usually 'iao, were scooped out of the malau and tossed into the sea near a school of aku while the pā lure was skittered in their midst. Kahaulelio says that his father quit aku fishing with the malau in about 1848 because it involved too much work and it took too many people to support it.

Kākā Technique

Kākā fishing, or what sometimes is called kialoa fishing, was a deep sea technique where 40 to 50 baited hooks were lowered on a line to the bottom and allowed to drift freely near the bottom at depths of up to 1,200 feet (366 meters), catching kāhala, 'ula'ula, 'ōpaka, hāpu'u, koa'e, 'ula'ula niho, 'ōpakapaka, hananue, ilikiki, lehi, uku, mahukia, and 'ō'io. See Figure 1.

Kūkaula Technique

The kūkaula technique was not described by the late nineteenth century authors but Kahaulelio says it was used in more shallow areas than the kākā technique. Although the depth limitation for the kūkaula technique seemed to have been about 450 feet (137 meters), the line used was some 600 feet (183 meters) long with coconut husk markers tied at intervals of about 30 feet (9 meters), starting about 250 feet (76 meters) back from the lower end. The baited hooks and a stone weight were attached to the lower end; the weight was jerked free in the same manner as in the kākā technique. The hooks used were "crescent shaped," called mahina, and were so designed that the fish hooked themselves without the fisherman having to set the hook, thus making them incurved (rotating) hooks. Bait was used and was tied to the hook with a thread to attract the 'ula'ula, 'ōpakapaka, āholehole, hananue, 'ukikiki, kāhala, ulua, and lehi.

Distinction Between Kākā and Kūkaula

The primary distinction between the kākā and kūkaula techniques would seem to be the greater depth and the larger number of hooks attached to each line with the kākā technique. There is no mention by Kahaulelio of the use of coconut mid-rib spreaders for the kūkaula fishing, so this may be another difference, although it might have been merely an omission. It is strongly suspected that the larger rotating hooks so often described in Hawaiian archaeological literature, were primarily used in the kākā and kūkaula techniques, and this reasoning will be presented later in this chapter.

Pole, Line, and Hook Techniques

Poles were used in aku and mahimahi fishing with the pā lure but not in the kākā or kūkaula techniques, where hand lines were used. Evidently much inshore sub-surface fishing was also practiced with hook, line and pole, using baits of crushed hā'uke'uke, wana, 'ina, 'a'ama, sand crabs, shrimp, or palu, to catch moano, 'a'awa, hīnālea, lae-nihi, pualu, humuhumu, 'ō'io, ulua, 'āweoweo, nenue, moi, kūpīpī, 'ālo'ilo'i, uhu, a'ua'u, 'o'opu-kai, lelo, and ula; quite a substantial list. In addition, eels were caught on gorges made from coconut midribs.

Sub-surface Angling with a Lure for Octopus

Cowry Shell Lure:--The description of fishing for octopus with a cowry shell lure is the same as that of Cobb but Kahaulelio adds many very interesting first-hand details:

> In joining the stone sinker and cowry shell together a piece of stick is inserted about the length of a lead pencil but a trifle wider. It is about six inches long and two inches are allowed to project and on this projection, the hook called kakalahee, or makau, is fastened. They are tied to a line, like a three-ply cord, two kaau or eighty fathoms long. . . . When the line is let down to the bottom, it is again raised a half a foot or a whole foot from the floor, then jerk and keep jerking up and down all the while. This keeps the stone and shell moving and as soon as the squid sees it, it hurries and grasps the top of the shell. You will feel its weight and if the tentacles are trailing on the sea floor, you will feel a steady downward pull although it has landed on the shell. Pull the line straight then give it a hard, quick jerk toward the side of the canoe. Draw up the line and when the squid is close to the canoe, hold it out and away to prevent its grasping the edge of the canoe and holding on tightly. If it does beat it with a stone and stab it with a knife until it is dead. If it does not cling to the canoe, then stab it at the top of the head until it weakens. Put it away in a tall woven basket. Some people beat the squids with a wooden

> club but that is hard work that leaves the arms very tired. (pp. 31-32)

Kahaulelio also says that the cowry shell lure was used in relatively deep water. The "squid" mentioned in the passage above is the true he'e, or octopus, and not truly a squid, but even today the cowry shell lure is often referred to as a "squid lure" although this is not strictly correct.

Okilo Lure:--Kahaulelio described this technique for catching octopi and it was not found in any other source. In the okilo technique, a lure that had several nohu blossoms (*Tribulus cistoides* L.) substituted for the cowry shell, was lowered in about six feet (2 meters) of water and placed in front of an octopus visible to the fisherman. Most of the octopi caught with the okilo method were smaller than those caught with the cowry shell lure, or lūhe'e.

Early Nineteenth Century

Data Sources

Information from Campbell

Data are more sparse for the early nineteenth century but still appear quite adequate to provide a general picture of basic exploitative practices. The most direct evidence comes from the diary of Campbell (1967:140-142) who observed fishing by net, hook and line, and poisoning during his thirteen month residence on Oahu between 1809 and 1810.

Nets:--The nets were made of olonā and seem to have been the laulele type described by Kahaulelio, for they were 300 feet (91 meters) long, 12 feet (4 meters) in depth, and had a large bag attached in their center. Campbell describes their use as follows:

> They are set like herring-nets, with the upper edge floated by buoys of light wood, whilst the lower edge is kept under water by weights of lead or iron. In order to prevent the fish from flying over, branches of trees are laid all along the head-line. When properly extended, a canoe at each end of the net gradually advances, forming it into a circle, into which the fish are driven by a number of canoes, who fill up the open side, and beat the surface violently with branches. When the canoes at each end of the net meet, they gradually take it in, contracting the circle till the fish are forced into the bag in the center. (pp. 141-143)

Hook and Line:--Campbell says the hooks were made of pearl or turtle shell and also noted that iron trade fish-hooks were coming into general use. The only type of hook and line fishing mentioned was trolling with the pā type lure for bonito, albacore and mahimahi, but Campbell does say that the fish lines were made of olonā, spun into lines by rolling the fibers between the hand and thigh.

Poisoning:--Campbell describes fish poisoning in substantially the same way as does Cobb for the late nineteenth century, but Campbell stated that the fish were instantly gutted after being poisoned to keep the poison from affecting the quality of the flesh while Cobb says the poison did not affect the flesh.

Other Early Nineteenth Century Sources

Malo:--The material in David Malo's Hawaiian Antiquities (1951) would have been helpful since Malo was born about 1793 at Keauhou, Hawaii, and described fishing techniques before his death in 1853. Unfortunately, his information on fishing usually consisted of merely naming various net and hook types with no explanation or description. Explanations and/or descriptions were often given parenthetically or by footnotes, but since Malo's work was first translated and edited by N. B. Emerson and later edited by W. D. Alexander, it was impossible to tell when the additional detail was that of Malo, Emerson, or Alexander (Rohsenow 1967:11). This meant an uncertainty about the time period reflected for it could be from early to late nineteenth century; therefore, for the purposes of establishing a description of Hawaiian fishing for a particular time plane, it was necessary to disregard the data in Malo.

Ii and Kamakau:--The accounts of Ii (1963) and Kamakau (1961) are usable for amplifying early nineteenth century accounts because they specifically discuss activities of Kamehameha I after he became ruler of Hawaii. John Papa Ii was born in 1800 and served in the Kamehameha I household under Liholiho, the son of Kamehameha I. Ii was sent to school under the missionaries after they arrived in 1820 and served in many responsible government and religious positions until his death in 1870. Because of these close connections with the Kamehameha household, the following description of Kamehameha I concerning fishing could be accepted as accurate for the early nineteenth century:

> Kamehameha was often seen fishing with his fishermen in the deep ocean, where the sea was shallow, and where fish-poison plants were used. He took care of the canoe paddlers who went out for aku fish, bringing in supplies from the other islands for them, and sent ships to-and-fro fetching nets, lines, olona fibers, and other things (p. 69).

The accounts of Kamehameha I by Kamakau also mention fishing techniques that are applicable to the early nineteenth century. Kamakau was born in 1815 but his work is included in the early period for he wrote as a scholarly native historian of events in the life of Kamehameha I (cf. Rohsenow 1967:12). The following passage has been accepted as accurate for the early nineteenth century since it is from a section explicitly about Kamehameha I:

> There were deep-sea nets for fishing (aumaiewa), shallow-sea nets for fishing (laulele), nets for fishing by diving ('upena-lu'u), fishing by enticing into the net by means of a stick with a strong odor (lawai'a melomelo), aku trolling with mother-of-pearl hooks (lawai'a-hi-aku), ahi trolling with hook and line (hi-ahi), net fishing for flying fish (hano-malolo), trolling for kahala fish with hook and line (hi-kahala), and several other kinds (p. 176).

These three sources tend to substantiate one another and depict the use of seine/bag net combinations, bag nets used alone, melomelo bait sticks, fish poisoning, hand held diver's nets, trolling for aku with the pā lure as well as hook and line fishing for 'ahi and kāhala.

Late Eighteenth Century

Data Sources

A.D. 1778 to 1779

If the goal is to use the direct historical method to extrapolate historic exploitation back into prehistory, the best possible sources would be those written precisely at the time of initial contact in 1778. Careful research through the journals of Cook, Clerke, King, Anderson, Samwell, Burney, Williamson, and Edgar, however, yielded only the following scant materials on sea exploitation:

> In none of these Islands have they yet arrived at that pitch of refinement in their Arts, to divide their Labour, the same(e) man is taught to make a boat, a house, Nets &c. (King 1967: 1184).

> They catch fish with Nets and Hooks of different sizes made of Mother of pearl, bone and wood pointed with bone, and the latter are of a great size with which they catch Sharks and other large fish (Samwell 1967:1184).

> Before we left Keragegooa [Kealakekua] we saw many small fishhooks which they made with the nails they got from us . . . (Samwell 1967:1186).

Thus, all that can be said for the time of contact is that the Hawaiians had nets and fishhooks of pearl shell, bone, and wood. It is interesting to note that iron fishhooks fashioned by the Hawaiians themselves were being made by the time the expedition left Kealakekua Bay.

A.D. 1779 to 1800

The information from the time of contact was inadequate to use as a basis for this research so other journals recording observations on Hawaii before 1800 were checked; unhappily, with much the same results. The journals of Ingraham (1918), Dixon (1789), Portlock (1968), Ledyard (1963), Meares (1791), Mortimer (1791), Vancouver (1967), Broughton (1804), La Perouse (1798), and Marchand (1801), were studied and only the following passages were found:

> A number of their fishing lines were purchased, many of which were from three to four hundred fathoms long, and perfectly well made. Some were made with two and others with three strands, and much stronger than our lines of twice the size (Portlock 1968:59).

> It was not our Captain's intention to anchor at this island, but ply off and on occasionally, in order to procure a good supply of hogs and vegetables, and all the line we could meet with, this part of Owhyhee [Hawaii Island] affording great plenty of fishing-lines, which we had found, by experience to be particularly useful in making ropes for various purposes (Dixon 1789:250).

> Fish-hooks are made of the pearl oyster-shell, and so contrived as to serve for both hook and bait. Those intended for sharks are considerably larger, and made of wood (Dixon 1789:273).

> Besides the variety of fishing-lines already mentioned, they have various other kinds of cordage, and made of different materials. The worst sorts were found useful in rounding our cables; that of a better kind was appropriated to other purposes; and the fishing-lines made excellent tackle-falls, top-gallant haulyards, etc. (Dixon 1789:273).

> We purchased of these people 8 pigs, 20 fowls and a great quantity of potatoes, taro, plantains, cocoanuts and sugar cane, besides many hundred fathoms of fine line of various sizes, for which we paid bits of iron hoops and nails (Ingraham 1918:4).

The journals checked during the course of this research constitute virtually the whole of written literature available for the late eighteenth century. As can be seen, the picture developed from these sources is exceedingly sketchy and about all that is known is that nets and fishhooks were in use during this period.

Synthesis of Historic Hawaiian Maritime Techniques

Historically authenticated details of Hawaiian marine exploitation show that native techniques included fishing with hook and line by both surface trolling and sub-surface angling, netting, spearing, hand catching, poisoning, snaring, and the use of basket traps. Data in the historic literature can also be used to determine which techniques were most generally used to exploit particular types of marine biota and these are summarized in Table V of Appendix C.

Inshore Exploitation

An analysis of the marine zones in which these organisms normally are found shows a pronounced correlation between habitat and exploitative technique. The inshore habitat was exploited by sub-surface angling with pole, line, and fishhooks for fish within the surge and portions of the sub-surge zones while the octopus was taken by hand line and cowry shell lure, from the sub-surge zone. Only gill nets primarily tapped the surge and reef-protected zones; seine/bag combinations were able to exploit the sub-surge zone to a depth of about 50 feet (15 meters) through the use of lau ropes to drive the fish into the shallower surge and reef-protected zones where the fish could be surrounded by the seine and forced into the central bag, if one was used. The surge zone and upper portions of the sub-surge zone were exploited by divers hand-collecting fish, crustacea, molluscs, and echinoderms, sometimes through the use of spears, hand-held small bag nets or poison. Basket traps and snares were used in the surge, reef-protected, and portions of the sub-surge zone. Molluscs, crustacea, fish, echinoderms, and seaweed were collected by hand from the tidal pools, supra-surge zone, and shallow water surge zones from above the surface, while spears and hand-held bag nets were similarily used in shallow water areas, particularly at night to collect fish and octopi.

The inshore area has the highest biomass, the most intensive techniques, and the greatest emphasis in Hawaiian ethno-taxonomy, so it most likely was the primary maritime exploitation zone.

Bottom Fishing

The lower limits of the sub-surge zone of the inshore area and the beginning of the benthic zone are ill-defined by the marine biologists and also in the exploitation practices of the Hawaiians. At some unknown depth hand-line fishing with baited hooks replaced pole and line fishing. No pertinent information was forthcoming in the historic literature but simple logic would indicate that pole and line fishing must be a very shallow water technique, for without reels to wind up line, it would be quite difficult to fish with a line exceeding the length of the pole. Thus, it could be speculated that pole fishing gave way to hand line fishing at any time the fishing depth exceeded about 15 feet (5 meters). Herbivorous fish normally are found in close proximity to the substrate where their food is located, and concomitantly, the predacious fish are also found near the herbivorous fish. Relatively few fish are found separated from the substrate. Therefore, it would seem most reasonable to suggest that even the inshore area was primarily fished along the bottom or near areas of vertical substrate, such as cliff zones. If this is the case, and it is a suggestion unbased in historic documentation, then pole and line fishing would most likely have been restricted to waters less than about 15 feet (5 meters) in depth. This means that hand line fishing would have been begun well within the inshore area to exploit the high biomass bottom zone.

Benthic Exploitation

This bottom exploitation continued throughout the inshore area and into the benthic habitat to a maximum depth of about 1,200 feet (366 meters). Although two techniques (kākā and kūkaula) were recorded for handline fishing this bottom area, it proved impossible to discover if both could occur together, or if each exploited a different depth. The kūkaula technique was definitely used in shallower waters for it was pointed out in the historic literature that its maximum depth was about 450 feet (137 meters), but the beginning point remains unknown. Likewise, the kākā technique was described for depths down to 1,200 feet (366 meters) but no mention was made of its beginning depth. However, the two techniques were so similar in principle that it makes little difference for it would be reasonable to state that the bottom was exploited from depths of about 15 feet (5 meters) to 1,200 feet (366 meters) with hand-line techniques.

Just as there was probably little fishing in the upper water levels of the inshore area, there was no apparent exploitation of the mid-water portion of the benthic and pelagic zones. There is a possibility that 'ahi was fished in the mid-water zone with hand line techniques but there were insufficient data to satisfactorily establish this. The fish caught in the benthic zone were primarily various types of large snappers and groupers; it may well be that a reasonably high biomass exists in this habitat.

Pelagic Exploitation

The transition between the inshore area and the pelagic zone is similarly indistinct for some generally pelagic fish are found quite close to the shore at times. Gosline and Brock recognized this problem from a zoological standpoint and defined the surface waters inshore of the 600 foot depth (183 meters) as the inshore pelagic zone.

It is immaterial to this paper, for the true pelagic zone generally occurs within one-half mile (.8 kilometers) of the shore in Hawaii, and although it is reasonable to expect some use of trolling gear in the more inshore area it must undoubtedly have been the predominate technique for exploiting the pelagic zone. Other techniques were variations of surface fish drives into bag nets, especially for the mālolo and iheihe. In any case, only about the upper 25 feet (8 meters) of the pelagic zone were exploited by the Hawaiians. Furthermore, although the pelagic zone extends indefinitely across the ocean as its upper water area, it is unlikely that the Hawaiians ventured far offshore in their pelagic fishing.

Horizontal Limits to Pelagic Fishing

The bait fish ('iao or nehu) are quite delicate and tend to die rather quickly in the bait tanks of modern aku boats, and much the same problem would probably have occurred with the Hawaiian bait box, or malau. It would be expected that every effort would have been made to fish as close to the source of the bait supply as possible, both from the standpoint of the bait life and from re-supply.

Also, although schools of pelagic fish are to be found scattered over the ocean, the signs by which these schools can be located are found more commonly near shore. For instance, bird flocks circling over feeding aku schools signaled the presence of the school to the Hawaiian fishermen just as they do to the aku sampan today. Drifting flotsam and jetsam attracts pelagic fish (cf. Gooding and Magnuson 1967) and it would be expected that such floating materials would be more common close to the islands and would have served as signals for fish concentrations. Finally, the size of the canoes would have limited the amount of bait that could be carried and would have limited the amount of fish that could be brought home.

In essence, what is suggested is that although the pelagic zone is practically boundless, the Hawaiians most likely only exploited the zone fairly near the islands. Modern aku fishing with motorized sampans concentrates its fishing emphasis within 20 miles (17 kilometers) of the islands and for the period of 1952 to 1962, an average of 75 percent of all aku were caught within this range (Uchida 1967:183-184). It is probable that the Hawaiians generally fished the pelagic zone to a distance of no more than 5 or 10 miles (8 to 16 kilometers) offshore, but there is no direct support for this speculation.

Hawaiian Emphasis on Pelagic Fishing

The role of pelagic fishing in Hawaiian substance patterns has been emphasized by many authors, but it would appear from this study that pelagic fishing was of tertiary importance--behind both the benthic and inshore areas. It is a spectacular technique and this might have caught the attention of the early observers, who found it romantic, but in terms of consistent food supply it is a reasonable conclusion that inshore was the primary area, followed by the benthic. Although the yield would be high in the pelagic area for successful fishing trips, such a good yield would be completely unpredictable for several reasons:

(1) akū, the primary fish taken, occur in schools which continually move [aku must move to respire so they never stop] hence the precise location of a school could not be predicted;

(2) only those schools associated with drifting objects or birds could normally be located from a distance, which eliminated all schools unassociated with these signs except for chance;

(3) even when a school was located it might not have been possible for a canoe to reach it, for aku swim at a speed of .6 to 13.9 miles per hour (.3 to 6.9 meters per second) (Manar 1966:8) and even if fishing began in a school, this same speed might have caused the canoe to lose the school before many were caught;

(4) even when a school was overtaken and fishing began, often only about fifty percent of the schools would bite (Uchida 1966:148);

(5) schools are composed of the same size fish (Nakamura 1967:3) and a school of small aku

> will yield a lower biomass than a school of big aku for, although the time required to land a large aku is about the same as for a small aku, fishing had to take place within a maximum period of perhaps ten to fifteen minutes before the school outdistanced the canoe.

It is suggested that aku or other pelagic fish were only a supplementary source of food, either to inshore and benthic habitat exploitation or to land foods. There is a possibility that it was limited to those who could afford to take the chance of not catching anything, either the higher socio-economic levels of Hawaiian society who received food from the efforts of lower ranking people or those with adequate food supplies from other sources.

This argument is an extension of what ecologists have termed "Liebig's Law" which simply means that a population is limited by whatever necessary component occurs in minimal quantity (Liebig 1965:12-14). Obviously a population cannot exceed its food supply for long without a population reduction and hence not only is quantity of food important, but its predictability or consistency is critically important. If food supplies oscillate widely over a long period of time, the population will tend to reach stability at the largest number that can be supported with the minimal level of food during the period. Thus, although large catches of aku might occur it would never be a major source of food necessary to maintain a population because of its unpredictability. Not only is aku unpredictable in fishing, it is a seasonal resource for aku migrations arrive primarily during the summer months in Hawaii.

Although the Hawaiians did exploit the pelagic zone for aku and other surface feeding fish, it is very unlikely that pelagic exploitation accounted for a substantial portion of the basic food supply. It can be seen that the Hawaiians exploited the marine ecosystem from the tidal and splash pools above the mean water level down to depths of about 1,200 feet (366 meters) and from the shore line to perhaps ten miles (16 kilometers) to sea.

Hawaiian Maritime Econiches

These marine zones are not human habitats, for habitat literally means the place of residence or where an organism is found (Odum 1959:27). Man's habitat must have air and this eliminates the sea for the Hawaiians, but the sea is a human econiche. The econiche is an ecological concept that carries the association of both location and behavior; thus although man does not live in the sea, the Hawaiians did exploit various portions and these may be termed human econiches. Figure 2 shows a summary of the Hawaiian maritime econiches for 1800 that were derived from this study.

Reinman suggested a division of exploited marine habitats into inshore and off-shore in his general summary

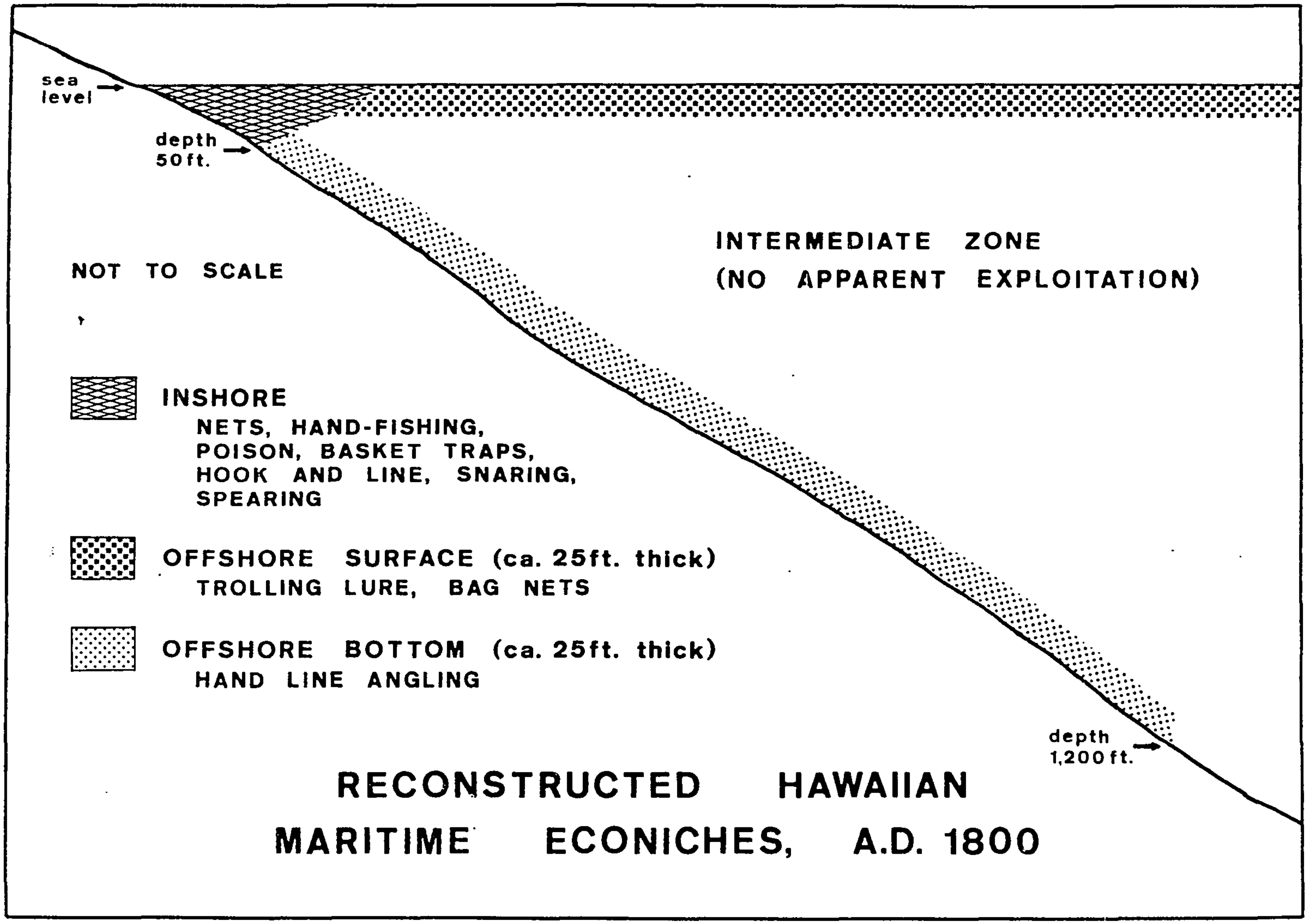

sea level
depth 50 ft.
INTERMEDIATE ZONE
(NO APPARENT EXPLOITATION)
NOT TO SCALE
INSHORE
NETS, HAND-FISHING, POISON, BASKET TRAPS, HOOK AND LINE, SNARING, SPEARING
OFFSHORE SURFACE (ca. 25ft. thick)
TROLLING LURE, BAG NETS
OFFSHORE BOTTOM (ca. 25ft. thick)
HAND LINE ANGLING
depth 1,200 ft.
RECONSTRUCTED HAWAIIAN
MARITIME ECONICHES, A.D. 1800

Fig. 2

of fishing in Oceania (1967:112). Cross-cutting these were vertical exploitation zones he called "surface" and "sub-surface" (p. 112). Although Reinman's discussion is confusing, apparently the econiches reconstructed in Figure 2 differ from his primarily in lumping the inshore surface and sub-surface zones together, and in limiting the offshore sub-surface econiche to that near the bottom.

Exploitative Techniques and Midden Analyses

Since certain biota are restricted to particular habitats, or exploited in human econiches, a knowledge of this distribution will help in archaeological analyses. If a particular fish type, for example, is represented in a midden and known to have been almost exclusively caught with only a single technique, it is reasonable to infer the exploitative technique from an identification of the midden remains. Thus, on the basis of this research, it is possible to reconstruct specific exploitative techniques for Hawaiian sites if particular marine midden remains are found. The correlations between midden remain types and exploitative techniques are shown in Appendix C, Table VI.

No marine biota were exploited solely by basket traps, snares, or spearing so these techniques cannot be reconstructed on the basis of midden remains. Unfortunately, the present ability of marine biologists to identify fish remains down to so fine a taxonomic level is hindered by by lack of appropriate skeletal taxonomic studies, for most identifications are now made on the basis of soft body parts. The potential is there, however, to utilize these data to reconstruct quite precisely the exploitative techniques for Hawaiian maritime focused sites.

Summary of Historic Maritime Exploitation

In summary, the historic data reveal a primary Hawaiian maritime dependence upon relatively stable inshore resources which yield a high and consistent biomass through the use of diverse exploitative techniques. Practically every available, culturally acceptable and sufficiently nutritive marine organism was exploited in this inshore area. The benthic habitat was most likely of next importance and was exploited solely through the use of hand-line angling techniques, primarily to take larger fish such as the various snappers. The pelagic habitat was of tertiary significance to the Hawaiians and primarily yielded surface-feeding carnivorous fish such as aku and mahimahi through the use of surface trolled lures, although mālolo and iheihe were caught with nets.

Exploitative Stability

Perhaps the major conclusion of this analysis is that historic marine exploitation was quite stable, even in a context of widespread social change. Most of the body of data is consistently present from the beginning to the end of the nineteenth century. The only non-native artifacts to appear during the historic era were sinkers of lead and iron, European manufactured metal fishhooks, metal fishhooks crafted by Hawaiians, and the cast net. It is also possible that the gill net is the result of diffusion but the data are unclear; it was probably indigenous. This nineteenth century stability of maritime exploitative techniques may be reasonably projected backwards to the time of contact in 1778 although the specific data are sparse, because there was even less social upheaval and change from 1778 to 1800 than there was from 1800 to 1900. If sea exploitative techniques were stable and consistently present throughout the nineteenth century, it is logical to assume they were present during the latter part of the eighteenth century, a time of much less general change. Thus, the general observations of nineteenth century native techniques can be assumed to have been present for the entire pre-twentieth century historic period.

A Functional Study of Hawaiian Fishing Gear

Introduction

These historic data and interpretations may be synthesized with a brief functional study of fishing gear to broaden the overall picture of Hawaiian maritime exploitation. The study of Hawaiian fishing gear has been quite important in Hawaiian archaeology for the past decade.

Archaeologists such as K. P. Emory, W. J. Bonk, and Y. H. Sinoto have made extensive analyses of fishing gear shapes, sizes, materials, and manufacture techniques (e.g., Bonk 1954; Emory, Bonk and Sinoto 1959; Sinoto 1962, 1967, 1968). The emphasis has been on the formal analysis of these artifacts to uncover the cultural ties of the early Hawaiians and to develop a temporal sequence for Hawaii. A functional analysis of fishing gear, however, is required for an ecological study such as this.

Fishhooks

The function of a fishhook is quite simple: to catch fish. The manner in which this is accomplished, however, depends upon particular fishhook characteristics, especially size and shape.

Fishhook Size

Small hooks are normally used to catch small fish and large hooks used to catch large fish. This is obvious for the extremes of fish and hook size, but much less obvious for the intermediate sizes. Rather large fish can be caught on a small fishhook, but it is unlikely that this was a frequent occurrence because a small fishhook is structurally too weak to hold a fish much larger than that for which it was intended. Likewise, a small fish might be caught on a large fishhook but this is even more unlikely because a large hook would penetrate the mouth of a small fish only with difficulty. Metal fishhooks are a possible exception for their tensile strength is much greater than native materials so that a small metal hook might hold a large fish; likewise, metal malleability allows a large hook to be made with a long sharp point capable of penetrating the mouth of a small fish. In general, however, there is a definite correlation between hook size and size of fish to be caught; at least with the extremes of hook and fish size.

There is also a general correlation between fish size with water depth, larger fish being found in deeper waters. Small fishhooks were probably used in the inshore, shallow water areas while large fishhooks were used further off-shore in deeper water. This point will be amplified and definitions provided for "large" and "small" fishhooks later in this section.

Fishhook Shape

Fishhook shape is a functionally important characteristic, particularly in the shape distinction between hooks having incurved points (rotating hooks) and those with straight or outcurved points (jabbing hooks). A typical rotating hook is illustrated in Appendix G, Figure 8, Number 15; typical jabbing hooks are shown in Figure 8, Numbers 3-9. For example, Nordhoff says of Tahitian fishing:

> In one respect the use of all these in-curved or angular native hooks differs from that of ours [the European 'jabbing' hook]. When the

> fisherman using a European hook "gets a bite," he strikes to set the point and the barb in the fish's mouth. With the native hook, on the other hand, one must never strike; a steady gentle tension is kept on the line and the fish allowed to hook itself. The pull of the line, leading from the inner head of the shank and causing the hook to revolve, sets the point deeper and deeper in the fish's jaw. (1930:156)

Kennedy discusses the catching of palu, or deep water ruvettus, as follows:

> When the palu takes the bait (which is lashed with thread to the point-leg of the hook, leaving the point and shank exposed) he forces the angle of his jaw through the clearance between the point and shank of the hook; the pull of the line then causes the point to penetrate the thin tissues of the bottom or side of the jaw, after which the whole point-leg slips through. Once the point enters the fish's jaw, escape is practically impossible. (1942:62)

Robinson describes his fishing experiments with the incurved rotating type hook as follows:

> I found that every fish caught had worked the thin tissues at the side of its mouth through the clearance between the point and shank of the hook and that the pull of the line then rotated the hook and caused the point to slide through. In using hooks of this type one must be careful not to jerk the line or "set" the hook as one sets the European barbed hook. A steady gentle tension is kept on the line and the fish given sufficient time to hook itself.
>
> A fish once caught on an incurved hook with a relatively narrow clearance between point and shank . . . has little chance of escape. This fact was clearly evident during my experiments, and appears to be the strongest recommendation for using them rather than European hooks. (1942:63-64)

The essential functional attribute of the incurved shape is the ability of a hook to securely hold a fish after the fish hooks itself. This suggests a basic functional reason for rotating and jabbing fishhook shapes in Hawaii.

A rotating fishhook could hook and hold a fish without any action by the fisherman, while the jabbing fishhook had to be set by a jerk on the line.

Small jabbing and rotating hooks from Hawaiian sites indicate that both techniques were practiced in shallow waters, but it is significant that virtually all large and robust hooks are the rotating type.

Fishhook Types Used for Deep Water Fishing

There is most surely a correlation between deep water line fishing and the large rotating fishhook. In the first place, a large hook is needed since deep water fishing would consistently yield larger fish than shallow water fishing. Secondly, as pointed out by Dr. J. Maciolek, Marine Biologist at the University of Hawaii, a fiberous native fishing line would have become heavier the deeper one fishes (personal communication 1970). The maximum Hawaiian fishing depth of 1,200 feet (366 meters) may have been the limit on human strength to raise a line of that length: the line itself might also have tended to break from static weight at greater line lengths. Such a heavy line would also tend to dampen any sharp jerk by a fisherman who attempted to set a jabbing hook. Thirdly, a heavy wet line would make it difficult to detect fish nibbling the hook and, hence, hard to judge when to set it. Finally, the holding characteristics of a jabbing hook depend upon a steady pull opposite to that applied by the hooked fish; in most cases upward. It would be necessary to immediately bring a hooked fish back to the surface instead of allowing the line to remain at the original depth. Such a holding limitation to the use of a jabbing hook would mean that only a single hook could be used effectively.

Fishing at great depths must have involved great expenditure of energy to bring the line back to the surface so it would be advantageous to use multiple hooks, leaving the fish below until all could be brought up together. Multiple jabbing hooks used on deep water lines would be almost impossible to employ because of the nature of the holding design, the fact that multiple fish on a line would prevent feeling fish nibbling at the remaining hooks, and the inability of the fisherman to administer the necessary sharp jerk against both the weight of a sodden line and other thrashing fish.

In summary, it is unlikely that multiple jabbing hooks were used on deep water lines. Since the historic data indicate multiple hooks for both the kākā and kūkaula deep water hand line techniques, these were most likely rotating hooks.

Function of Two-piece Fishhooks

"Rotating" and "jabbing" have most often applied to one-piece fishhooks, as illustrated by the formal typology of Emory, Bonk, and Sinoto (1959:10). These terms, however, are applicable to the two-piece hooks from Hawaii if both parts are considered together as a single fishing device, not as shanks and points. Two-piece hook points from Hawaii are both incurved and straight, and when fitted to shanks function as rotating or jabbing hooks. Both one-piece and two-piece incurved fishhooks rotate according to the same mechanical principles, holding a fish in the exact same manner.

Function of Fishhook Barbs

Barbs on Hawaiian fishhooks appear, on the basis of shape and position, to have served two basic functions:

(1) to serve as an anchor point for tying bait to the hook, and

(2) to prevent the fishhook from backing out of the fish after penetration.

Barbs that probably served as bait lashing points are usually found on the outside of the bend on one-piece hooks. Barbs serving to hold the fish are usually found on the inside and outside of the point and on the inside of the shank. Various combinations of barbing may appear on any one fishhook.

Barbs were probably more consistently used on jabbing hooks because without barbing the retentive power of the hook depended upon a steady upward pull of the fish line. The generalization that rotating hooks were most likely the type used for deep water hand lines would have to be qualified if it were shown that the usual fish caught struck jabbing hooks so savagely that they impaled themselves with no "setting" action necessary on the part of the fisherman. If this happened and the jabbing hook barbs were sufficient to hold the fish without the necessity of immediately raising the whole fishing line, then jabbing hooks could also have been used for deep water hand lines. This demands experimentation to determine, however, and is beyond the scope of the present study.

Size and Shape Characteristics of Hawaiian Fishhooks

Table III shows that Emory, Bonk, and Sinoto found that 155 one-piece unbarbed bone jabbing hooks had an average shank length of 0.79 inches (19.8 mm.) and that 62 one-piece unbarbed bone rotating hooks had an average shank length of 0.79 inches (19.5 mm.). Two-piece hook points were found to cluster into two distinct distributions dependent upon whether they were small and thin (slender) or large and thick (robust). Table III shows that 119 base notched slender inner barbed points averaged a length of 0.87 (21.9 mm.) while similar knobbed points averaged a length of 0.79 inches (19.7 mm.). Robust base notched points with inner barbs were an average of 1.83 inches (46.6 mm.) in length while equivalent knobbed points averaged 1.5 inches (37.1 mm.) in length (Table III).

There is a general agreement in average size for both the one-piece and two-piece hooks on the basis of small thin hooks and large thick hooks. Furthermore, if the

TABLE III

HAWAIIAN BONE FISHHOOK SIZE CHARACTERISTICS[a]

Fishhook Type	Number	Average Shank Length	Range	Standard Deviation
One Piece Jabbing (unbarbed)	155	0.79 in. 19.8 mm.	0.28-1.3 in. 7-32 mm.	0.16 in. 4.4 mm.
One Piece Rotating (unbarbed)	62	0.79 in. 19.5 mm.	0.39-1.53 in. 10-39 mm.	0.26 in. 6.6 mm.
Two Piece Points				
Slender (inner barb) Notched	119	0.87 in. 21.9 mm.	0.53-1.31 in. 13.5-33.5 mm.	0.13 in. 3.6 mm.
Knobbed	53	0.79 in. 19.7 mm.	0.47-0.96 in. 12-24 mm.	.11 in. 2.9 mm.
Two Piece Points				
Robust (inner barb) Notched	42	1.83 in. 46.6 mm.	1.08-3.0 in. 27.5 - 76 mm.	.29 in. 7.5 mm.
Knobbed	28	1.5 in. 37.1 mm.	0.87-2.0 in. 22-51 mm.	0.27 in. 6.8 mm.

TABLE III (continued) HAWAIIAN BONE FISHHOOK SIZE CHARACTERISTICS

Fishhook Type	Number	Average Shank Length	Range	Standard Deviation
Two Piece Points				
Jabbing (IID3)	338	1.04 in. 26.6 mm.		
Rotating (IID4)	33	1.6 in. 40.4 mm.		

[a]Based on data from Emory, Bonk, and Sinoto (1959:14-18)

large thick points are grouped together the notched base points fill in the upper portion of the size curve for they are generally larger than the knobbed base points. The curve, however, would probably be slightly bimodal. Emory, Bonk, and Sinoto provide data on the sizes of two-piece fishhooks in terms of average length measurements for each formal classification (1959:17, Table 2). Although not the best statistical procedure, if the average lengths of all jabbing-hook (IID3) sub-types are totaled and divided by the number of hooks, a rough average length of all 338 two-piece jabbing hooks (straight or slightly incurved) is 1.04 inches (26.6 mm.). The average length of 33 rotating hooks (IID4) is 1.6 inches (40.4 mm.). This should be recomputed to average all individual hook lengths together instead of averaging the means of the sub-types. There is apparently a clear distinction between the average size of two-piece rotating and jabbing fishhooks.

Function of the Notched/Knobbed Traits

Emory, Bonk, and Sinoto have suggested that notched points were probably attached to wooden shanks and that most knobbed points were lashed to bone shanks (1959:27). If this is correct then it is possible that these wooden shanks had an incurved wooden-point limb to convert even the slightly curved jabbing two-piece hook points into an integral part of a large rotating hook. In other words, if a wooden shank is a reasonable suggestion, it is also reasonable to suggest that many of the straighter points completed a large rotating fishhook of wood; a type not uncommon in Polynesia. Such a large rotating hook might have been used singly at great depths to catch very large fish. It is also possible that the Hawaiian crescent points were similarly set in a rotating wooden hook.

Exploitation Techniques and Fishhook Size

What has been suggested here is that fishhooks larger than 1.5 inches (38 mm.) in overall length were probably used to catch large fish from deep water with long line rotating hook techniques, regardless of the formal classification of the hook. Hooks less than about 3/4 inch (20 mm.) in length were most likely used for shallow water inshore fishing. Hooks measuring between these two extremes were probably used in both areas, or used in graduated fashion according to water depth and size of fish expected to be caught.

Function of the Two-piece Fishhook Construction

It has been suggested that two-piece hooks existed in Hawaii because there were no animals large enough to supply a bone large enough to make big one-piece hooks. This would seem a safe hypothesis for large fishhooks, but the same hypothesis will not explain the presence of two-piece hooks small enough to have been made of a single bone piece. The data of Emory, Bonk, and Sinoto suggest that there is a higher percentage of small two-piece jabbing hooks than small one-piece jabbing hooks (338 two-piece to 219 one-piece small jabbing hooks; 1959:14-16). This may be explained by the nature of the hooking technique. Greater force would be applied to the point and bend of a jabbing hook than to that of a rotating hook by the very act of setting, regardless of the size of the fish. A sudden jerking force setting a jabbing hook might snap a one-piece hook at the bend, its weakest point. This weakness is greatly bypassed by lashings in the two-piece hook. Small bones would be weaker than the larger bones and thus it may be the increase in structural strength that can explain the large number of small two-piece fishhooks. The same rationale holds for large fishhooks; if a large fish is hooked on either a rotating or jabbing hook a great amount of force and torque is applied to the hook bend or base. A greater structural strength may have resulted from using the two-piece construction technique for manufacturing large fishhooks. Although available bone size was certainly a major consideration in Hawaii, the explanation for the existence of two-piece fishhooks may be partly the functional one of structural strength increase. In addition, should a two-piece fishhook still break, only half the hook would have been ruined, thus creating a saving of labor in the use of two-piece construction.

Hook Shape and Fishing Techniques

Correlations may exist between jabbing hooks and pole fishing and between rotating hooks and hand line fishing. It is easier to properly set the jabbing hook with a pole than with a hand line because of the increased snap a flexible pole gives. A twitch of the pole can set a jabbing hook more swiftly than a jerk of the hand, giving the fish less time to react and escape. It also prevents jerking so hard that the hook is torn from the fish mouth because of the give of the pole; the same is not true for jerking on a hand line.

Octopus Lure Sinkers

The function of the octopus lure has been well established by the historical analysis and this type of fishing can be substantiated in archaeological contexts if any part of the lure is found except the "breadloaf" sinker type.

This sinker cannot be used to unequivocably demonstrate octopus lure fishing because it has been reported as a net weight as well as a weight for the octopus lure (Emory, Bonk, and Sinoto 1959:28; Buck 1957:345). The "coffee-bean" sinker type, however, undoubtedly indicates the presence of octopus fishing using the cowry lure as do octopus lure points, toggies, and cowry shells with lip broken or holes punched in the dorsal side.

This completes the synthesis of maritime exploitation techniques and ecological data into a broad picture of Hawaiian use of the sea, a picture that may now be correlated with archaeological data.

CHAPTER IV

ARCHAEOLOGICAL EVIDENCE FOR SEA EXPLOITATION

Correlation Criteria

The archaeological materials to be mated with the materials from Chapter III, must demonstrably fulfill the following criteria:

(1) the data must be from archaeological sites reflecting significant maritime exploitation;

(2) the body of data must be large enough and of such a nature that it provides a reasonable basis for discussing maritime exploitation patterns; and

(3) the data must be from a site on the Island of Hawaii.

Although a number of archaeological sites meet part of these criteria, only Koaie fully meets them all. This makes it necessary to correlate the general body of historical material with data from only one archaeological site, hardly a desirable situation, but the Koaie data are uniquely able to provide the basis for these correlations.

Koaie was occupied from late prehistoric times up to about 1900, to judge from radiocarbon and artifact dating. Thus the historic and ecological materials will be correlated with archaeological data that are both historic and prehistoric. This is logically acceptable for the purpose of this paper since it is not economical to hypothesize that the techniques and technology changed in function although exploitive emphasis might change. If, for example, the pa lure was known to have been used in surface trolling for aku in historic times, it is most probable that the pa lure was used for surface trolling for aku in prehistoric times; not for deep water hand line fishing or some other purpose.

The emphasis on certain exploitive patterns did change over time at Koaie but there is no reason to think that the patterns or functions themselves changed. This paper closely focuses on correlating historic and ecological data with the Koaie archaeological materials to prepare the way for future studies of exploitation patterns through the use of archaeological data alone. As such, changes in emphasis on the use of particular patterns over time are beyond the scope of the present paper for these basic correlations must be made first. The Koaie data, therefore, are treated as a whole and internal shifts in exploitive emphasis will be handled in a later work.

The first part of this chapter will provide an overview of the Koaie data to assess how well it meets the correlation criteria listed above. The last portion will first deal with the types of archaeological information that may be correlated with materials from Chapters II and III, and then interpret the specific Koaie information to reconstruct exploitation patterns discernible in these data.

Koaie

Koaie is a habitation complex located on the west coast of North Kohala, Hawaii Island, about 0.6 miles (one kilometer) south of Mahukona Harbor (Map 3). William Bonk, working under a contract from the Division of State Parks, first noted its presence during a site survey of major archaeological features along the west coast of North Kohala in 1967 (Bonk n.d.). Koaie was assigned the temporary site number of 04-11-01 using the Division of State Parks designation system (Ching and Rosendahl 1968). The geographical setting was discussed in detail in Chapter II and it is sufficient here to merely note again that the site lies immediately adjacent to the shoreline in an area of scattered rocky beaches between low bluffs and lava outcroppings.

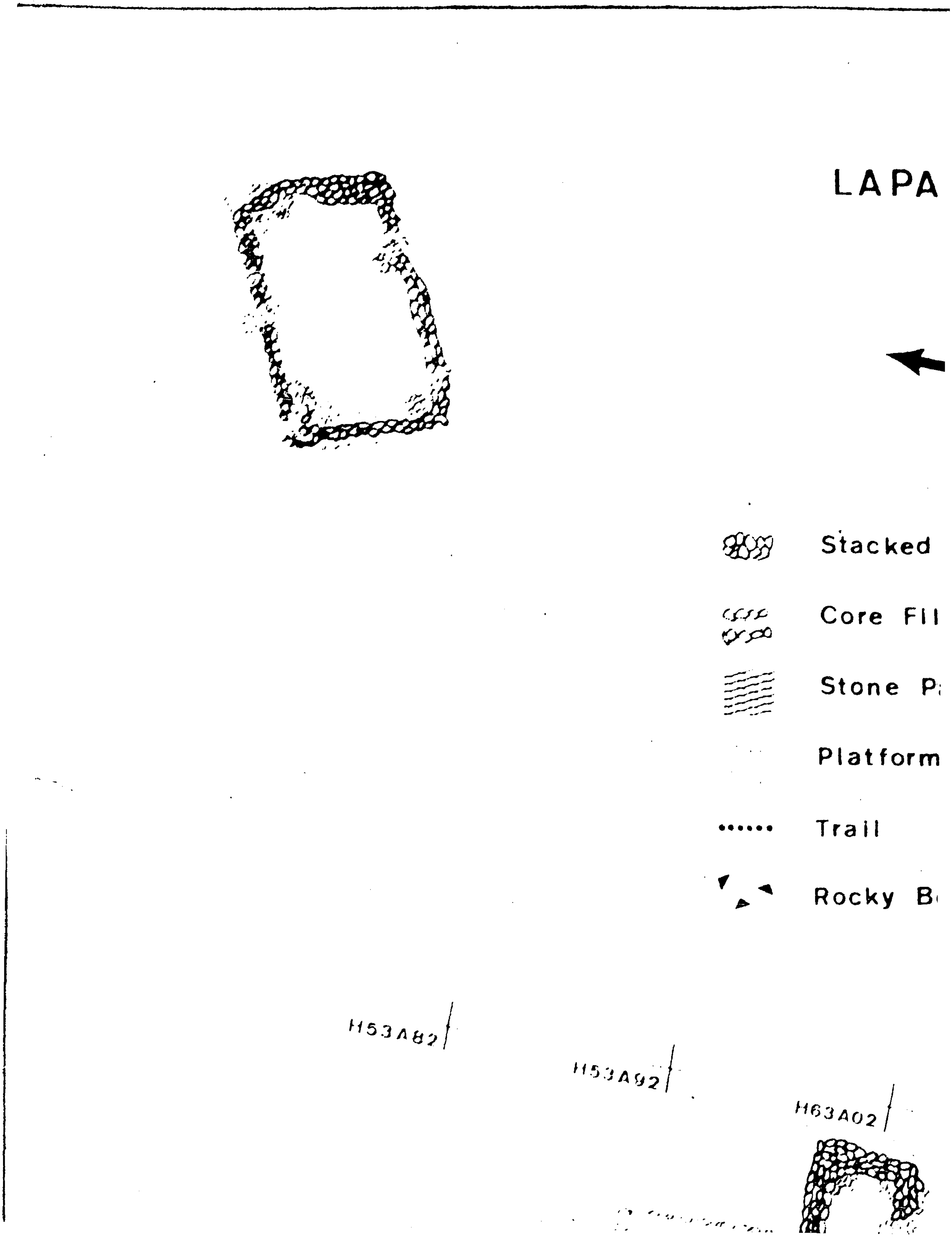
Background

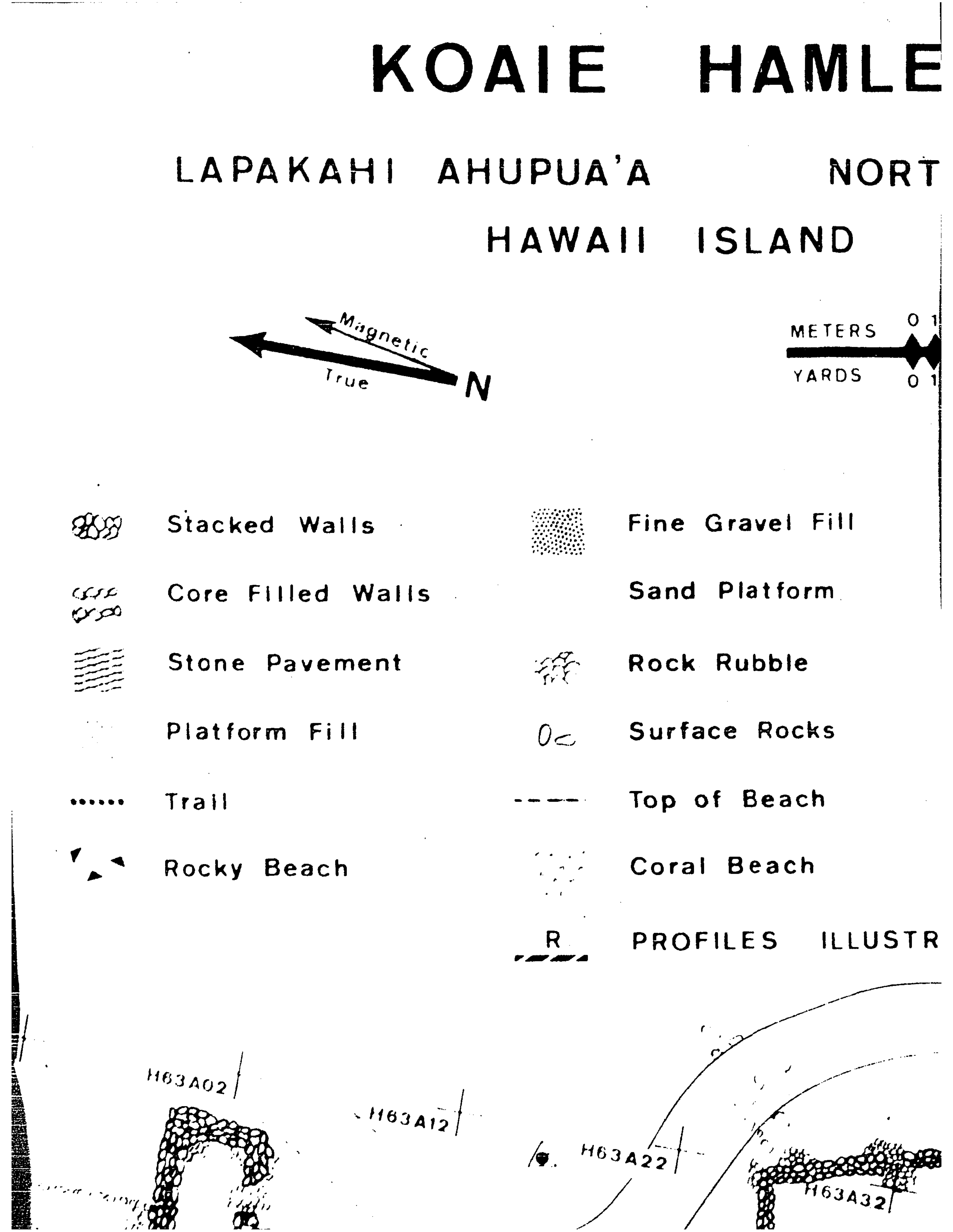
The choice of Koaie for excavation was based upon its high degree of preservation, logistic accessibility, visible historic materials on the surface, and most importantly, its coastal position within a native land tenure unit that exhibits an extensive agricultural field system beginning about 1.8 miles (3 kilometers) inland. Excavations were conducted for approximately ten weeks during the summer of

1968 by some 30 students, hired workers, and supervisory personnel taking part in the Summer Field School in Archaeology of the Manoa Campus, University of Hawaii. The Field School was under the guidance of Dr. Richard Pearson, Project Director, while this author directed the field work; funding was provided by the Division of State Parks, the National Science Foundation, and the University of Hawaii Summer Session. Joining the Manoa Campus team in excavations at Koaie, was the Summer Field School from the Hilo Campus of the University of Hawaii under the direction of William Bonk.

General Site Description

As can be seen in Map 8, the Koaie site lies parallel to the coastline for about 650 feet (200 meters) and extends inland only an average of 60 to 100 feet (20 to 30 meters) except for the ancillary area on top of a small rise in Hectare 63 Ares 85 and 86 (see Appendix B for a description of the grid designation system) and the inland portion of Hectare 73. The site as a whole can best be described as a central complex of interrelated stone walls, raised platforms, and sub-surface midden deposits with peripheral areas to the north of Hectare 62, Are 30/Hectare 63, Are 21; in Hectare 64; and to the south of Hectare 73, Are 41/Hectare 72, Ares 46-50. These peripheral areas are not connected to the central complex by either surface features or sub-surface midden deposits. William Bonk and the Hilo team excavated

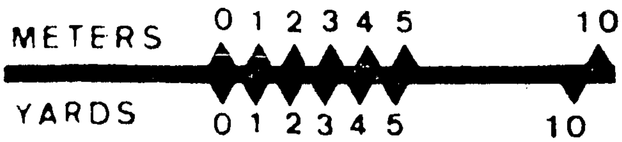

LAPA
Stacked
Core Fil
Stone P
Platform
Trail
Rocky B
H53A82
H53A92
H63A02


KOAIE HAMLE
LAPAKAHI AHUPUA'A
NORT
HAWAII ISLAND
Magnetic
True
N
METERS
0 1
YARDS
0 1
Stacked Walls
Core Filled Walls
Stone Pavement
Platform Fill
Trail
Rocky Beach
Fine Gravel Fill
Sand Platform
Rock Rubble
Surface Rocks
Top of Beach
Coral Beach
R
PROFILES ILLUSTR
H63A02
H63A12
H63A22
H63A32

HAMLET

NORTH KOHALA

SLAND



Gravel Fill — Jeep Road

Platform — Survey Points

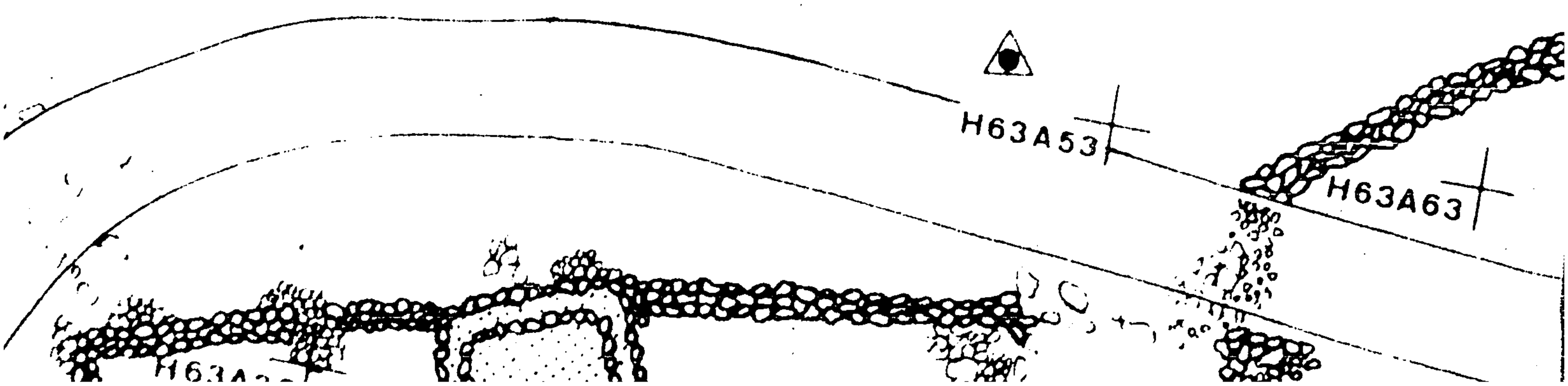
Rubble — Elevated Area

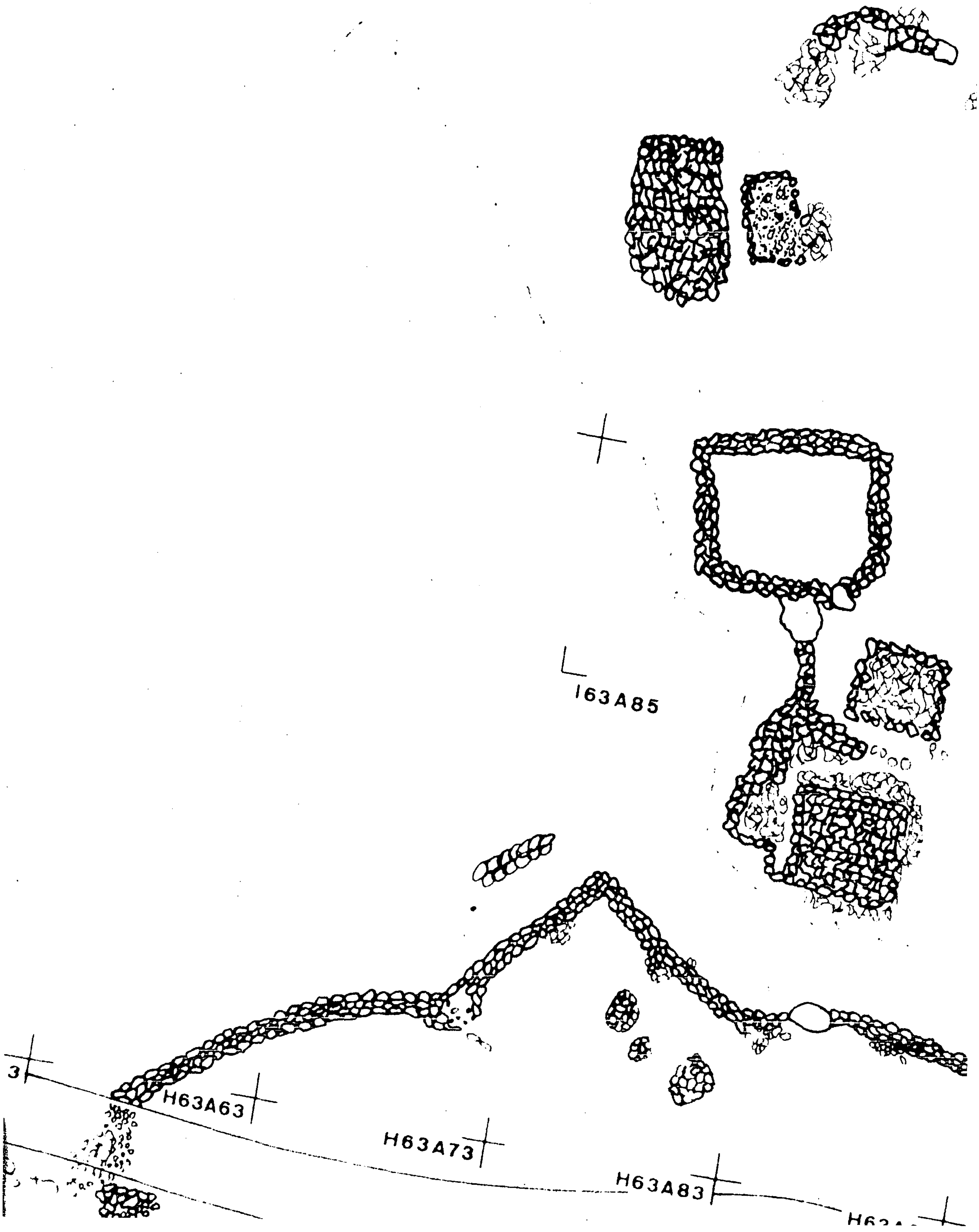
ce Rocks — Ocean

f Beach — H3A12 H3A1 Grid Corners
H: Hectare
A: Are

Beach

LES ILLUSTRATED IN TEXT





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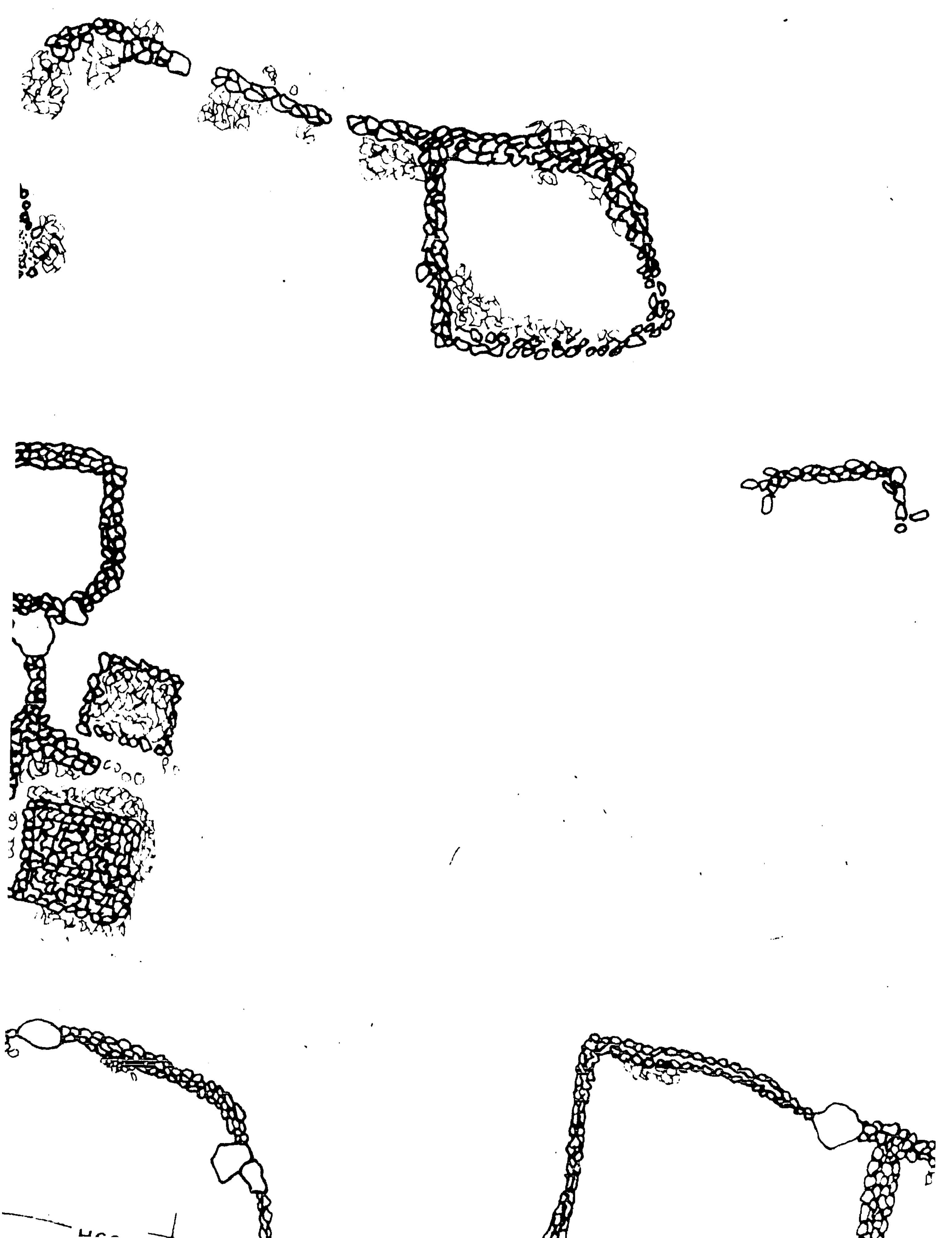
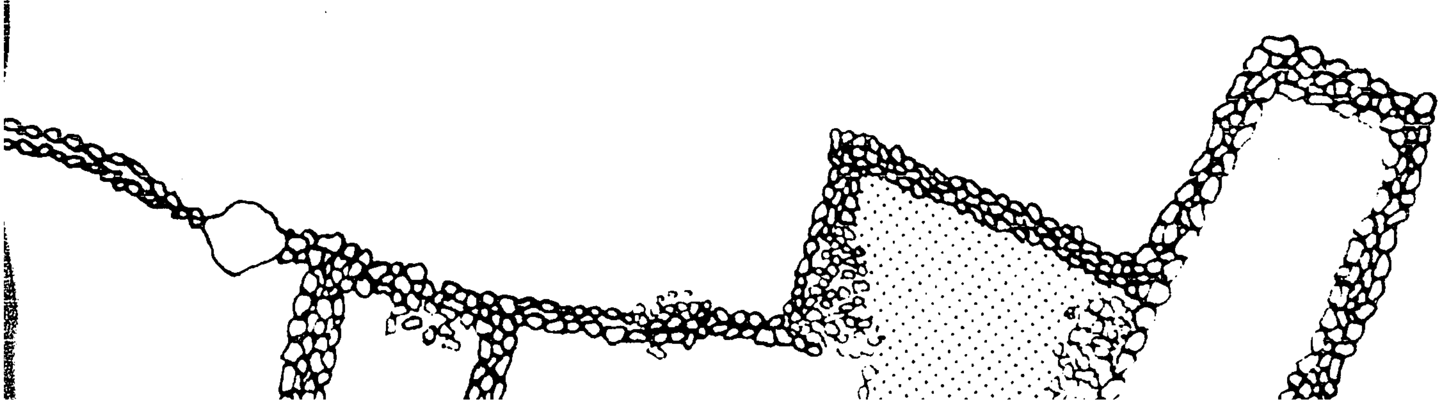
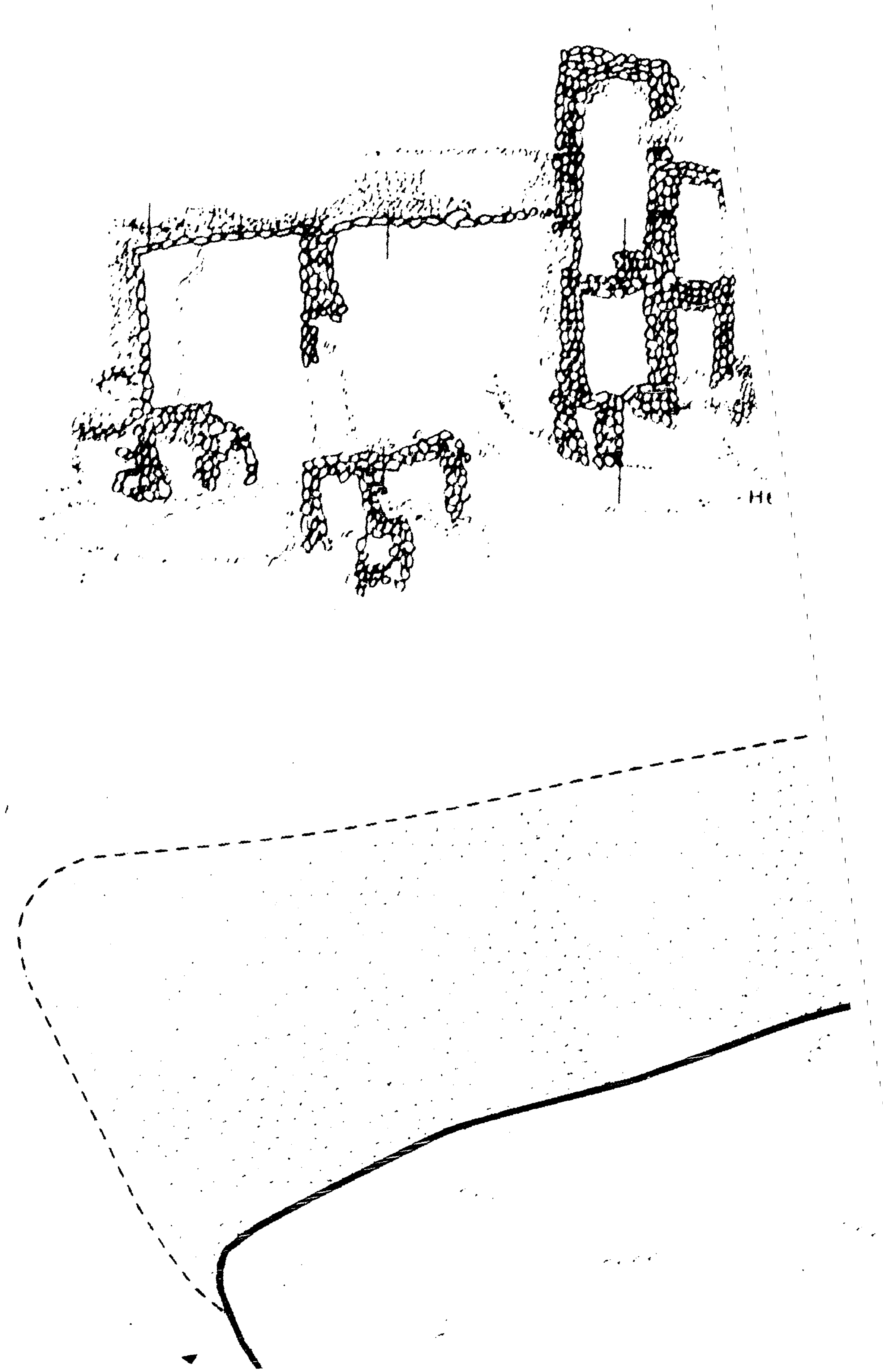
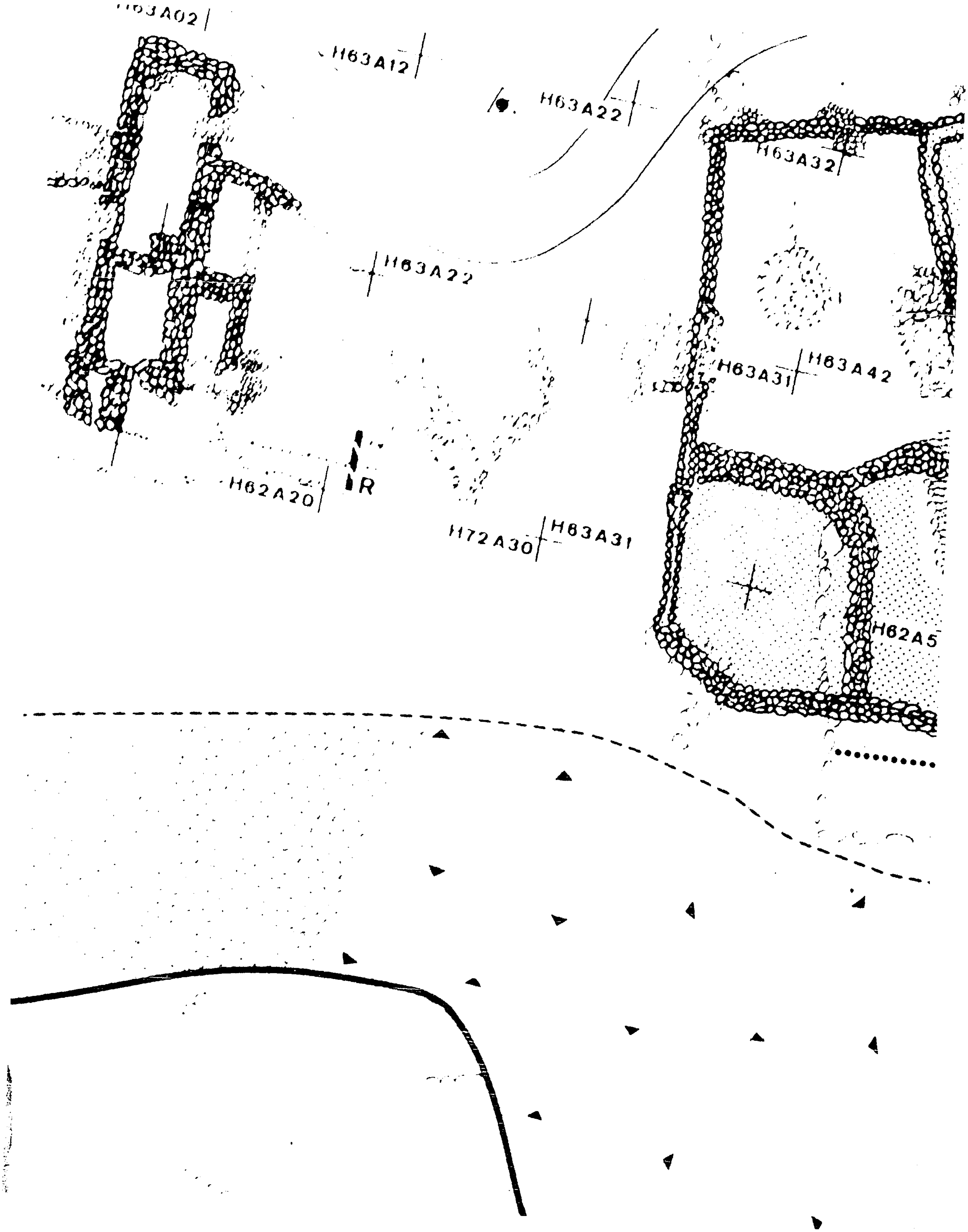
H63A73
H63A83








H63A02
H63A12
H63A22
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H63A22
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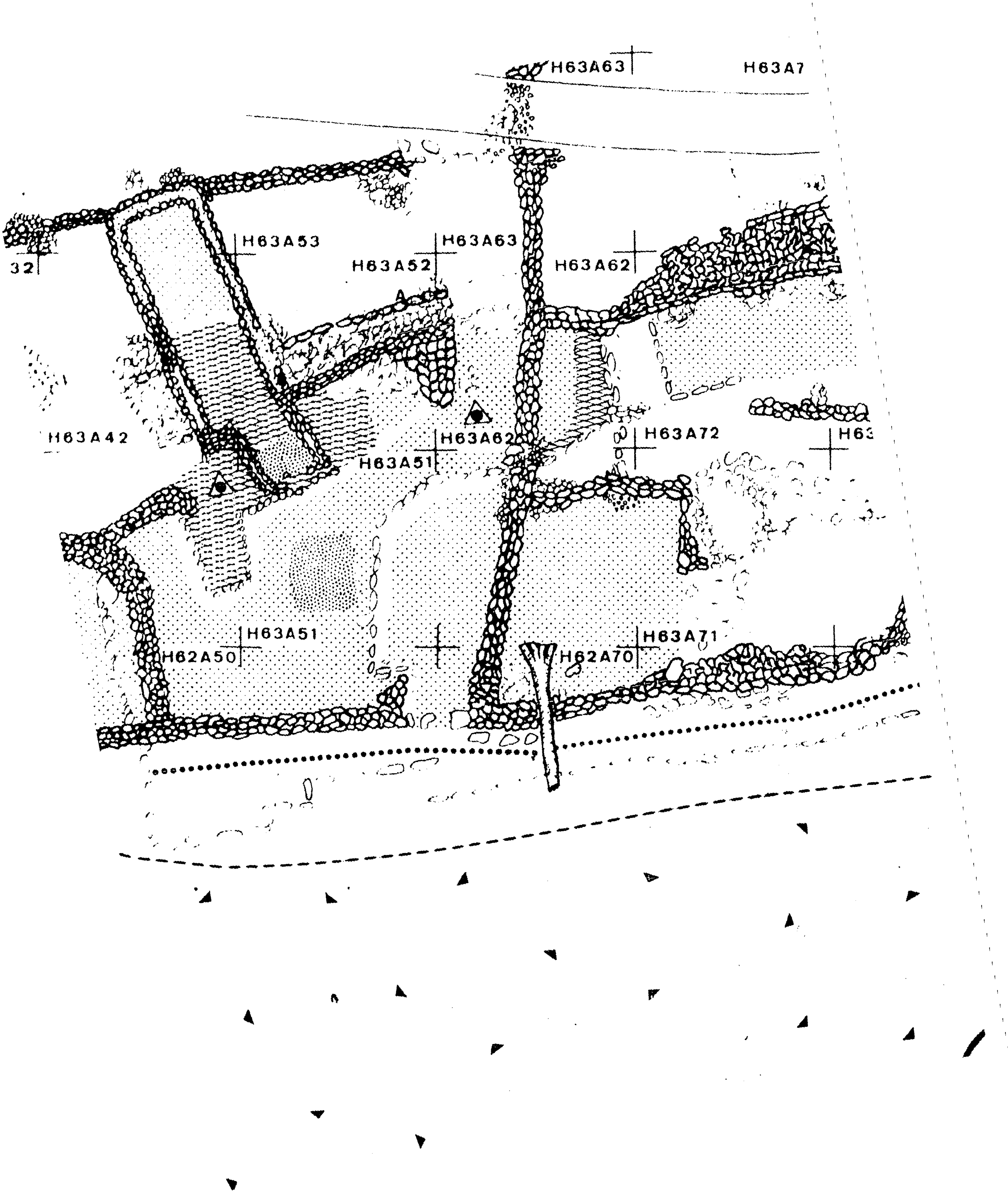
H62A5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H63A63
32
H63A52
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H63A51
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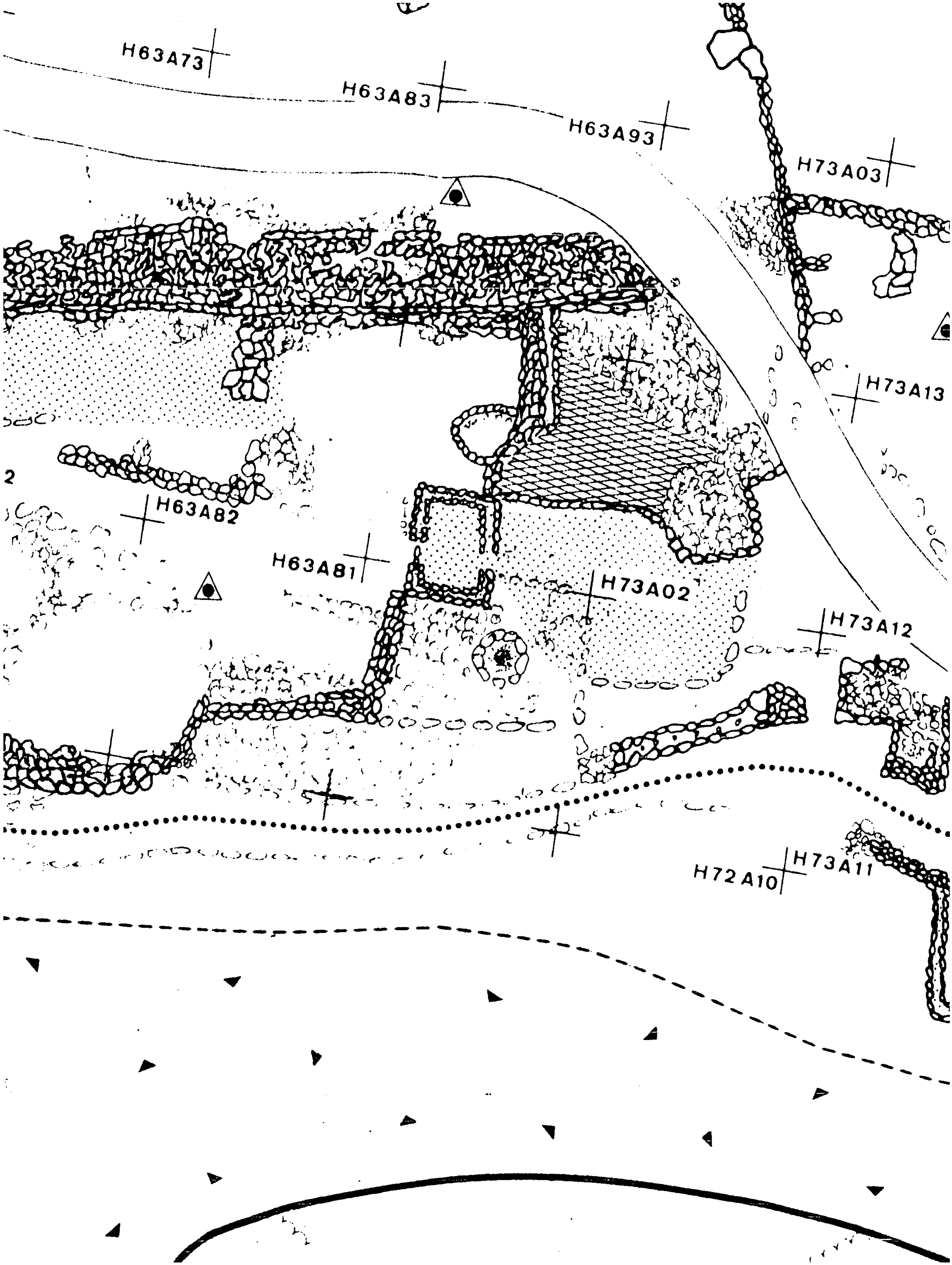
H62A70
H63A71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H73A03
H73A13
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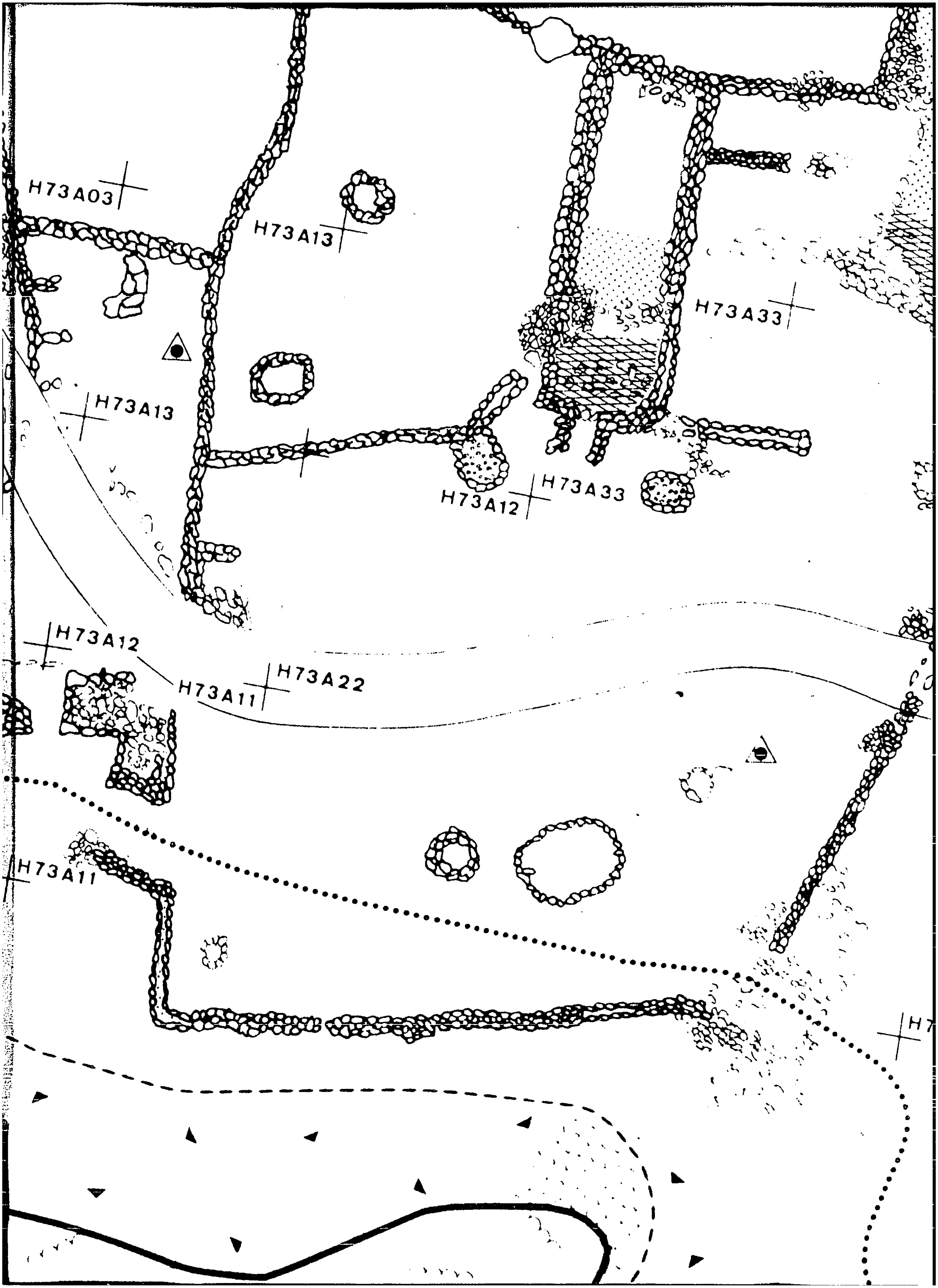
H73A02
H73A12
H72A10
H73A11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H73A13
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H73A12
H73A33
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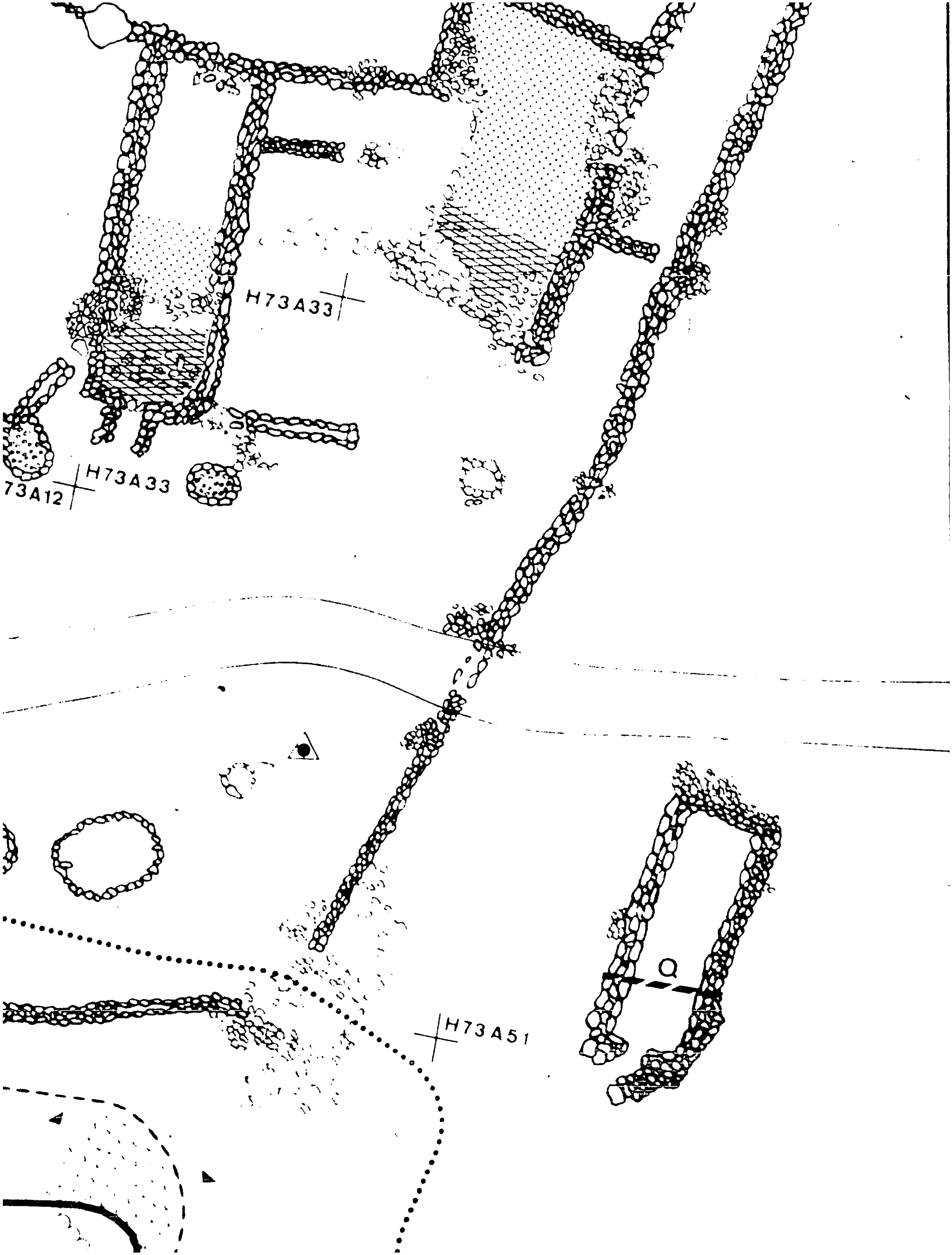
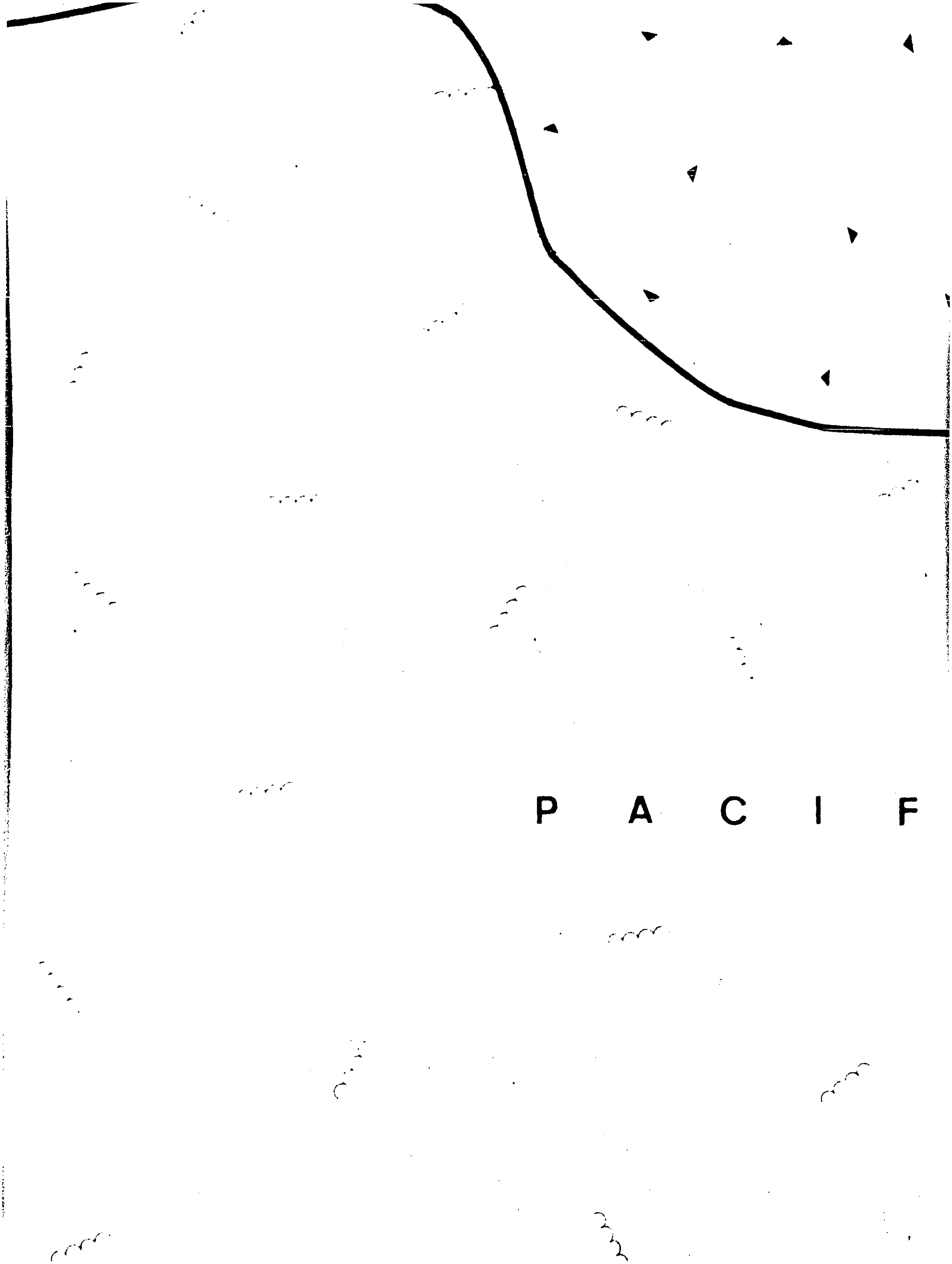
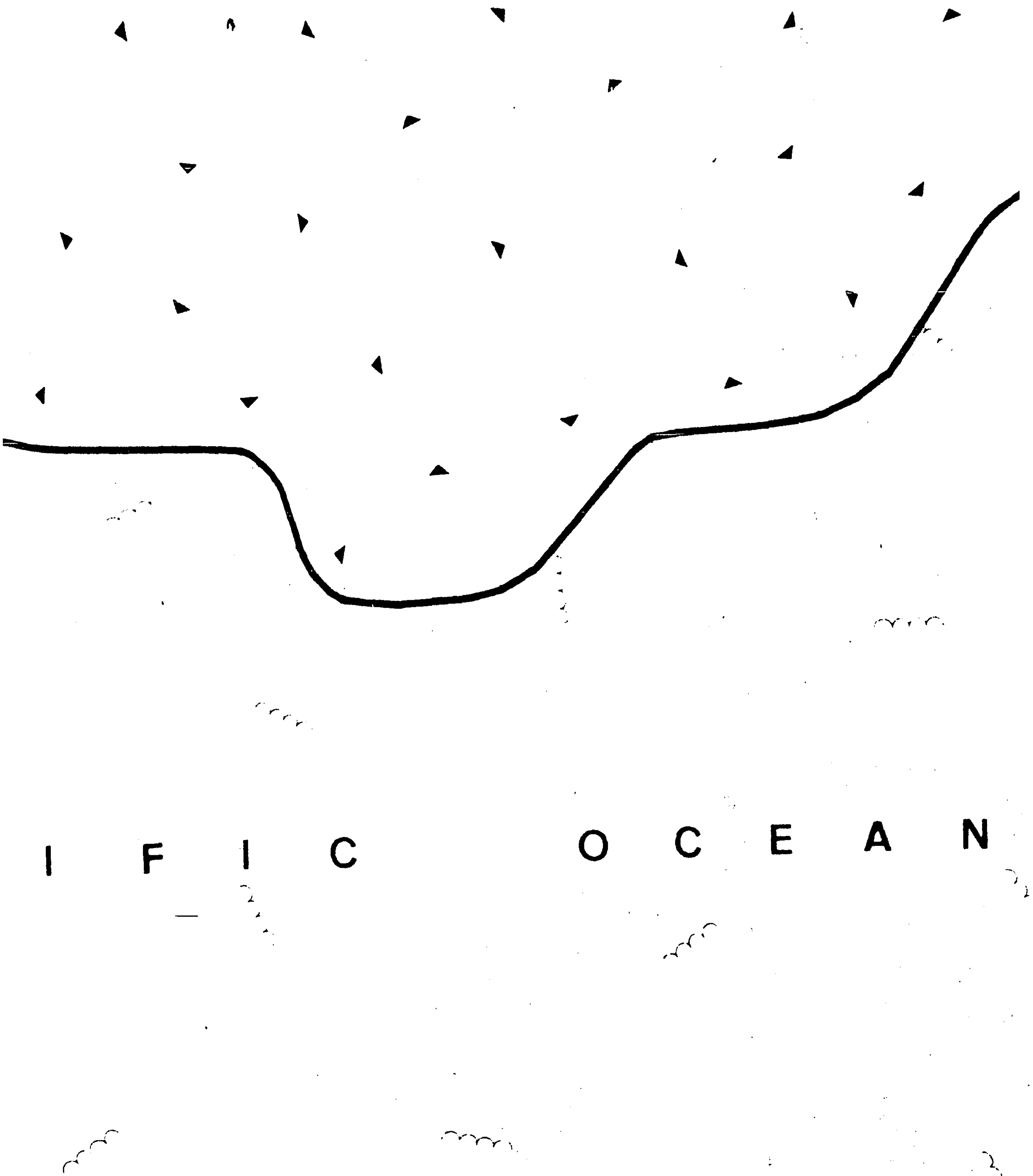
H73A11
H73A11

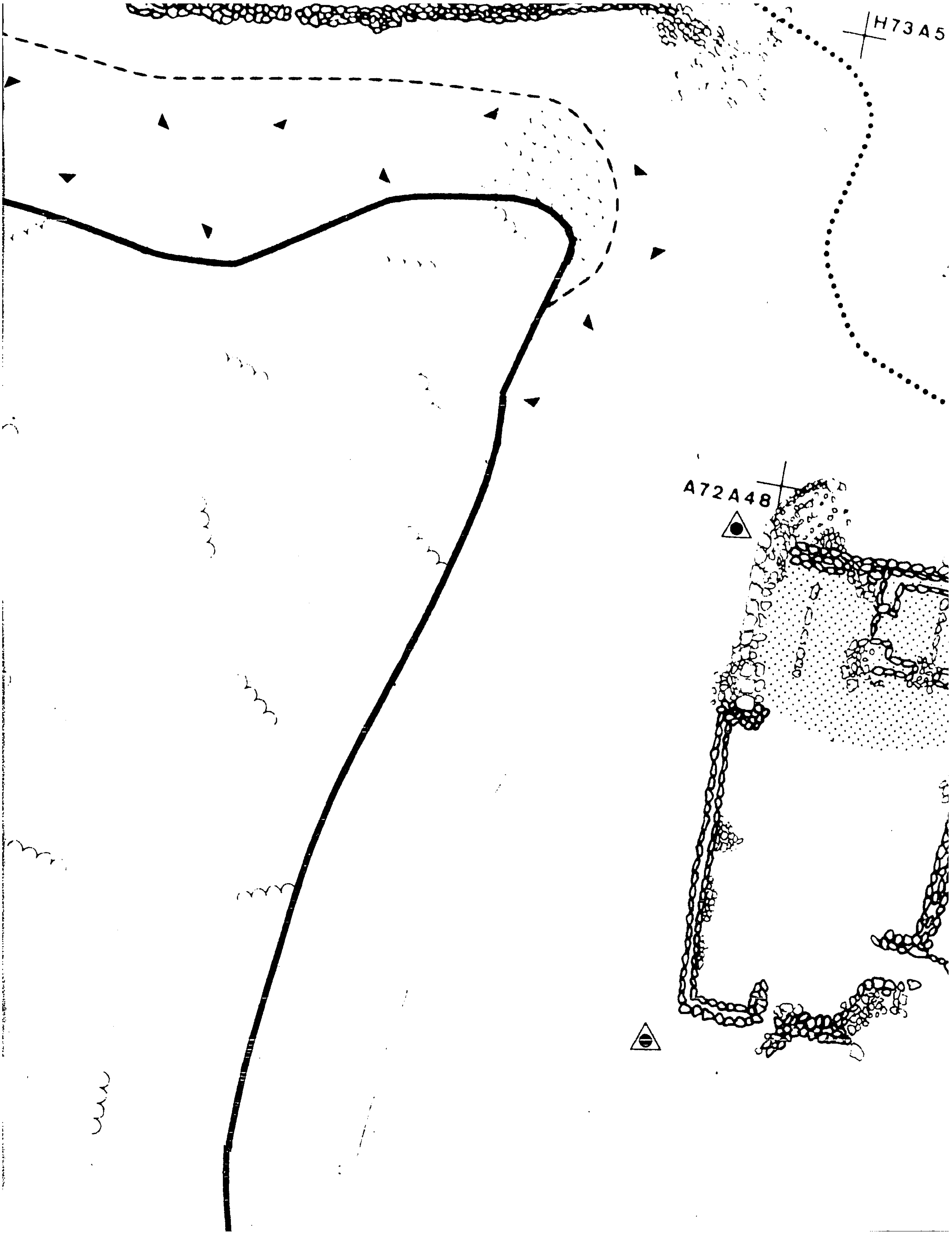

H73A33
H73A33
73A12
H73A51
Q


P A C I F



MAP 8


A N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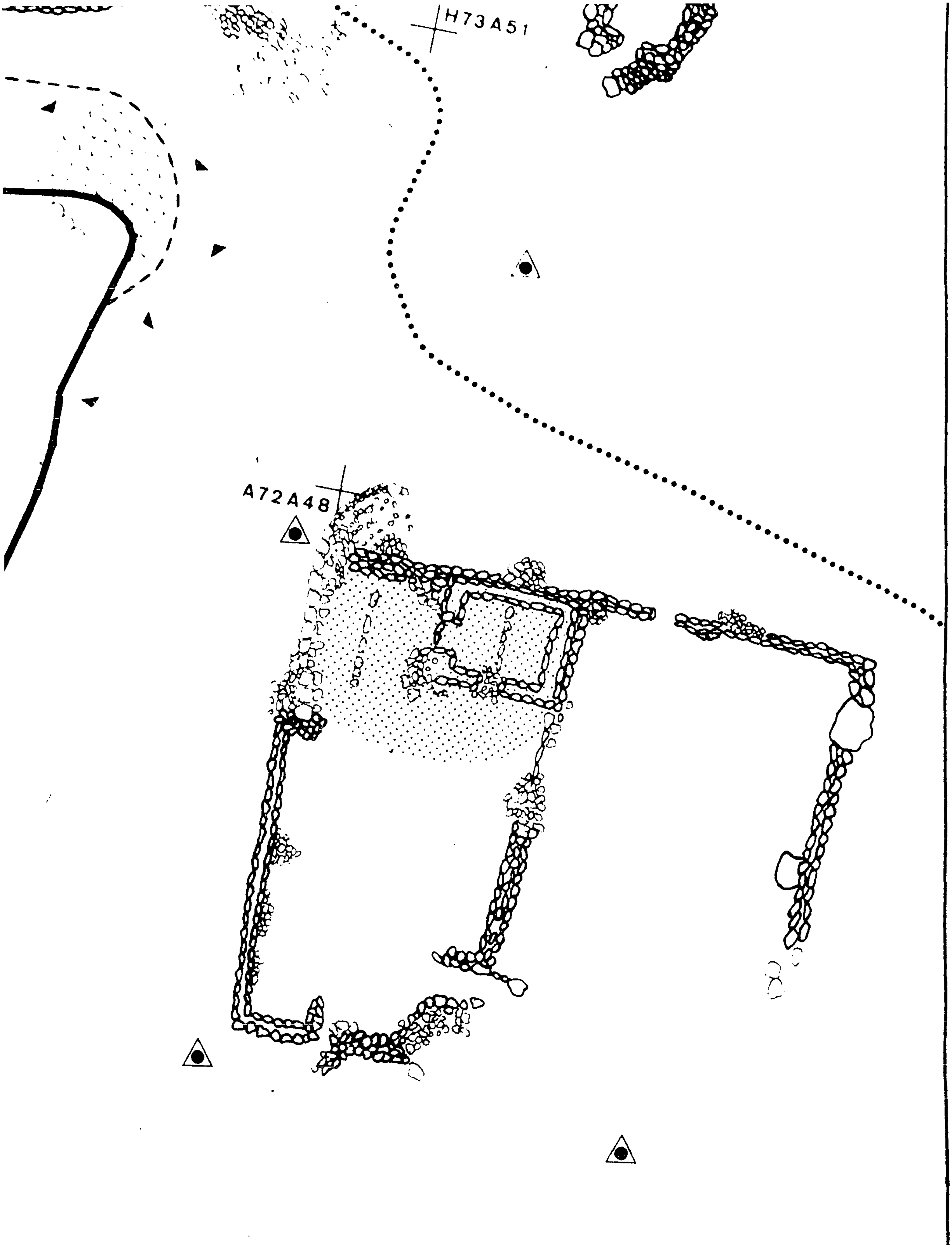
A72A48


H73A51
A72A48

in Hectare 73 and Mike Seelye has since done extensive research in the burial area in Hectare 63 Ares, so both areas are excluded from the present analysis and will be reported upon by these researchers.

Excavation Design

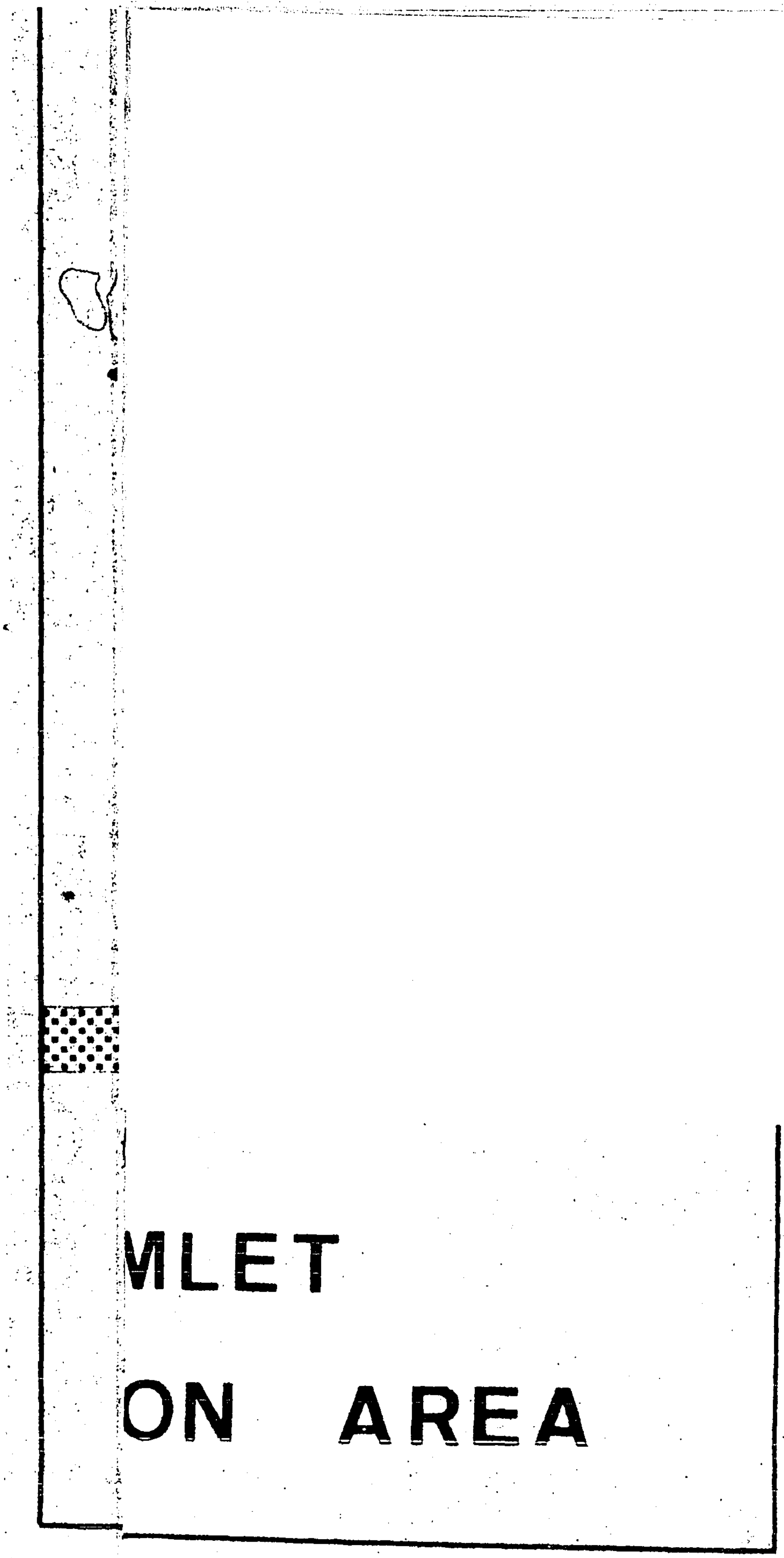
Faced with a site this large and one obviously quite complex, it was necessary to design the excavation approach to focus upon particular problems and not attempt to generate data on all aspects of the whole site. The decision was made to concentrate upon the ecology illustrated at the site rather than delineate feature relationships, collect a large body of artifacts for cultural history or seriational purposes, or study burial complexes or structure sequences. Some data, of course, were forthcoming on these problems but the emphasis was elsewhere. The old problem in archaeology of whether to excavate deep and narrow, or wide and shallow, was usually resolved to the deep and narrow side. The primary excavation unit used, therefore, was the one-meter square (Centare) and a checkerboard pattern was normally used instead of a trench to maximize the sample area dimensions for a given amount of time and manpower.

Stratigraphic Techniques

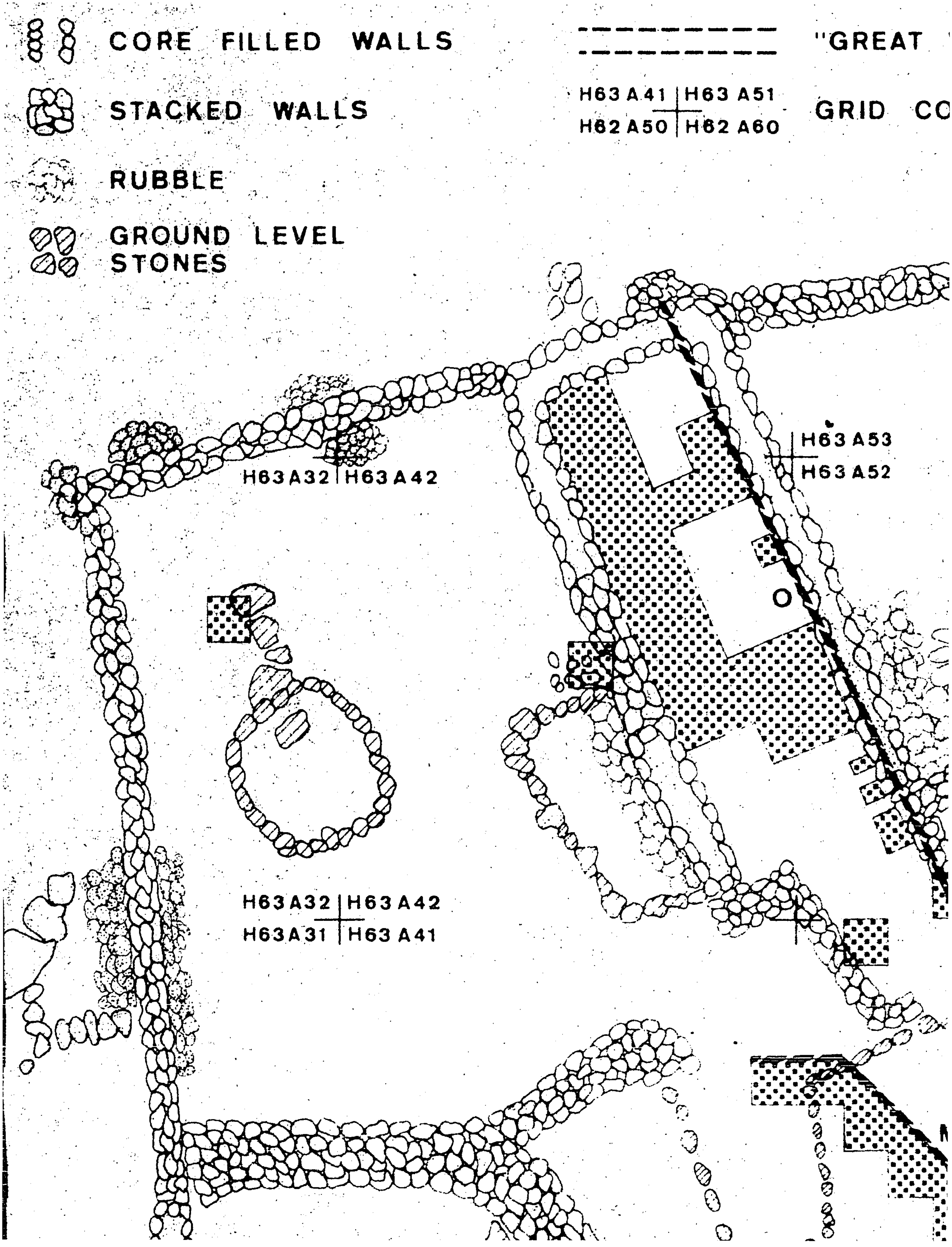
Most excavations took place within the central portion of the complex which lies mainly within Hectare 63 while some excavations took place in portions of Hectares 52, 62, 72 and in Ares 02, 03, and 51 of Hectare 73 (Map 9). It proved possible to excavate the major portion of the site by natural stratigraphic levels which were distinguished on the basis of changes in color, compactness, and differences in structural components. While most natural levels were readily discernible, some were marked by more ephemeral changes, particularly by a difference in "feel" to competent excavators. The only area where it was not possible to use natural stratigraphic techniques, was the area within Hectare 63, Ares 82 and 92, where it was necessary to convert to 5-centimeter arbitrary levels after early attempts revealed an apparent widespread disturbance of the whole area and a resultant "marbling" look to the stratigraphy. The peripheral excavations are illustrated on Map 8 and the major excavated areas on Map 9. A key is provided on each map to match the stratigraphic profiles in Appendix F (Figs. 5 and 6) to the particular areas illustrated.

Field Sampling Techniques

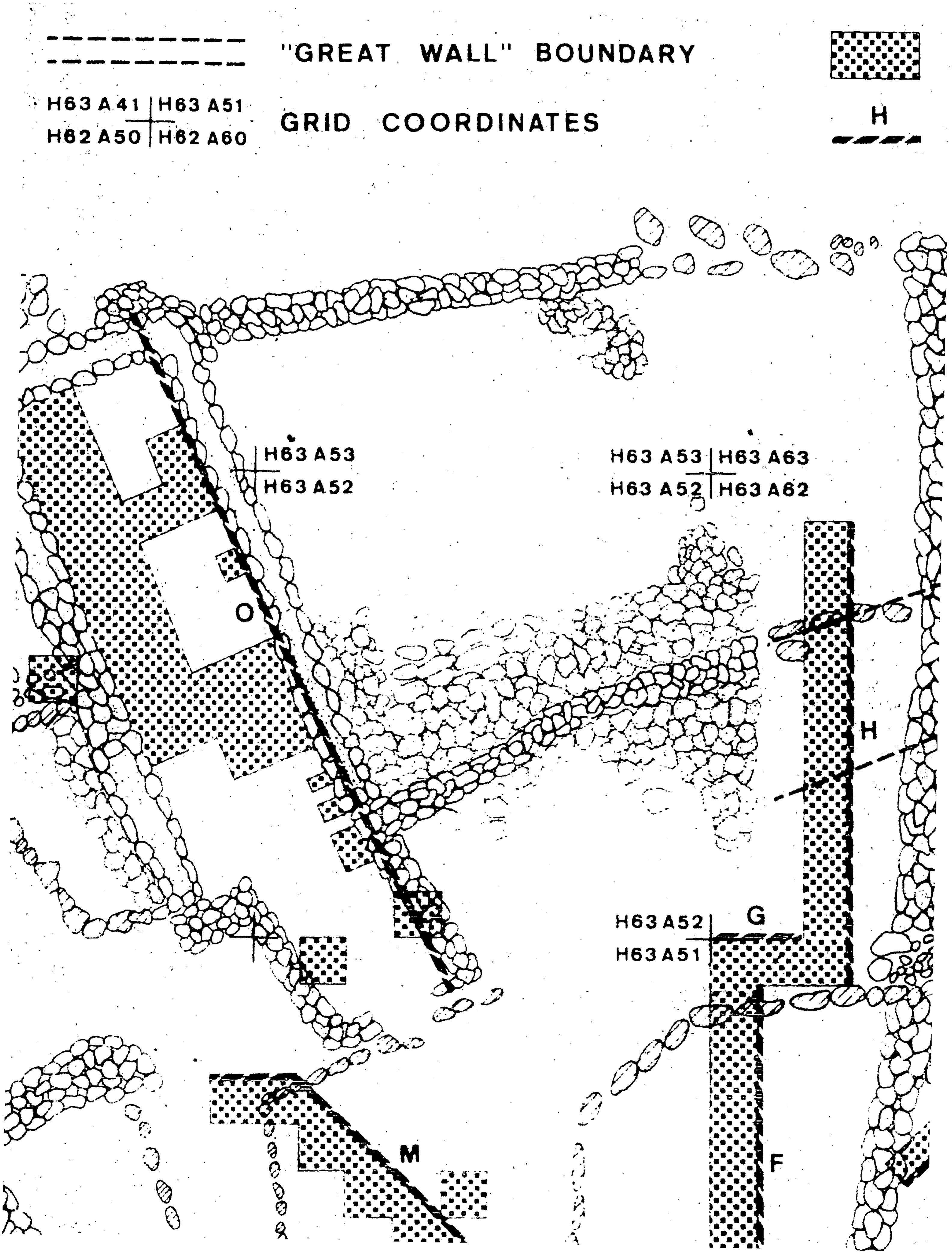
Just over 70 percent of all layers were excavated with micro-analysis techniques wherein all artifacts and non-structural midden components caught in the 1/8 inch screens were saved and analyzed. All water-washed shell was considered structural material and eliminated from the sample through three separate sortings. Food remains obtained consisted primarily of shellfish, sea urchin, fish, mammal, bird, turtle and kukui nut (candlenut or <u>Aleurites</u>

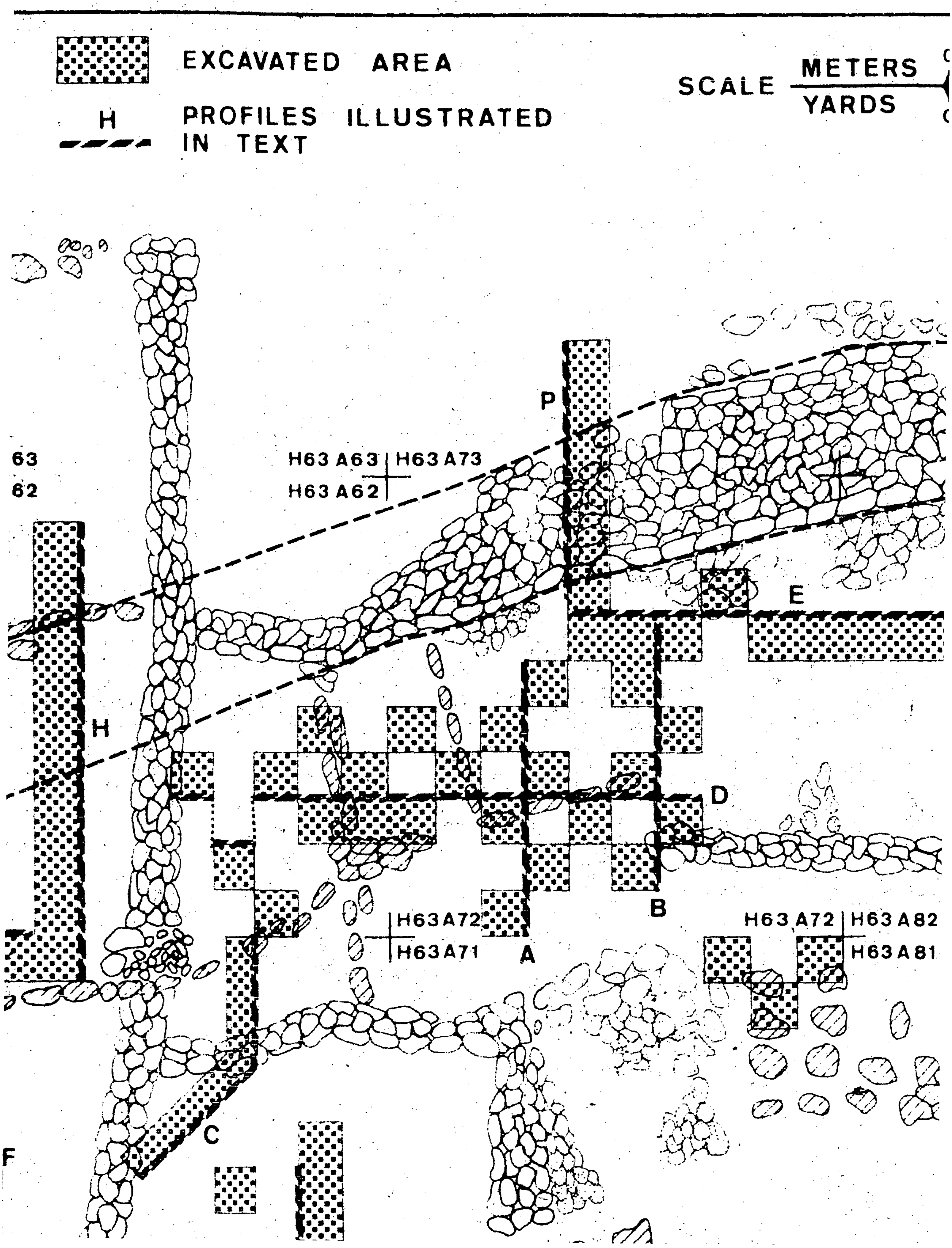


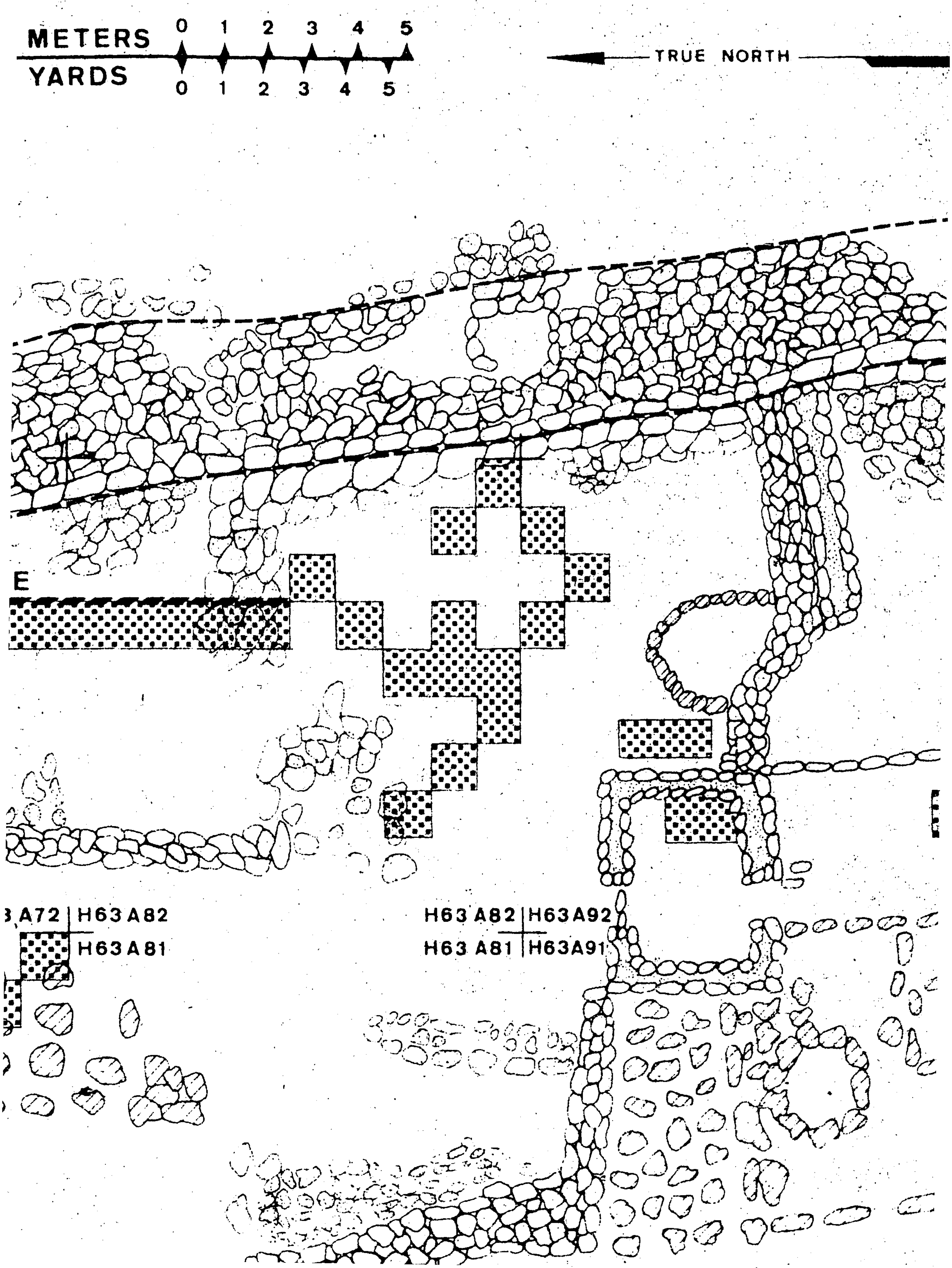
MAP 9

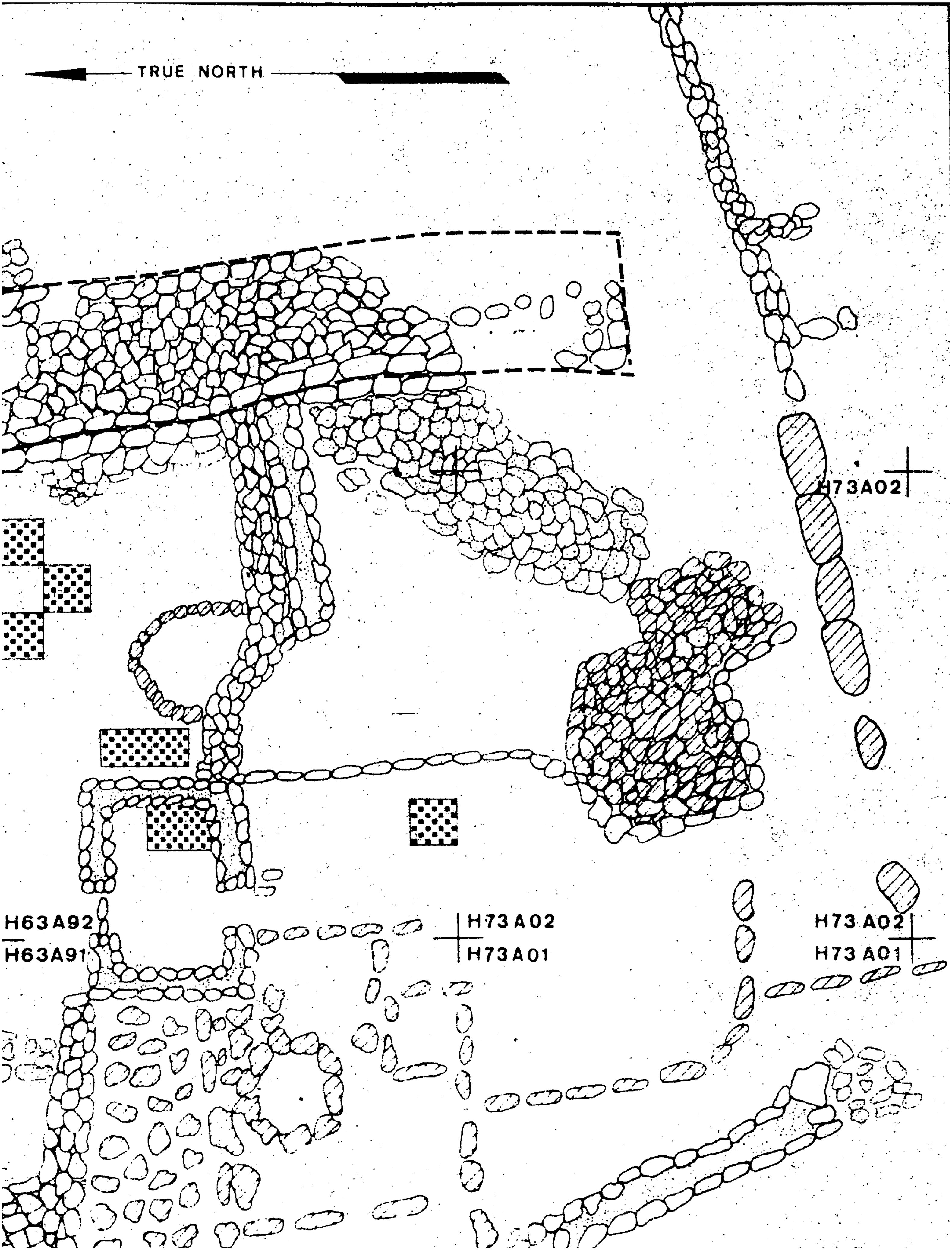


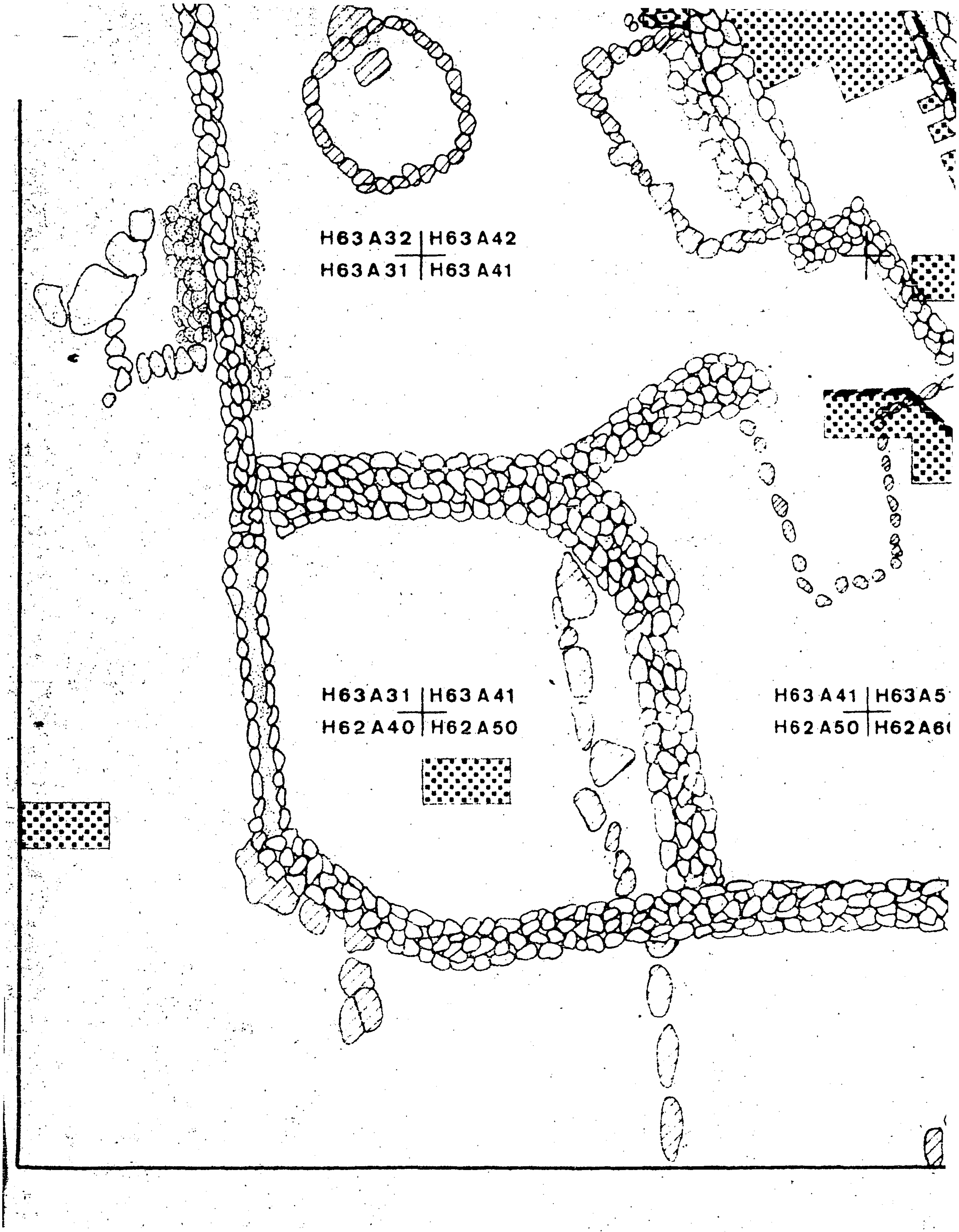
CORE FILLED WALLS
STACKED WALLS
RUBBLE
GROUND LEVEL STONES
"GREAT
H63 A41
H63 A51
H62 A50
H62 A60
GRID CO
H63 A53
H63 A52
H63A32
H63 A42
O
H63A32
H63 A42
H63A31
H63 A41


"GREAT WALL" BOUNDARY
GRID COORDINATES
H
H63 A41
H63 A51
H62 A50
H62 A60
H63 A53
H63 A52
H63 A53
H63 A63
H63 A52
H63 A62
O
H
G
H63 A52
H63 A51
M
F


EXCAVATED AREA
H
PROFILES ILLUSTRATED IN TEXT
SCALE
METERS
YARDS
63
62
H63 A63
H63 A73
H63 A62
P
E
H
D
H63 A72
H63 A71
A
B
H63 A72
H63 A82
H63 A81
C
F


METERS
0 1 2 3 4 5
YARDS
0 1 2 3 4 5
TRUE NORTH
E
A72
H63 A82
H63 A81
H63 A82
H63 A92
H63 A81
H63 A91


TRUE NORTH
H73A02
H63A92
H63A91
H73A02
H73A01
H73A02
H73A01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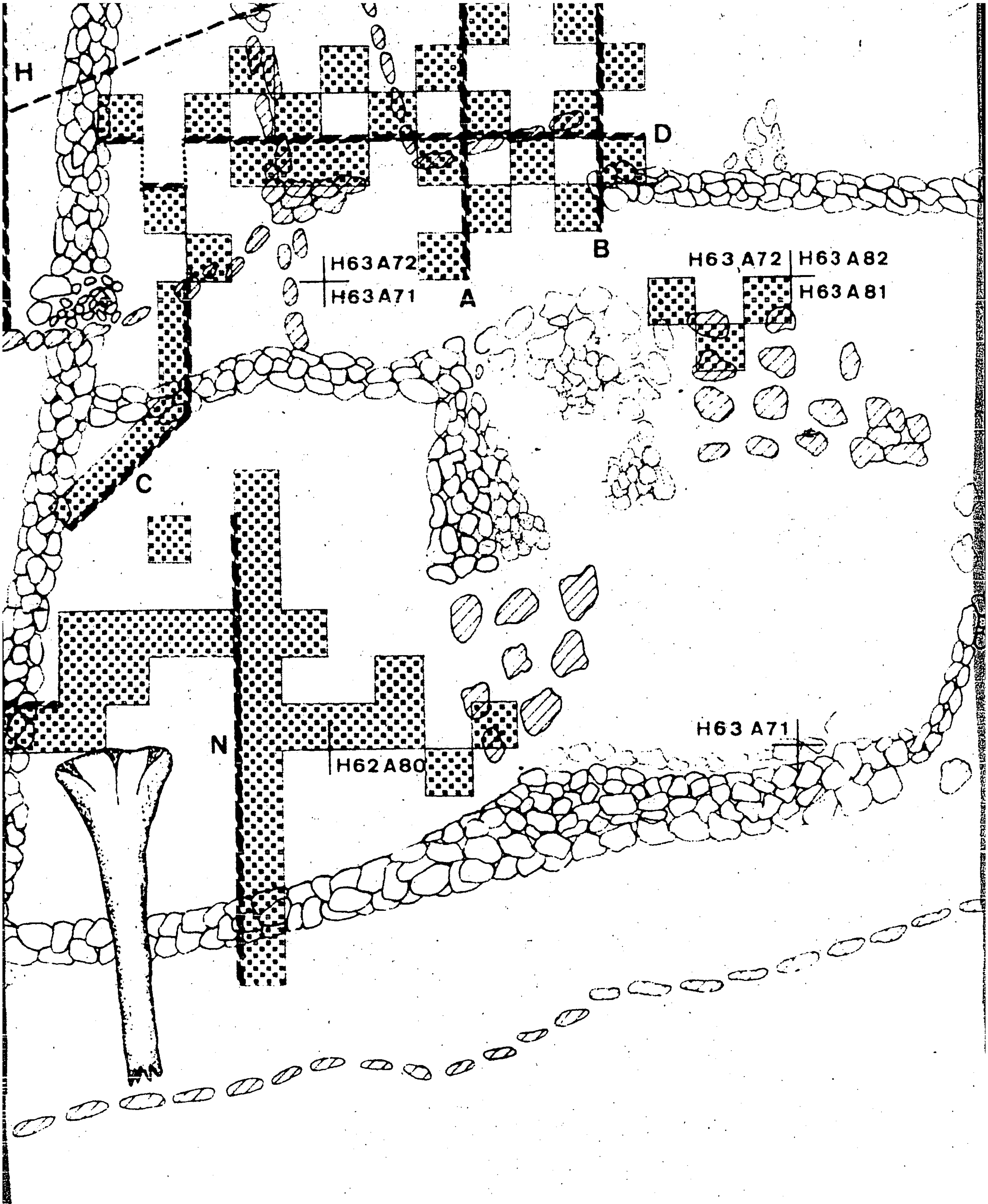
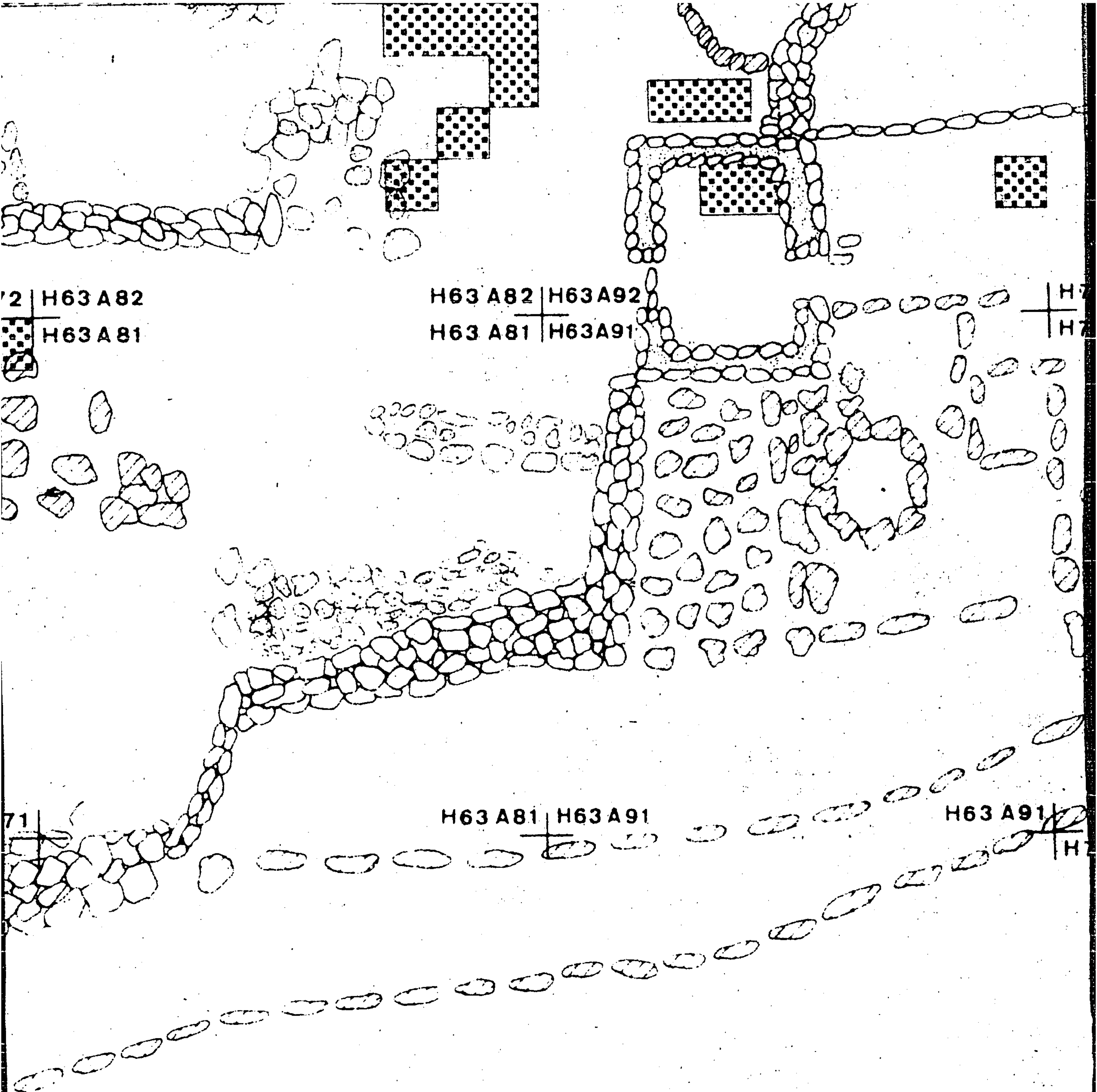
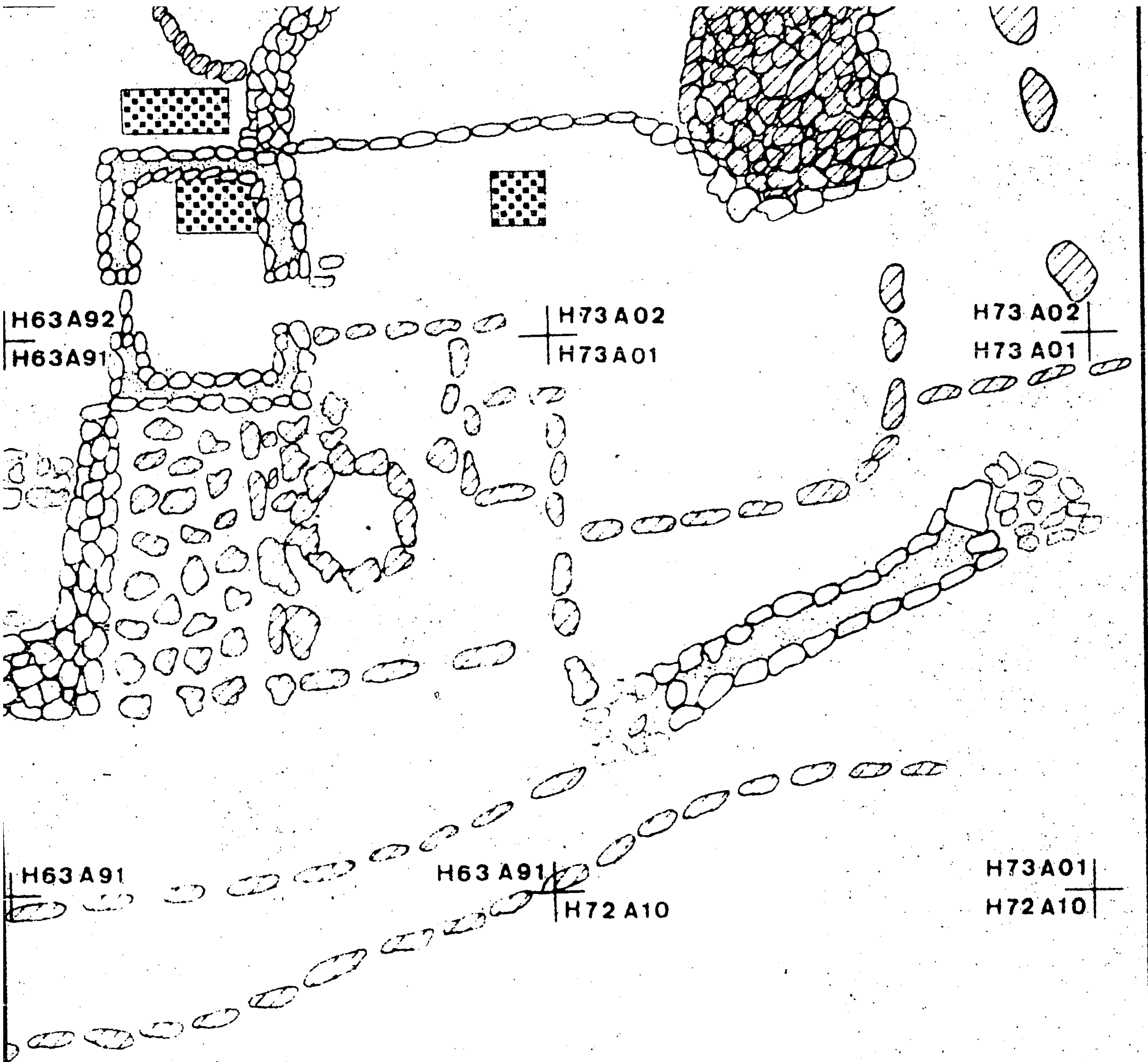


MAP 9



KOAIE HA

MAIN EXCAVATI



KOAIE HAMLET

AIN EXCAVATION AREA

moluccana) while non-food remains were primarily artifact debitage of glass, pottery, metal, and stone which were weighed as midden components before being treated as artifacts. Artifacts, per se, as well as shell and bone artifact debitage were not weighed and are excluded from the food remains sample. Virtually all field records were kept in a special format to allow computer processing and one supervisor was charged with checking all coded forms for completeness and accuracy throughout the entire summer. The net result of the Koaie research was the excavation of a very large midden sample, a reasonable artifact sample, and information about structural provenience of the midden and artifacts, all detailed in a coded format capable of data processing by computer.

Laboratory Techniques

The laboratory work following the field excavations consisted mainly of cross-checking all data for accuracy and completeness prior to placing it in the computer-based retrieval system; sending the entire shell sample to H. Snider of the University of Hawaii, a marine biologist; all fish remains to S. Swerdloff, also of the University of Hawaii, a marine biologist; and all mammal, turtle, and bird bones to A. Ziegler of the Bishop Museum, a skeletal taxonomist, for identification. The results of these specialist analyses were also coded and entered into the data file. Artifacts and artifact debitage were analyzed on the basis of three variables:

(1) material from which they were made,

(2) techniques used in their manufacture, and

(3) presumed function.

Several functional classes of artifacts such as fish-hooks, sinkers, cowry lures, and sea urchin spine files were also described through a formal analysis; all details of these artifact analyses were also coded and key-punched. The development of computer programs to manipulate the data gathered through both the field and lab research proved to be a time-consuming labor because of a general lack of precedent for this approach to archaeological analysis, but Dr. John Belshe, of Kentron Hawaii, Inc., acted as a volunteer consultant and was instrumental in designing a successful data retrieval and manipulation system. The computer programs developed allowed flexibility in analyzing the data and increased the depth to which certain time consuming and detailed analyses could be taken. In summary then, the research on Koaie has produced a large volume of data that is directly applicable to ecological analysis and it is this body of data that must now be subjected to the criteria listed above before being used in correlating historic and archaeological materials on maritime exploitation.

Correlation Criteria and Koaie

Exploitative Focus

The first, and likely the most important task to be accomplished at this point is to demonstrate that the Koaie data is truly comparable to the historic materials on maritime exploitation. It is necessary to demonstrate that Koaie was occupied by people who did exploit the sea and who left sufficient traces of these practices to allow a reconstruction of the extent and nature of their maritime exploitation. Theoretically, it is possible to demonstrate site exploitation through five lines of evidence:

(1) site geographical location,
(2) specific local history regarding the site,
(3) structural features,
(4) artifact types, and
(5) midden components.

Location and History:--The first two would definitely point to a sea exploitation focus for Koaie because this site is located directly along the shore in a known fishing area and the present local residents in North Kohala remember that the site was occupied in the early twentieth century by people who depended upon the sea for a major portion of their subsistence. No information was available, however, about pre-twentieth century residents of Koaie so this latter argument loses some force since it is the pre-twentieth century time period in which this study is interested.

In addition, the argument that a coastal location infers maritime exploitation involves the unproven assumption that function may be inferred from location. Both these lines of attack inferentially point to a sea exploitation focus for Koaie but are not sufficient to adequately fulfill the criteria established in the first part of this chapter.

Structural Features:--Some structural features at Koaie do illustrate maritime exploitation in that they obviously functioned as salt manufacture areas: several large salt pans of vesicular basalt were found located within Hectare 62, Are 90 and more within Hectare 63, Are 91. Additional salt pans were reported by William Bonk on his initial site survey, apparently located within Hectare 73, Are 01 or within Hectare 72, Are 10 but these were stolen prior to the summer of 1968. Although walls have been reported to be erected partially to provide drying areas for fish, it is not possible to demonstrate that any of the Koaie walls were, in fact, used for this purpose. All other structural features are likewise inconclusive in demonstrating maritime exploitation.

Artifact Analyses:--The artifact analysis yields more direct evidence of maritime exploitation at Koaie. Table VII of Appendix D provides a breakdown by artifact function of all artifacts found at Koaie and illustrates that 286 artifacts, or 7.3 percent of the total were directly associated with maritime exploitation, such as fishhooks, sinkers, and lure parts. Table VIII of Appendix D shows the artifact breakdown by type of material used in manufacturing artifacts and illustrates that marine materials were used in the manufacture of 588 artifacts, or 15 percent of the total. The materials used are all from marine invertebrates such as shellfish (2.9%), sea urchin (6.3%), and coral (5.8%).

It is not possible to use the remainder of the artifact analyses to demonstrate maritime exploitation for there are logical problems in their use. For example, if the general tool functional category (including sea urchin spine, basalt and coral saws, files, and abraders) were to be applied to demonstrate maritime exploitation then an additional 31.9 percent of the total artifact count could be added, but would hardly be unequivocable evidence for maritime exploitation. The problem is that although it is certain that such tools were, indeed, used in the manufacture of maritime artifacts such as fishhooks, there is no logical reason to believe that they were used only for that function.

Microscopic examinations were made of all use facets on each artifact and through these wear patterns it is possible to know how the tools were used, but it is not possible to know what they were used for. There was absolutely nothing inherent in these wear patterns to show that the tools were usable only for fishing gear manufacture; each could have been used to make either a fishhook or, for example, an ornament.

Sea urchin spine files provide a possible exception in that they most likely functioned to abrade bone. No bone artifacts other than fishhooks and shellfish picks showed manufacturing marks attributable to sea urchin spine files. It would seem permissible to suggest these files as tools used to manufacture artifacts for marine exploitation at Koaie. This brings the total artifacts illustrating maritime adaptation to 13.6 percent.

Midden Analyses:--By bringing in the midden analysis it is possible to further demonstrate maritime exploitation for Koaie and the midden analysis summarized in Appendix D, Table IX, shows that of some 111.8 pounds (50,847.7 grams) of food remains composing the microanalysis midden sample, the amount of marine remains equaled 106.8 pounds (48,532.0 grams) or 95.4 percent. This includes 95.5 pounds of shell (43,426.6 grams; 85.4%), 9.0 pounds of sea urchin (4,099.5 grams; 8.1%), 2.2 pounds of fish (1,002.3 grams; 2.0%), 0.005 pounds of sea bird (2.4 grams; .004%), and 0.03 pounds of turtle (12.0 grams; .02%). Looked at in a different way, marine food remains comprise 67.9 percent of the total food and non-food midden sample, indicating a substantial maritime orientation for Koaie; however, certain problems exist with such a breakdown that must be mentioned.

It is a simple matter to break down most of the midden categories into food or non-food components; for example, there is no problem with assigning metal, glass, pottery, basalt and obsidian flakes to the non-food component; it is also clear that fish, mammal, bird, and turtle remains in the table are food residue for all discernible artifact debitage was extracted prior to weighing. It is less clear, however, that all shellfish were collected only for food since some may have been intended as ornaments or as raw material for tools and fishing gear and just not so used prior to deposit in the midden. All shells showing tool marks were logged as artifacts and are not reflected in the weight tables, although this would be misleading if the organism was eaten and the shell later used for an artifact. Sea urchin remains include wana, 'ina, and Heterocentrotus mammalatus (pencil urchin), yet there is no indication in the literature of Heterocentrotus mammalatus being eaten as food. Mammalatus has often been called "wana" but this apparently is not correct. Not only were kukui nuts eaten but they were also used for illumination by being burned in special lamps, as well as used as a component in bait mixtures. It is possible to discount the use of much of the kukui remains as lamp fuel since relatively few shells show the charring that would be expected. The resolution of these problems must lie with additional literary and ethnographic research, so an arbitrary decision was made to include the total weights of such components under the category of food remains.

Problems in Demonstrating Degree of Maritime Focus

Artifacts

It would seem definitely demonstrated that Koaie had a maritime exploitation focus for all lines of evidence point to this, but it is difficult to assess the ratio between maritime and land exploitation emphasis at Koaie. The artifact analysis showed that some 13.6 percent of the artifacts were directly concerned with marine exploitation but only 0.03 percent (1 artifact) is tentatively identified as land exploitation equipment. This single artifact is a wooden tool (Appendix G, Fig. 10, No. 1) thought to be a small, hand-held digging stick on the basis of informant identification by Mr. Sam Po of Maui, but it could also have been a kind of fid or even a small and rude dagger. There is a definite skewing of any artifact inventory toward the maritime exploitative artifacts because rather few artifacts were used in land exploitation for food; about the only such artifact was the digging stick, but because the digging stick was constructed of wood, it most likely would disintegrate if deposited in the ground. The single tentative digging stick was found stored within a stone wall and hence not subject to the disintegrative factors of ground deposit, but this must be a rare occurrence. Sheer numerical comparisons of land versus sea exploitative artifacts, therefore, will be generally biased toward the maritime artifacts.

Midden Analyses

Given the midden analyses produced in this study one can apparently see a predominance of maritime exploitation in the sample, but a major problem also exists with this. Since shellfish have a high remains/low living biomass ratio and mammal, turtle, fish, and bird have a low remains/high living biomass ratio, it is not possible to legitimately state that there was a greater proportion of shellfish in the diet than these latter items. What is needed is a study to determine the ratio between remains weight and living biomass weight for each midden component, but this was beyond the scope of the present analysis. Beyond mammal and bird remains it is difficult to establish the relative emphasis upon land foods since these were primarily of vegetal base, such as taro, sweet potatoes, yams, breadfruit, and sugar cane. Land foods of these types would be represented in a midden only rarely and due to chance carbonization or other accidents of preservation. This means that although 95.4 percent of the midden food remains are of marine origin, it is not possible to state that 95 percent of the diet was of marine creatures, or even that the diet was predominately based on maritime biota.

There is no question about there being some degree of maritime exploitation at Koaie but the residual and unanswered question is the degree of relative emphasis upon land/sea exploitation. It is not possible to draw any conclusions about Koaie in terms of major exploitative focus on the basis of the Koaie data alone nor is it possible to make comparative studies with other sites having a demonstrated major maritime focus for no such studies have been made that escape these logical problems. The way out of the dilemma seems to be to bring in the data from the Apaapaa 1 site at this time for its geographical position within the massive native agricultural field system inland of Koaie would present a tentative argument that it is a site illustrating a basic land exploitation focus. By assessing the relative emphasis upon maritime exploitation between the two sites, it will be possible to roughly establish the relative degree of maritime focus for Koaie, at least between the two sites. Again, a major assumption is that geographical provenience does provide some insight into the exploitative function performed by the inhabitants of the site.

Correlation Criteria and Apaapaa 1

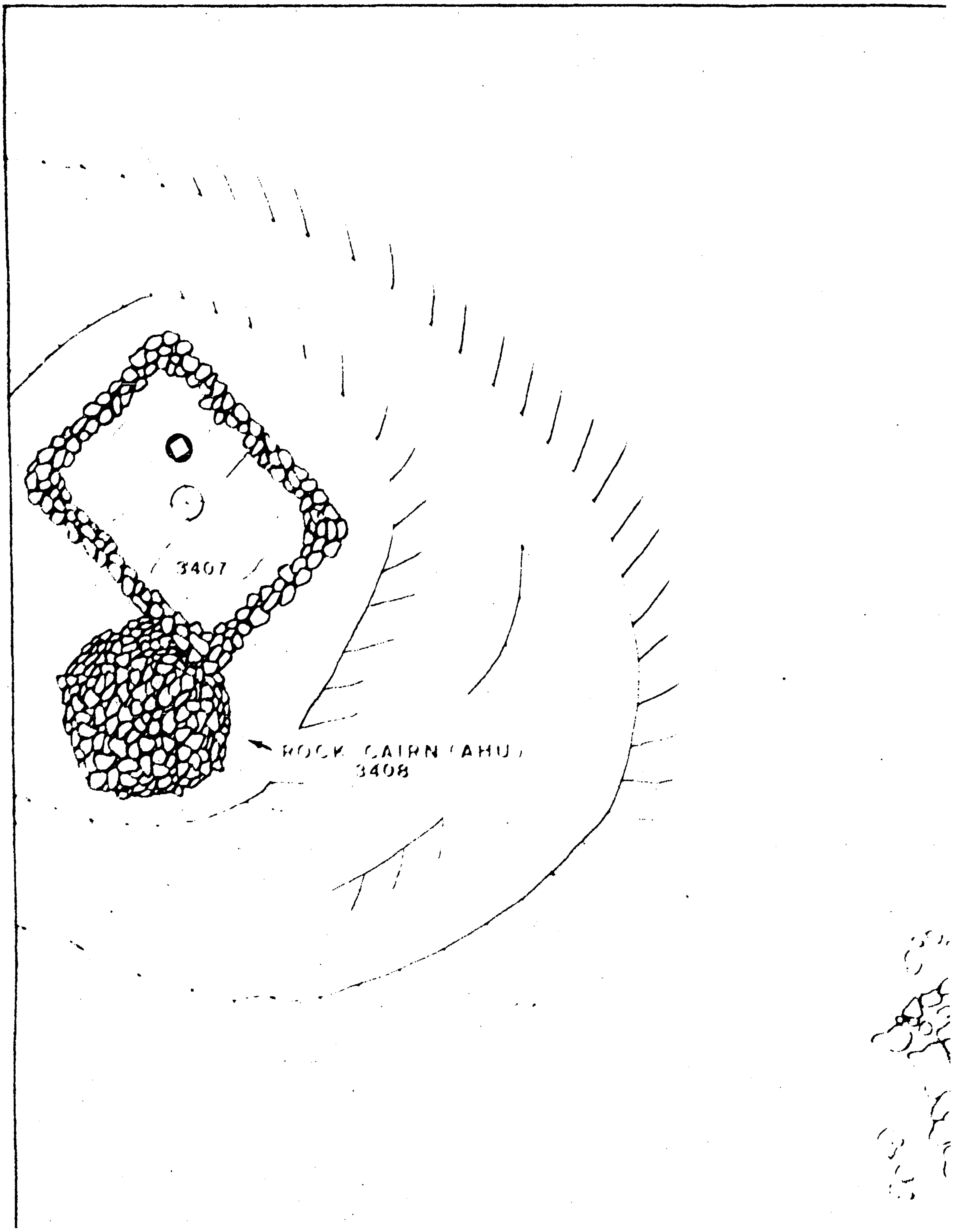
Background

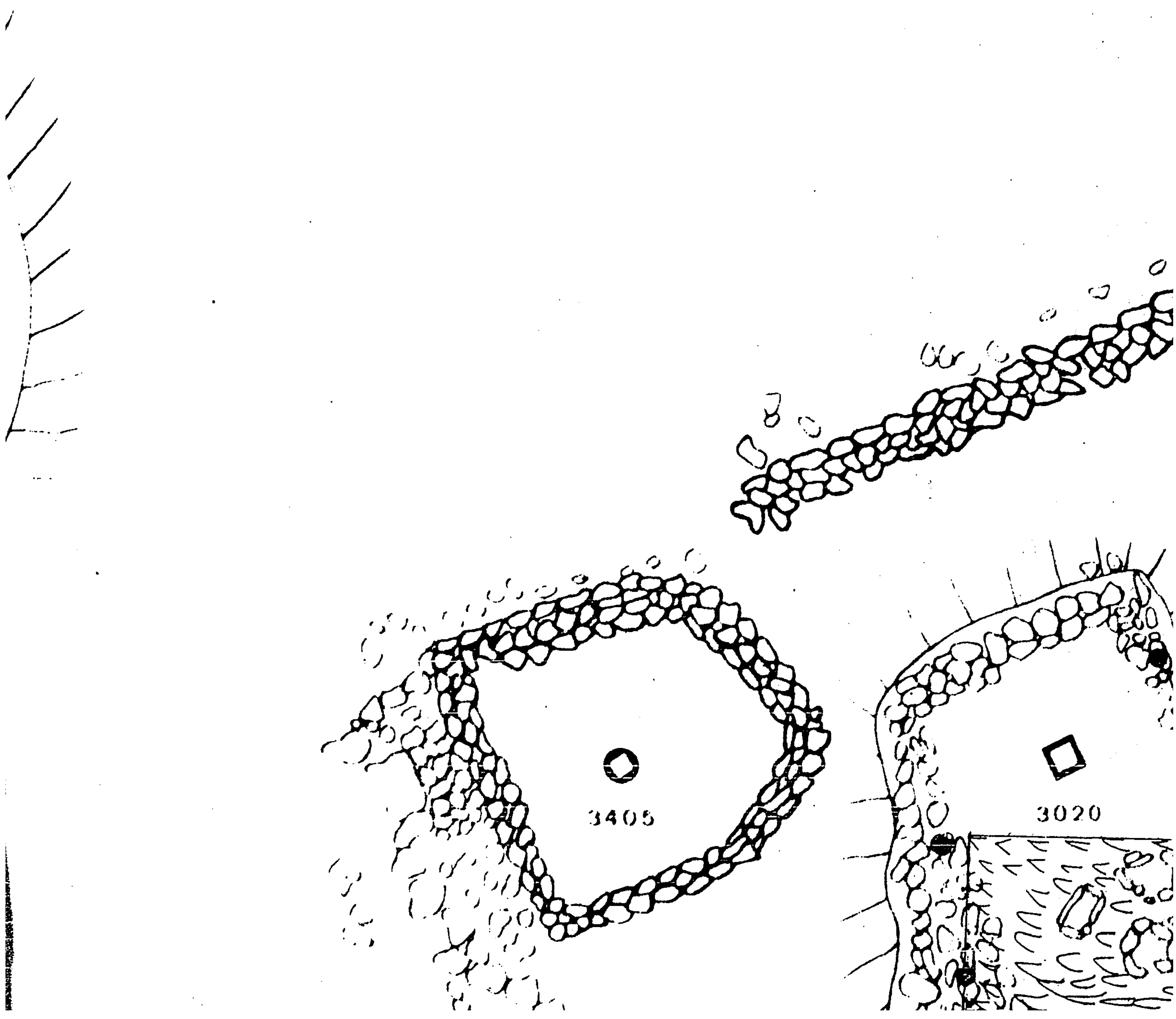
The Apaapaa 1 site is located at an elevation of approximately 1100 feet (305 meters) above mean sea level some 2.8 miles (4.5 kilometers) directly inland of Koaie (Maps 3, 4). A detailed coverage of the environment was presented in Chapter II. The site itself is a cluster of low stone walls and slightly raised earthen platforms set upon a small rocky knoll within the large network of aboriginal fields depicted on Map 4. Apaapaa 1 is located within two grid kilometers because the grid line runs through the site in such a way that about one-quarter is within Kilometer 95 and three-quarters within Kilometer 05. Excavations were conducted for approximately two weeks by about fifteen workers after the Koaie excavations had been completed, primarily as a preliminary assessment of the upland area preparatory to additional work planned for the summer of 1969. All excavations were conducted under microanalysis conditions and after it had been determined that a single cultural level existed, it was removed by means of five centimeter arbitrary levels. All other excavation and recording techniques remained the same as for the Koaie excavations. The major excavations took place within an earthen platform designated as Feature 3000 in Kilometer 5, Hectare 6, Are 22 (Map 10). Other excavations took place in Feature 2999 (Kilometer 05, Hectare 06, Are 12 and 22), Feature 3130 (Kilometer 05, Hectare 06, Are 33), Feature 2966 (Kilometer 05, Hectare 06, Are 15), Feature 2966 (Kilometer 05, Hectare 06, Ares 05 and 06), and Feature 3020 (Kilometer 95, Hectare 96, Ares 83, 84, 93, 94).

Exploitative Focus

History:--Local informants knew of no historic information about the site and the name, Apaapaa 1 is simply derived from a nearby named hill although the word "'āpa'apa'a" refers to a high wind in Kohala.

MAP 10


3407
ROCK CAIRN (AHU)
3408


3405
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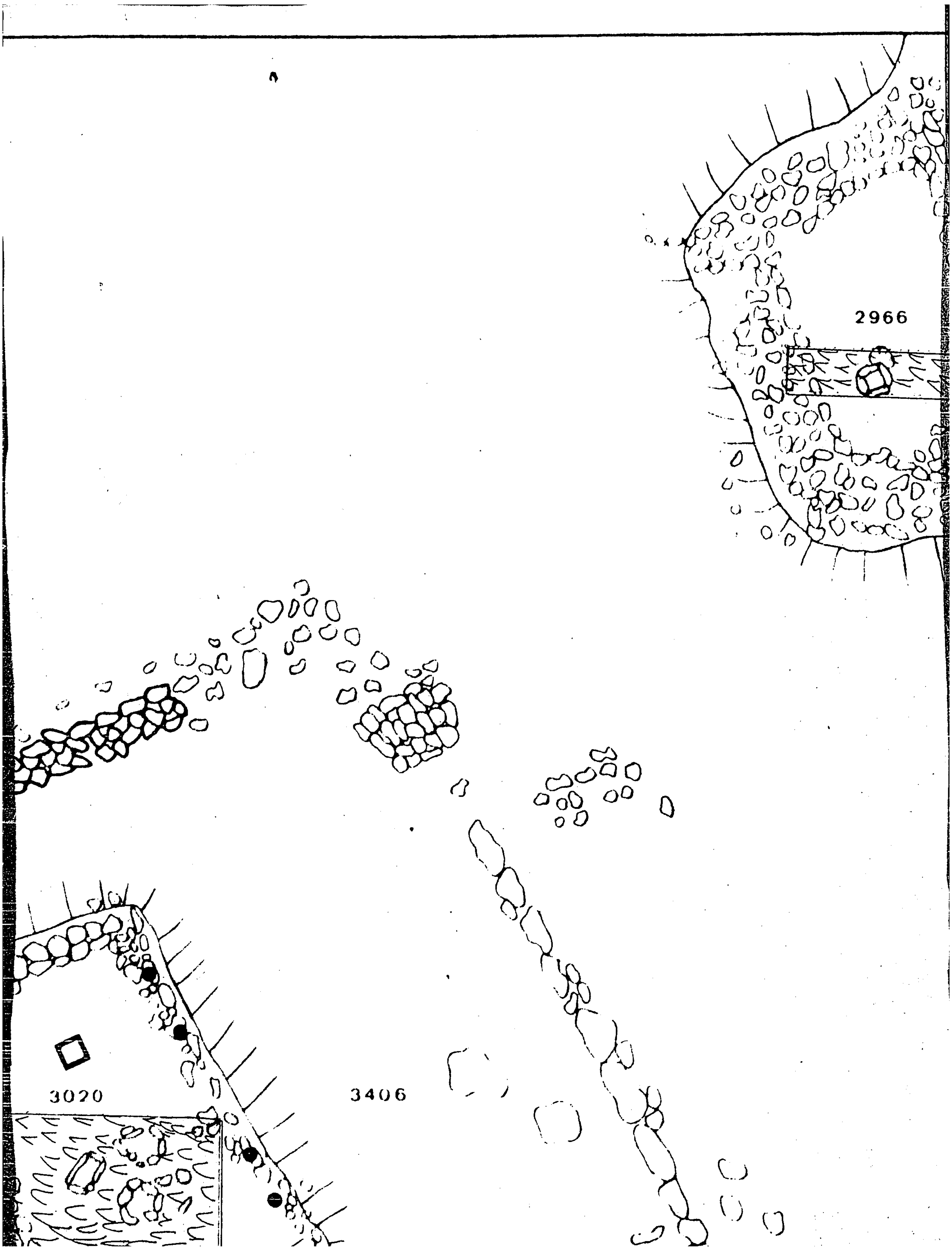
2966
3020
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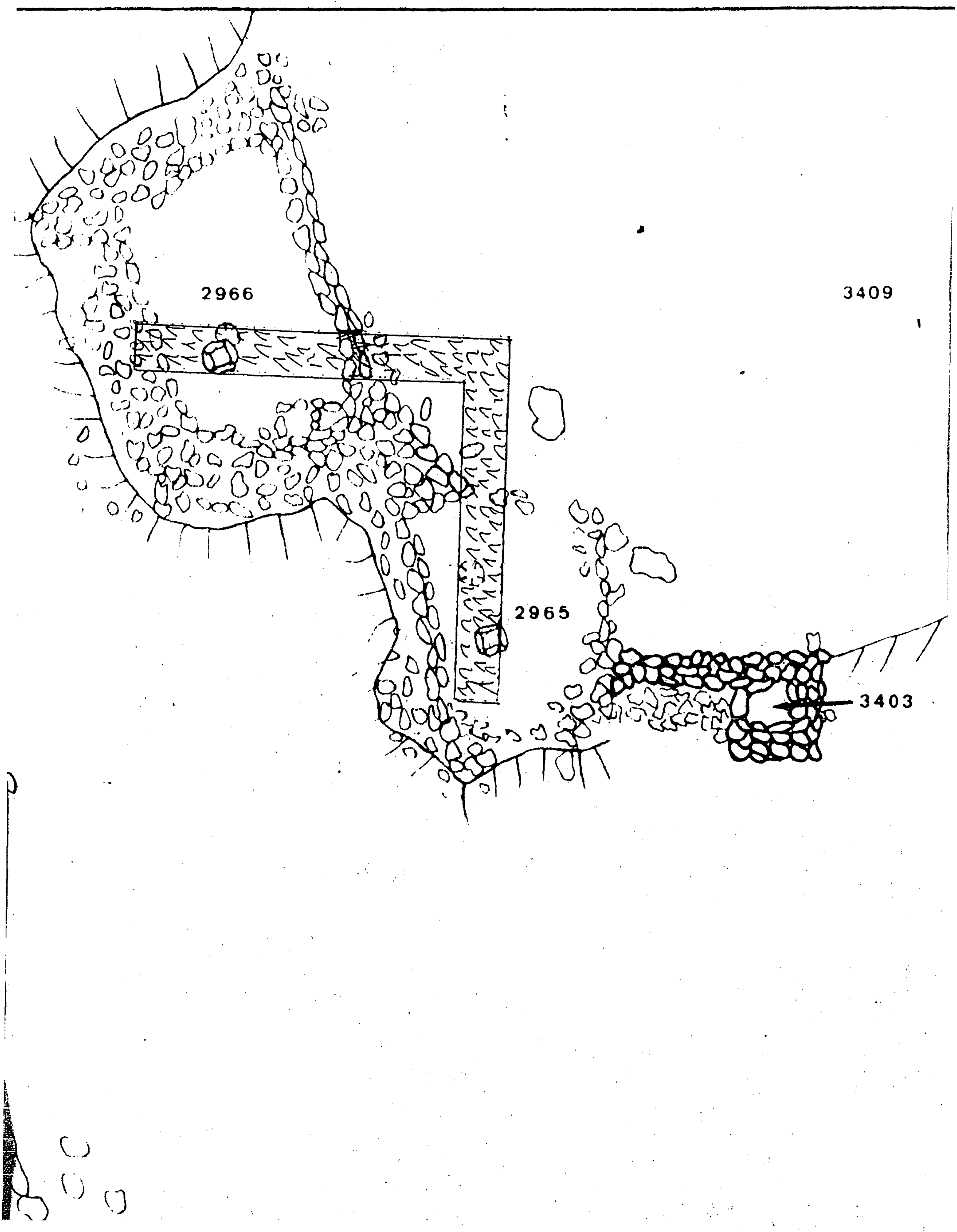
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2965
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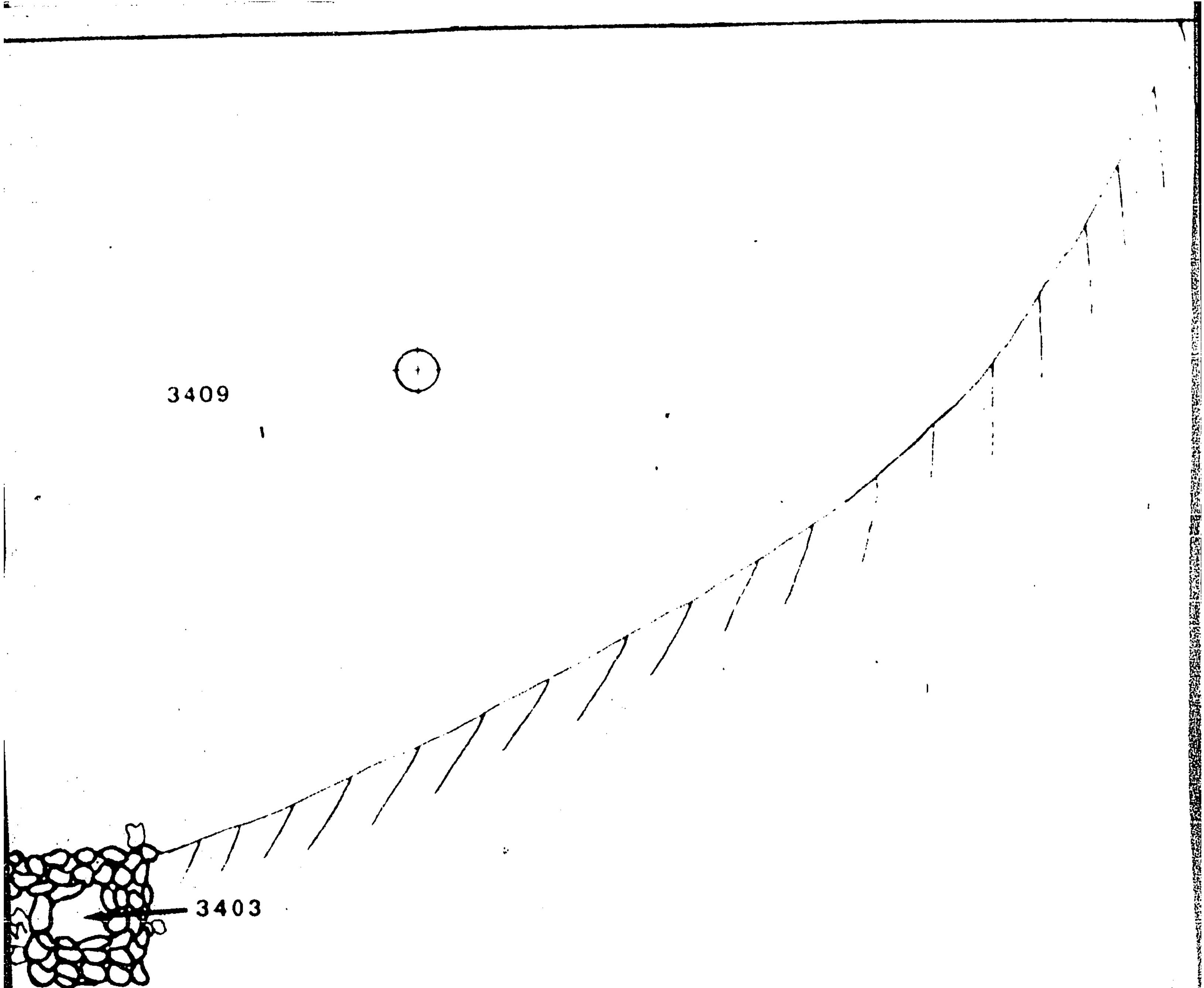
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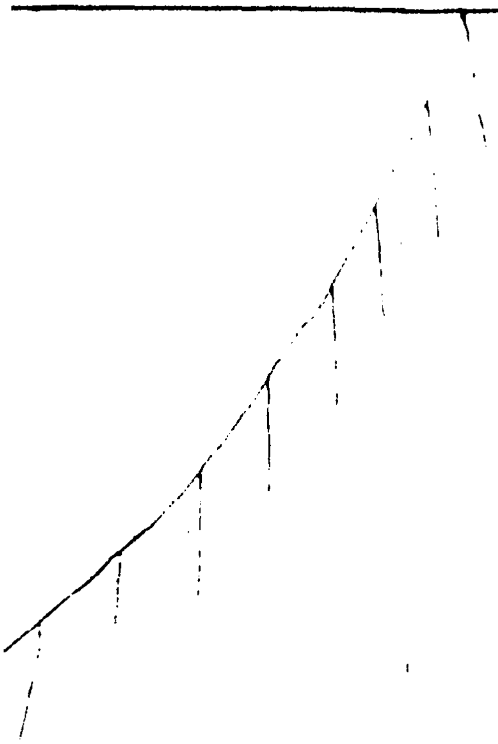
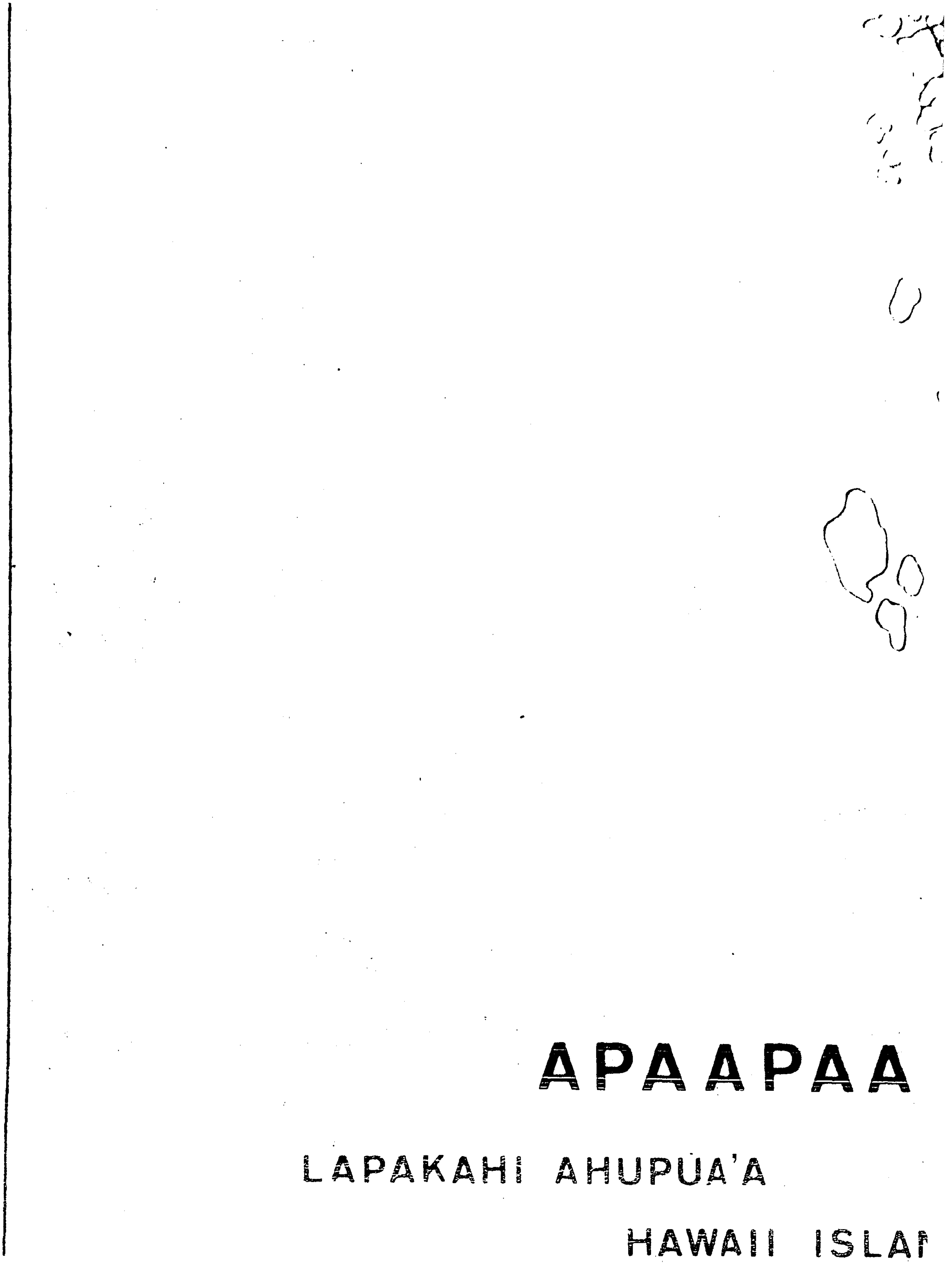
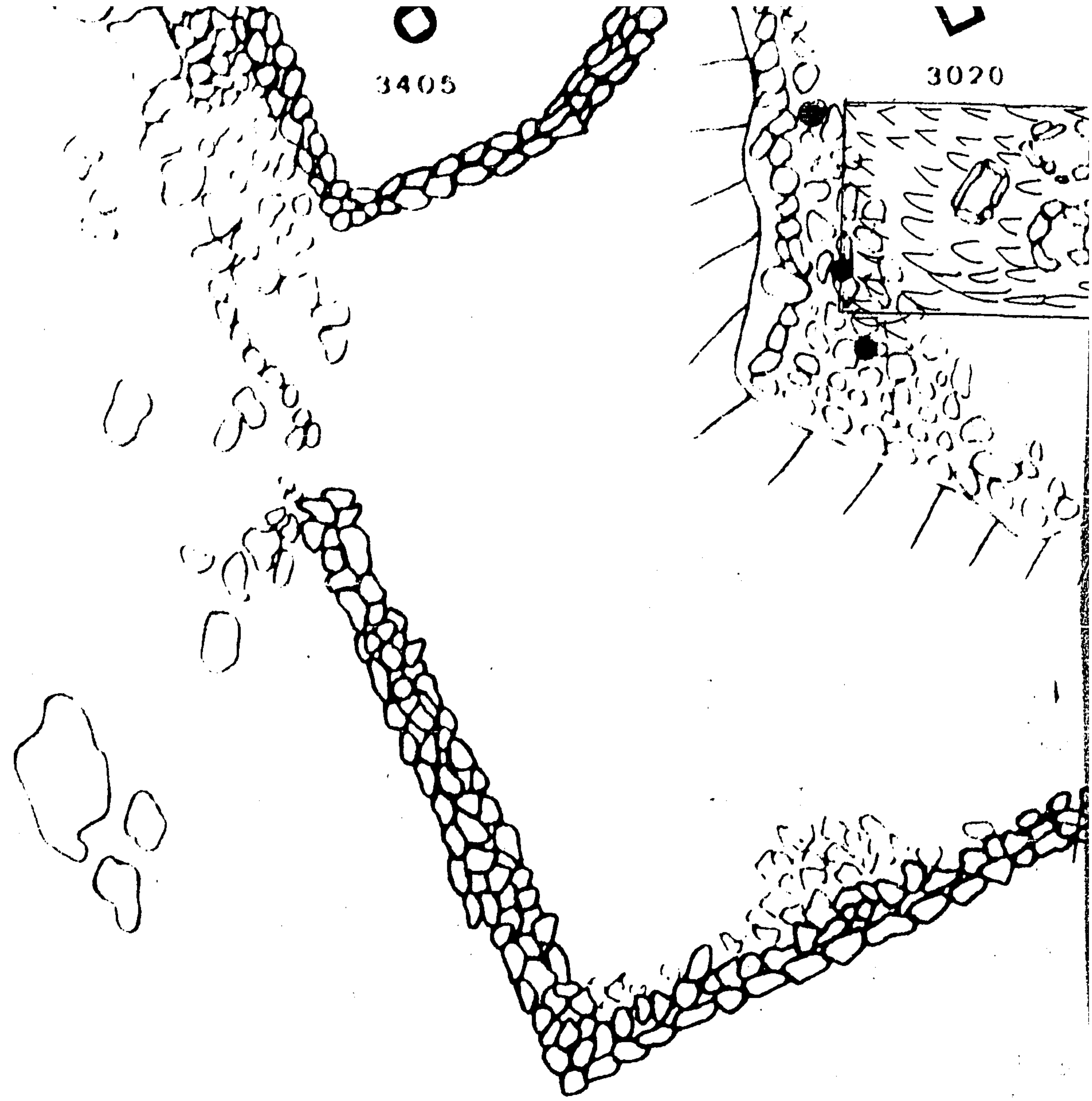


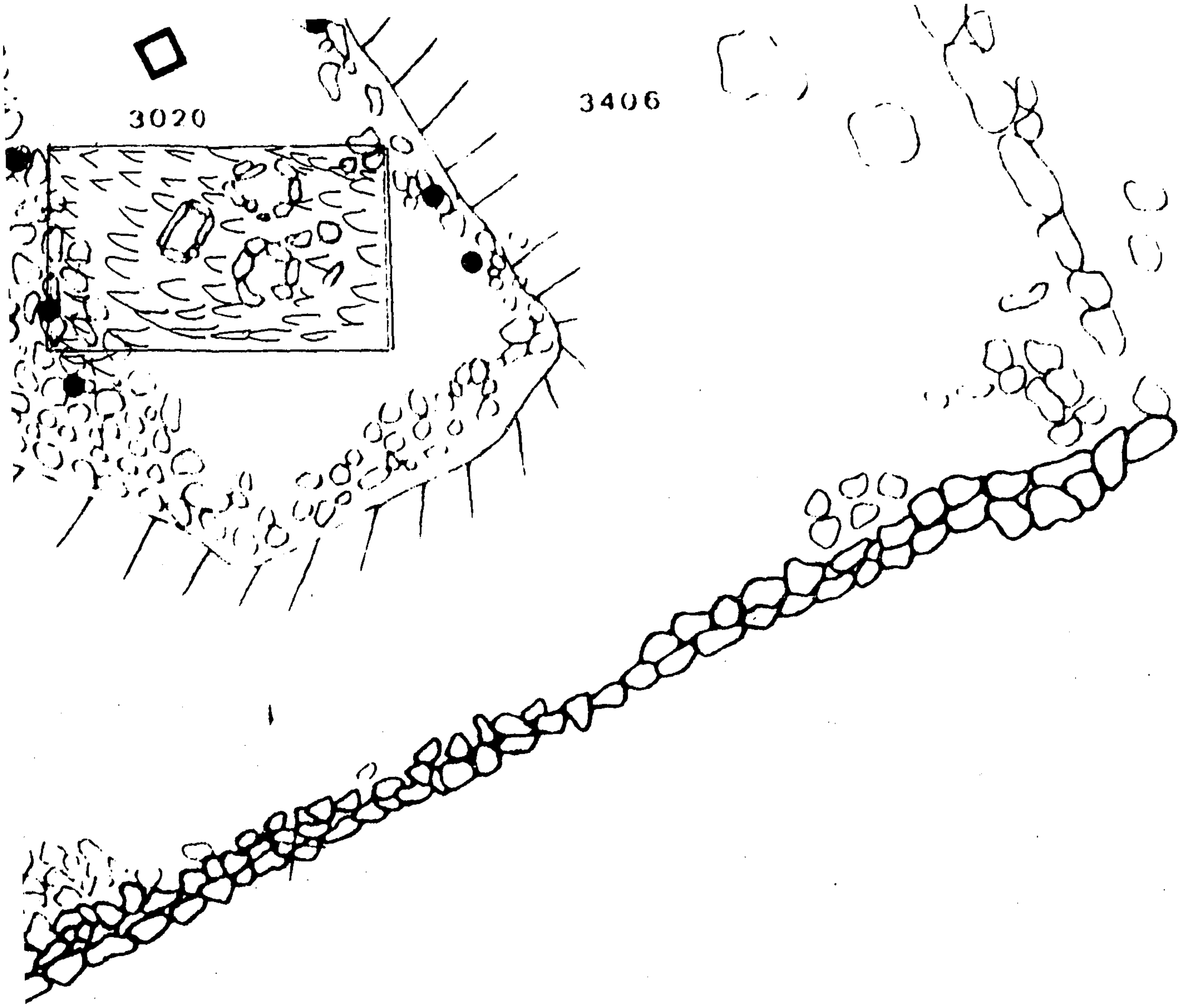

APAAPAA
LAPAKAHI AHUPUA'A
HAWAII ISLA



PAAPAA 1

AHUPUA'A NORTH KOHALA

HAWAII ISLAND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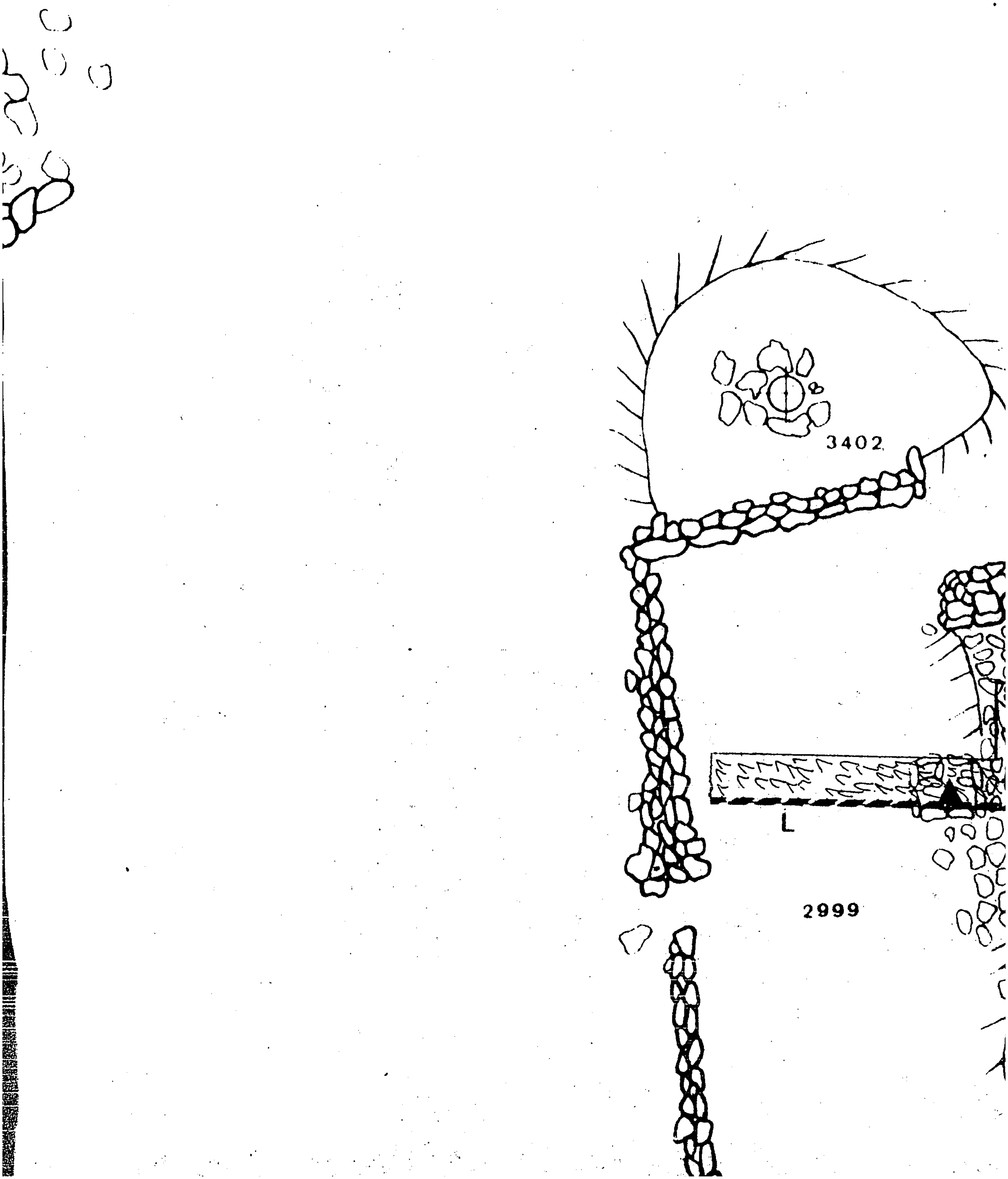
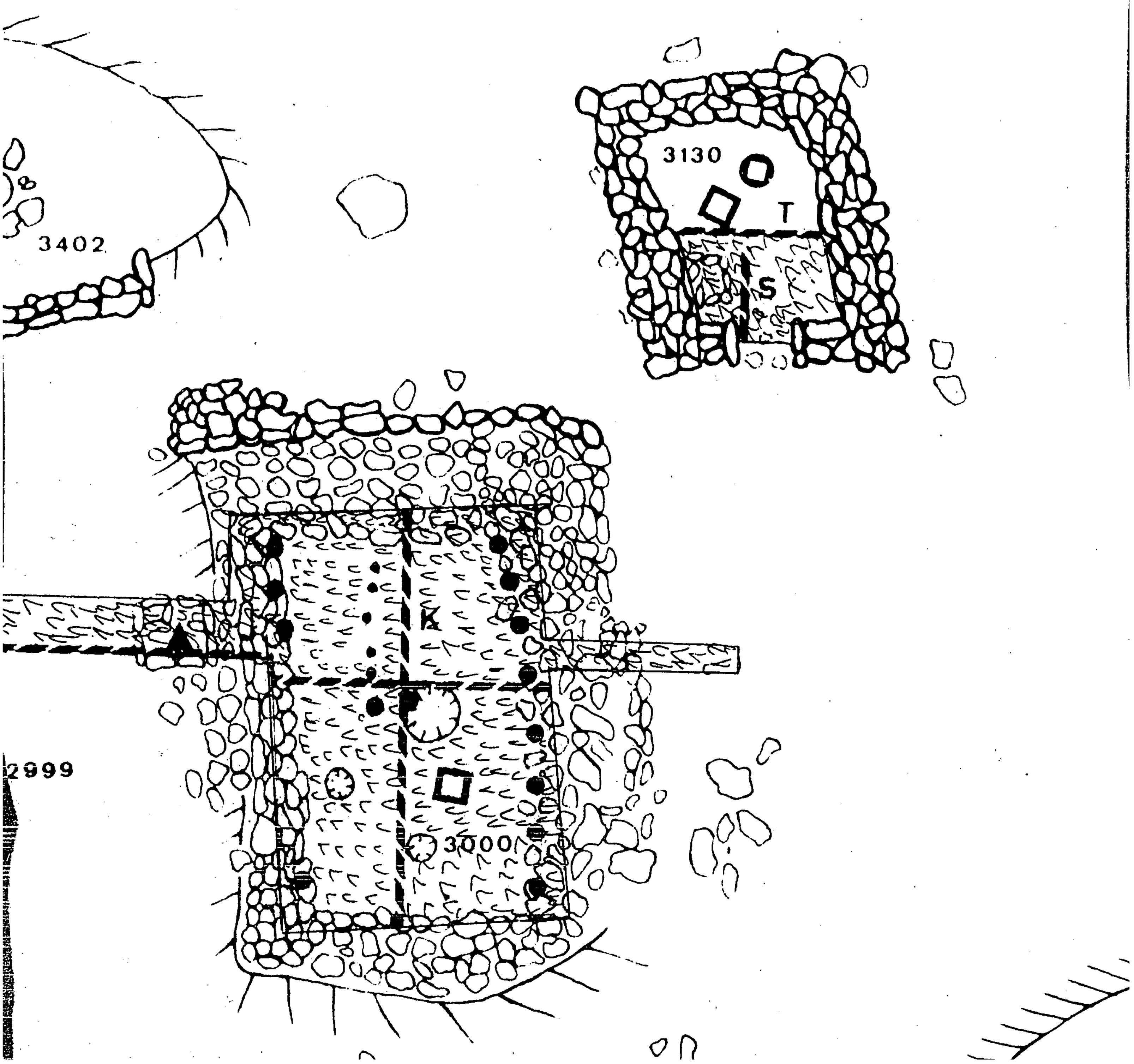
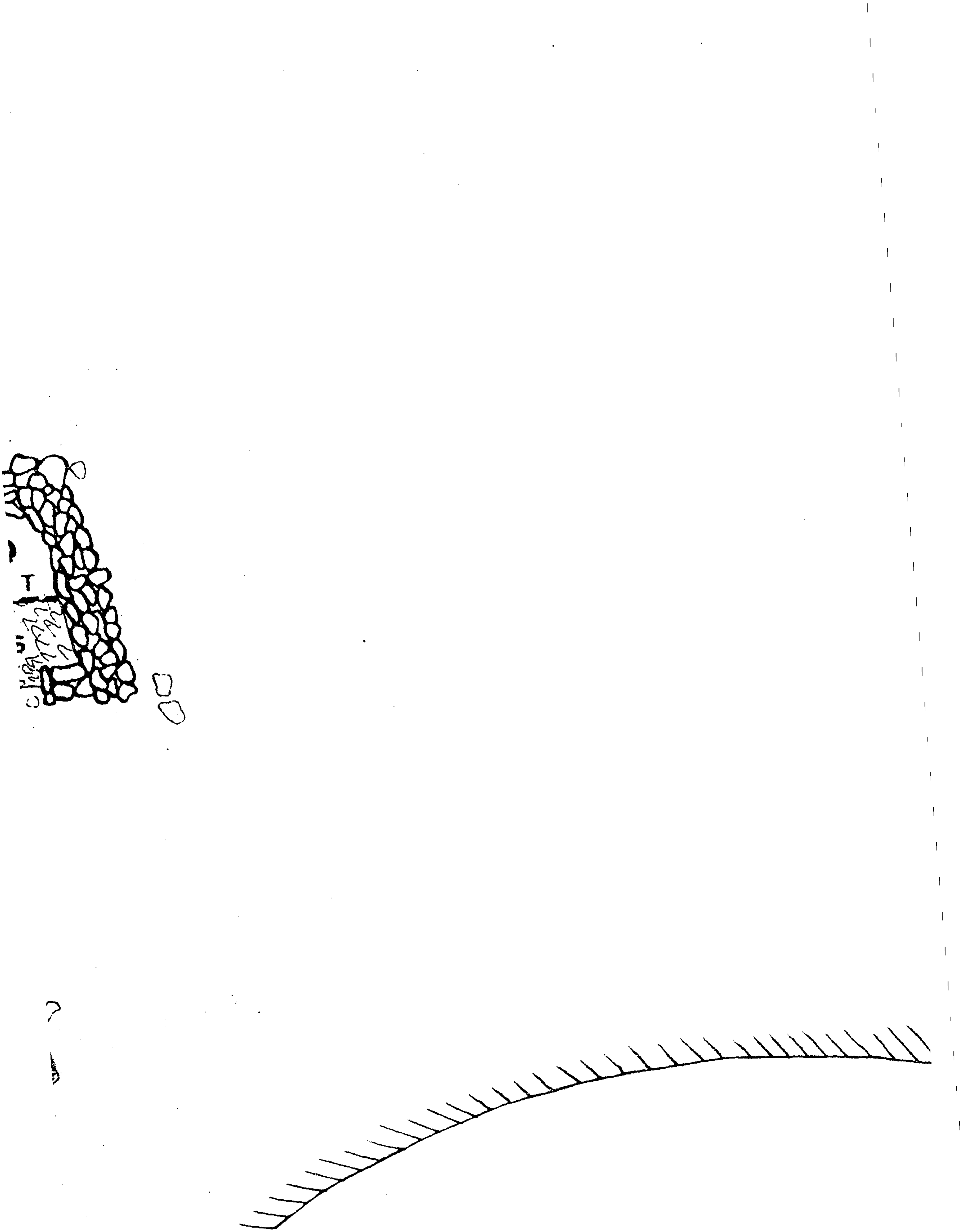
3406


3402
L
2999



3130
T
S
3402
K
2999
3000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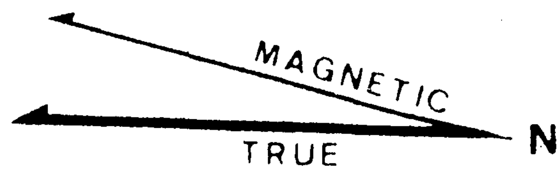
APAAPAA

LAPAKAHI AHUPUA'A

HAWAII ISLAN



me

y

Wall

Rock Rubble

Dirt Post Mold

Slab Firehearth

Firepit

House Site

3000

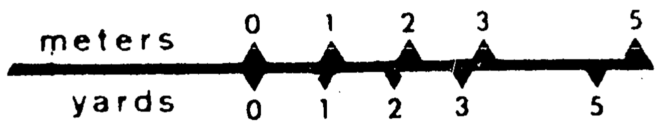
Elevated Area

K

ɔAAPAA 1

UPUA'A NORTH KOHALA

HAWAII ISLAND



N

Excavated Areas

Pavement

Water Catchment

d

Rock Filled Post Mold

·th

Oven

Walled Enclosure

3000 Feature Number

K

a

Profiles Illustrated in Text

LA

5

old

KILOMETER 95
HECTARE 96
ARE 91

KILOMETER 5
HECTARE 6
ARE 1

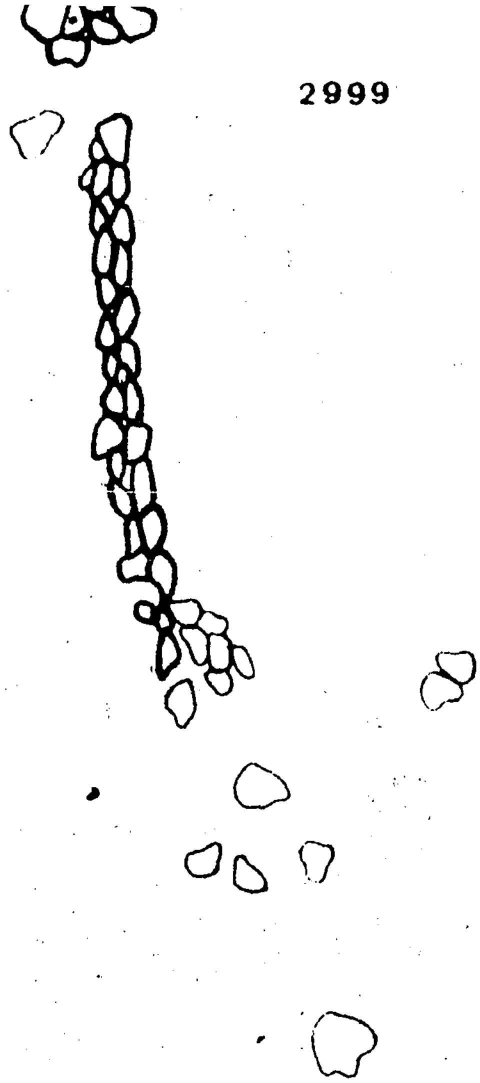
KILOMETER 95
HECTARE 95
ARE 00

KILOMETER 5
HECTARE 5
ARE 10

in Text

MAP

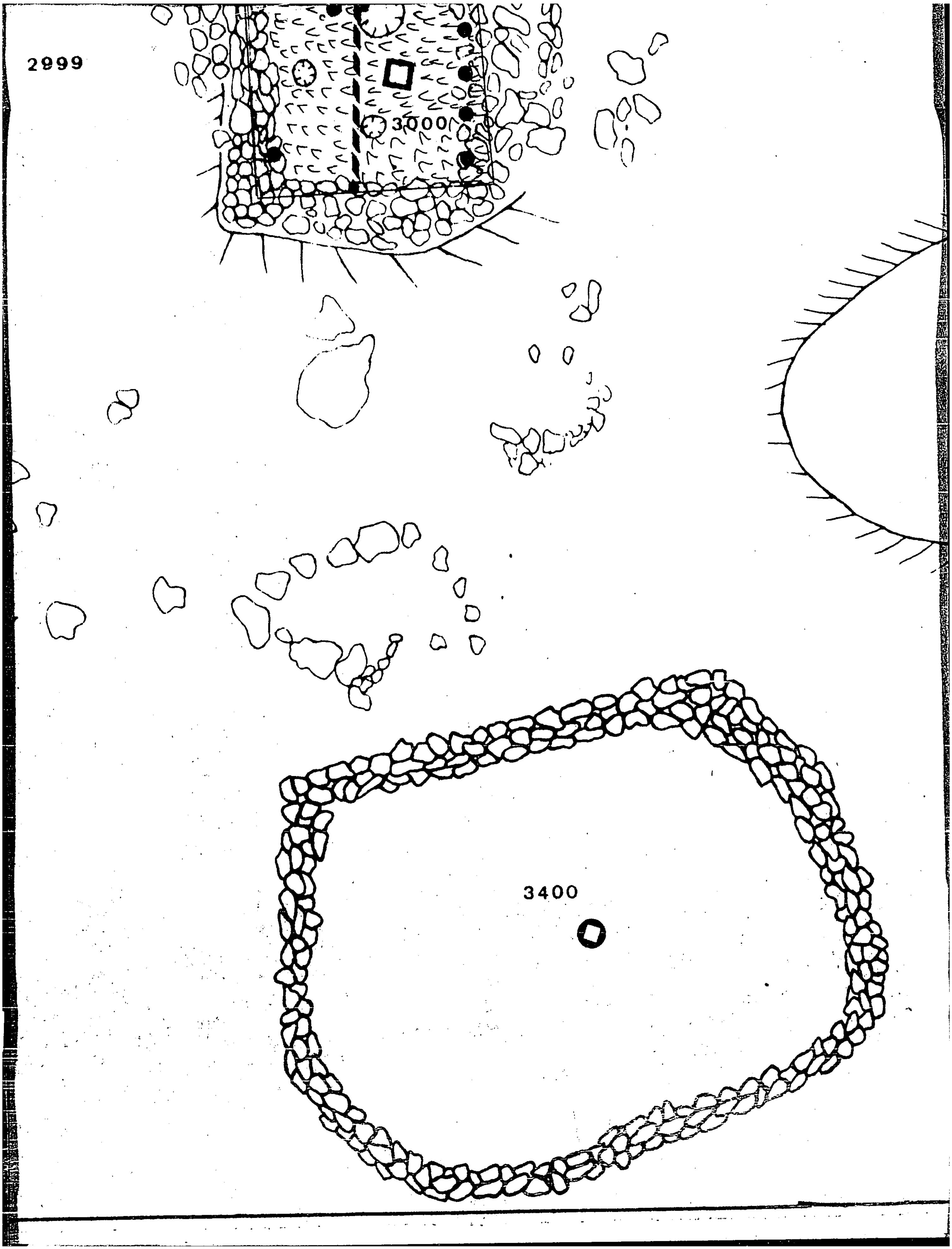
2999

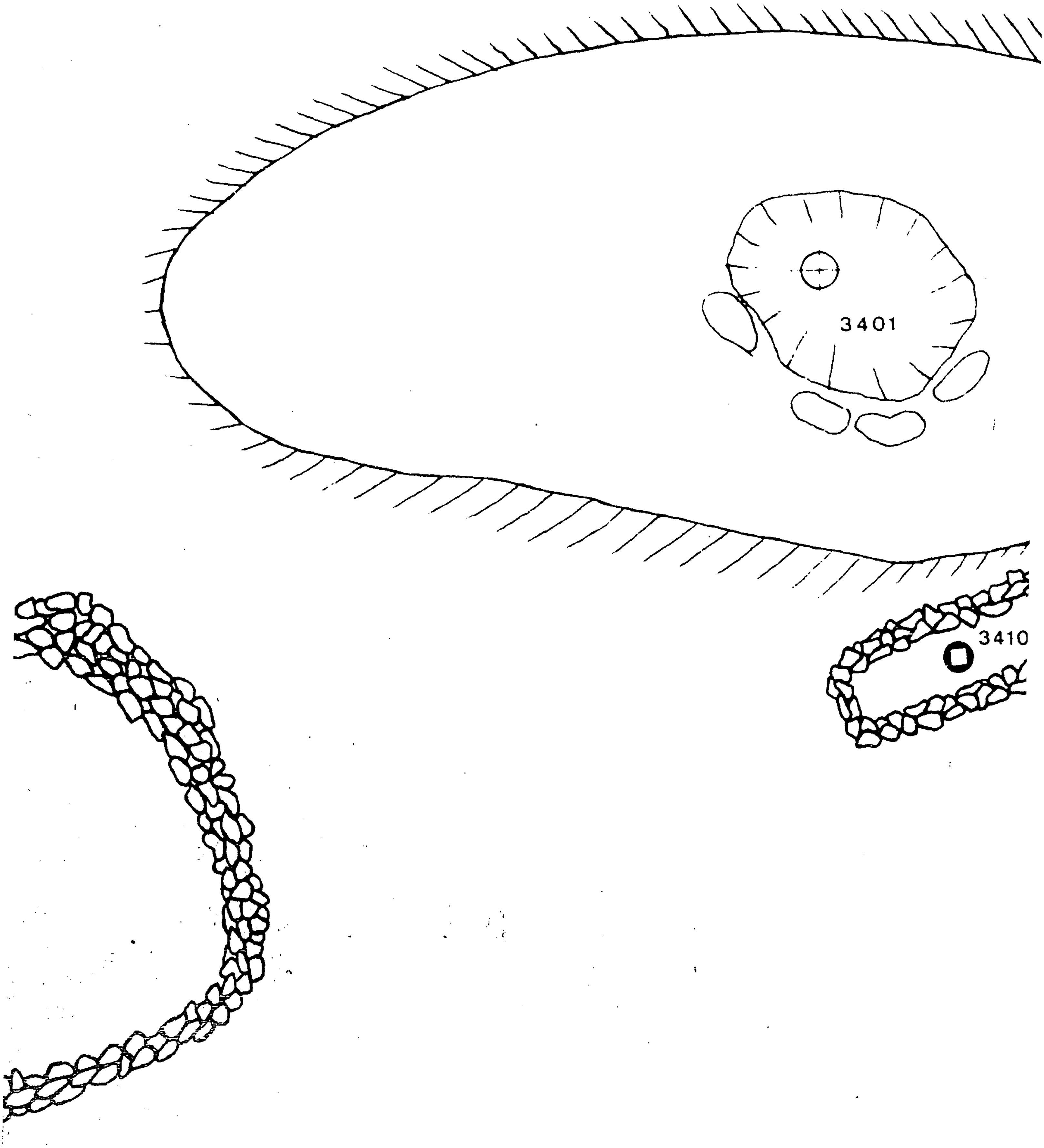


TER 5
E 6

TER 5
E 5

MAP 10


2999
3000
3400


3401
3410

Structural Features:--Features 3000, 3130, and 3020 were house platforms and these give no indication of exploitative focus; but it would appear that Features 3400 and 3410 are most likely agricultural enclosures for crops easily damaged by the constant high 'āpa'apa'a wind and by animals. The evidence for this is primarily the design of the walls which appear to function as exclosures to keep animals out instead of enclosures to keep animals inside because of more outer flat facing than inner flat facing to the walls. The height of the walls, however, was greater than necessary to keep animals out but would have been necessary for a windbreak. An alternate explanation that cannot be disregarded is that Feature 3400 functioned as an animal enclosure because flat facing appears on both the inner and outer wall faces. Its walls, however, would seem abnormally high for penning any animal but goats and the most economical, but still tentative, explanation is that the structure functioned as an agriculture enclosure designed to protect the plants within from both wind and animals. On the other hand, the stone structure labelled Feature 3405 may have served as an animal enclosure because the walls are more generally flat faced on the inside than the outside and are too low to provide much wind protection to any but very low growing plants. It apparently had no opening, such as was found in Feature 3130, and it is doubtful, therefore, that it functioned as a dwelling. There was no evidence that 3400, 3410, or 3405 were habitation structures, either in structural design or in midden deposits in the small test pits dug within them.

The structural features of Apaapaa 1 would seem to present some evidence of a land focused exploitative adaptation through the presence of specialized structures for plant protection and possibly for the penning of domesticated animals. It does not really matter at this time whether the structures were for plants or for animals since either function would indicate land exploitation at the site. No structural features could reasonably be interpreted as being used in maritime exploitation although it is conceivable that fish could have been dried on the walls of 3400, 3410, 3130, or 3405; there is no evidence of this however.

Artifact Analyses:--The artifact yield was much lower than that for Koaie, as would be expected for a shorter excavation period with a smaller crew. It is also possible that the lower yield can be explained, in part at least, as due to a difference in site function because relatively few land exploitative artifacts could be found in a land focused site.

In any case, there is a striking difference between Apaapaa 1 and Koaie in the category of artifacts for maritime exploitation as shown in Appendix E, Table XV, which summarizes the Apaapaa 1 artifact yield by function.

Whereas, artifacts designed for maritime exploitation made up 13.6 percent of the total artifact yield at Koaie, only a single maritime artifact (cowry shell for an octopus lure) was found at Apaapaa 1, making up only 0.4 percent of the total artifact yield. No artifacts were found that were directly indicative of land exploitation practices, although several food pounder fragments indicate utilization of land products. The same distinction is also visible in Appendix E, Table XVI, which shows the breakdown of Apaapaa 1 artifacts by the material from which they were made, for only two artifacts (0.7 percent of the total) were manufactured from marine substances. The basic difference in raw materials used is illustrated by the observation that some 32 percent of the Koaie artifacts were made of organic and 68 percent were made of inorganic materials, while at Apaapaa 1 the organic materials accounted for only 10 percent of the total and inorganic materials made up the remaining 90 percent.

Midden Analyses:--The midden analyses for Apaapaa 1 summarized in Table XVII in Appendix E illustrate a sample that is quite different in make-up from the Koaie sample for out of a total sample of 16.5 pounds (7,504.8 grams) about 58 percent was food and 42 percent non-food remains. Of 9.6 pounds (4,343.1 grams) of food remains, about 45 percent was of marine origin, including 4.1 pounds of shell (1,869.9 grams; 43.1%), 0.07 pounds of sea urchin (32.8

grams; 0.8%), and 0.1 pounds (55.6 grams; 1.3%) of fish. Although the sample weights are quite different in magnitude, the percentages of each component should be similar. This is patently not the case when the site midden components are compared in terms of percentage of food remains in Table IV.

TABLE IV

SUMMARY OF KOAIE AND APAAPAA 1 FOOD REMAINS

	Koaie %	Apaapaa 1 %
Shell	85.4	43.1
Sea Urchin	8.1	0.8
Fish	2.0	1.3
Turtle	0.02	0.0
Mammal	2.8	29.9
Pig	0.2	1.5
Dog	0.4	0.1
Foreign	0.7	8.2
Kukui	1.7	24.3
Bird	0.03	0.7
Chicken	0.007	0.2
Turkey	0.01	0.0
Sea Bird	0.004	0.0
Food	71.1	57.9
Non-food	28.9	42.1
Marine Origin Foods/Food Total	95.4	44.9
Marine Origin Foods In Total Site Weight	67.9	26.0

Comparison of Koaie and Apaapaa 1

Some differences between the two sites are quite marked, such as 8.1 percent sea urchin for Koaie and 0.8 percent for Apaapaa 1; 2.8 percent mammal for Koaie and 29.9 percent for

Apaapaa 1. There was a difference in preservation between the two sites with Apaapaa 1 having damper conditions and rather leached midden components. These preservation factors cannot explain such differences, however, especially when a fragile component such as fish is found in nearly equal proportions in both sites and certain other relatively easily leached components such as mammal bone and kukui were found in higher proportions at Apaapaa 1. The most economical answer is that the differences lie in exploitative focus, with Koaie being more sea-oriented and Apaapaa 1 more land-oriented. This is particularly indicated by the midden analyses where the land/marine food ratio for Apaapaa 1 is 45 to 55 while the land/marine food ratio for Koaie is 5 to 95 compared to marine remains. Clearly there was a greater emphasis upon low remains weight/high biomass foods such as mammal and bird at Apaapaa 1; very indicative of a predominant land focus. Taking all lines of evidence together, it seems warranted to conclude that Koaie illustrates a predominate maritime focus and Apaapaa 1 a primary land focus. With this, the first criterion of demonstrating a predominant maritime exploitative focus for Koaie has been met and it is now possible to proceed to the next criterion to be assessed for Koaie, that of sample size sufficient to base correlations upon.

Koaie Sample Characteristics

There is no clear answer to the question of what constitutes an adequate sample size to form a basis for analysis of archaeological sites nor how one obtains a random sample for an archaeological site. A sample can only truly be random when some parameter for the population (in this case, the site) is known and this is virtually never the case in archaeological excavations. The Koaie sample is most certainly not a random one for the levels to be excavated were carefully considered in terms of what the amount of information yield would be if dug by micro-analytic or macro-analytic conditions. It had been hoped to avoid some of these sampling problems by proceeding with total micro-analytic excavations but considerations of time, man-power, and funds necessitated the reduction of this goal by some 30 percent. However, since approximately 70 percent of all excavated levels were dug under micro-analytic conditions and this resulted in virtually a total sample of these levels, it is assumed that a sample of 70 percent of the excavated levels does provide a sufficient statistical validity for the research. The resultant Koaie sample was some 150 pounds of processed midden sample that excludes structural components. This sample size seems large enough to warrant correlation with the historical data, thus adequately meeting the second criterion.

Correlation of the Archaeological Data

The broad picture of Hawaiian maritime exploitation patterns illustrates interrelationships between man, culture, and aspects of the Hawaiian environment. The direct link between man and the marine ecosystem was through material culture items such as nets, fishhooks, poisons, traps, spears, snares, and canoes. Behind these artifacts lay detailed knowledge about the nature of the sea and how best to tap this resource.

Technology is the interface between man and nature; if any two parts of this relationship are sufficiently known, it is possible to deduce the characteristics of the third. To ensure accuracy for this logical argument the first step is to validate particular artifacts as archaeological indications for the exploitative patterns described in Chapter III. Once this is done it is possible to extrapolate this broad picture to other archaeological sites if key artifacts are found.

Not all sea exploitation patterns can be extrapolated into prehistory, or even correlated with historic archaeological evidence, because of artifact differential preservation. For example, the following would not normally be found in an archaeological context: poisons, nets, net floats, fish line, poles, basket traps, wooden hooks, bristles from pā or octopus lures, baits, spears, or melomelo bait sticks. These perishable artifacts would disintegrate rather rapidly, although on rare occasions fragments might be found. For example, Emory and Sinoto found a piece of netting in an archaeological site on Oahu (1961:57-58). Artifacts that the archaeologist could expect to find would be bone, shell, and metal fishhooks; metal, coral, and stone sinkers; cowry shells for the octopus lure; pā lure shanks and points.

A secondary line of evidence for particular exploitative techniques would be the occurrence of marine biotic remains in site middens. Only non-perishable skeletal materials would normally be found, such as shells, sea urchin parts, fish bones and scales and crustacean skeletal remains; no fleshy body parts would normally be preserved. These midden remains can provide correlations for both artifacts and exploitative techniques. If any large quantity of fish remains from Appendix C, Table VI, are found, then both exploitative artifacts and techniques may be inferred. The lack of midden remains of types that should have been preserved can be used cautiously to indicate little emphasis upon the exploitative patterns that would have caught these creatures.

If biota remains are found that would have normally been exploitated by particular techniques used only for that purpose, then those techniques can be inferred even without finding the artifacts. If artifacts are found that were solely used to exploit particular biota, then the exploitative patterns utilizing those artifacts may be inferred, even without midden remains. Thus, if one finds octopus-lure parts but no midden remains of octopi, it is still possible to infer the catching of octopi by lure. The reverse is not true, however. Even if octopi beaks were found, one cannot logically hold that a lure was used at the site because octopi can be caught with other techniques, such as by hand or spearing.

The reconstruction of exploitative techniques must be based upon mutually exclusive biota remains and artifacts, or it is not possible to differentiate between different techniques. This is not as restrictive as it may seem, however, for if remains or artifacts are not exclusive at the most precise exploitive level, they may be so at a broader level. For example, if mālolo midden remains are found it is not possible to infer the precise type of net technique used; but the mālolo remains demonstrate that nets were used at the site.

If the tie to a particular exploitative technique can be made on the basis of any one artifact or midden component type, then the exploitation of all other species taken by that technique from the same habitat can be inferred. For example, should pā lure parts be found, then it could be inferred that both mahimahi and aku were taken. If hāpu'u remains are found in the midden, deep water hand line fishing for hāpu'u, hannanue, ilikiki, kāhala, koa'e, lehi, mahukia, 'ōpaka, uku, and walu may be inferred. Shellfish taken in quantities indicate hand collection, and the taking of sea cucumbers and limu can be inferred if they normally occur in the area.

Koaie Maritime Exploitation

With these tools for interpretation of archaeological remains in hand, it is possible to make a detailed reconstruction of maritime exploitation at Koaie. The organization of this section will follow that used for the overview of the Koaie data earlier in this Chapter:

(1) local site history,

(2) geographic position,

(3) structural features,

(4) portable artifacts, and

(5) midden components.

Koaie Local History

Local informants remembered that shortly after the beginning of the twentieth century an Oriental family lived in Hectare 73 and fished extensively. Later, a fishing sampan was located at Koaie and its several fishermen lived in a small wooden house in Hectare 73, Ares 12 and 22 until the 1940's. There was no information on nineteenth century Koaie, however, and local history was little help in this analysis.

Geographical Position

The geographic position of Koaie along the coast and the nature of the marine environment was covered in detail in Chapter II and this need not be repeated. The marine conditions are such that the supra-surge and surge zones are small while the sub-surge zone is enlarged. The extensive offshore shelf is unusual for the Islands and increased the area available for benthic exploitation. Modern fisheries have found too few pelagic food fish in the area to support commercial operations and it is likely to have been the same for the Hawaiian fisherman.

These environmental parameters would indicate a maritime emphasis on hook and line fishing with a pole in the very shallow inshore area, and hand line fishing far out on the shallow benthic shelf. The many underwater caverns would have encouraged underwater spearing, poisoning, and the catching of fish by hand-held nets. The jumbled underwater topography would have restricted the use of seine nets so the emphasis in net fishing was most likely on set gill nets and various forms of bag nets. The reduced size of the supra-surge zone would have eliminated much emphasis upon shellfish such as 'opihi. The greatest emphasis in shelling would have been for those species occupying e surge and sub-surge zones, such as cowry and cone shells.

Structural Features

Canoe Houses

Koaie has one of the best canoe landing areas along this section of the coast. In Hectare 72, Are 39, is a small cove, well protected, and with a gradual slope up which canoes could be hauled. A walled rectangular stone structure immediately behind the cove in Hectare 73, Are 51 may have been a canoe house, or hālau. Test excavations inside the structure revealed that few cultural remains were to be found: very scant midden materials, only a single octopus lure part (toggle), and some scattered surface glass. The formal shape of the structure is similar to that described for canoe houses; the lack of general habitation refuse and the presence of the toggle all point to the structure having been a hālau.

It is certain that not all structures of this same formal character are canoe houses; in fact, the large structure of this formal type in Hectare 63, Are 42 was not a canoe house. The midden and artifact sample excavated demonstrate that this particular structure was a habitation.

The only other suitable canoe landing at Koaie is the coral rubble beach just north of the central complex in Hectare 62, Ares 09 and 19. Immediately behind are several stone structures that might have been small canoe houses; however no excavations were conducted within them so a functional identification is not possible at this time.

The small structure behind the cove provides the best evidence for a canoe house at Koaie and indicates the existence of fishing from boats. Canoes were used for sub-surface angling and for trolling so the presence of this structure would tentatively support these two techniques. This is not to be pressed, however, because it is possible that the canoe(s) could have been merely used for transportation.

Salt Pans

Salt manufacture must have been a form of sea exploitation at Koaie but since this was not part of the historic analysis, it is difficult to gauge the cultural role it might have played. A number of salt pans occurred in close proximity with one another at Koaie, indicating some emphasis upon salt manufacture. A number of other salt pan areas are scattered along the coast, both north and south of Koaie (cf. Conner 1969).

No other structural evidence of sea exploitation was discernible for Koaie; rather the site was a generalized habitation complex.

Portable Artifacts

Function

The Koaie artifact collection tabulated in Table VII of Appendix D shows a predominant fishing focus with a primary emphasis on sub-surface angling. Only 11 items of surface trolling gear were found and these only compose 0.28 percent of the total artifact yield. A breakdown of the fishing gear category shows about 4 percent trolling artifacts and 85 percent sub-surface angling artifacts, with 11 percent unassigned to either category.

Inshore fishing gear consists of fishhooks (182; 4.7%), octopus lure points (5; 0.1%), octopus lure cowry shells (25; 0.6%), octopus lure toggles (7; 0.2%), and sinkers (21; 0.5%). Formal analyses of the octopus lure sinker and cowry shell categories are found in Appendix D, Tables XI and XII. Inshore fishhooks make up about 64 percent of the fishing gear total; octopus lure parts 13 percent and sinkers 7 percent. The remaining 16 percent includes pelagic gear, items of incomplete manufacture, and those artifacts unassigned to either pelagic or inshore classifications.

These data indicate a primary emphasis upon sub-surface angling rather than pelagic surface trolling at Koaie. Although the artifact collection would indicate a greater emphasis on hook and line fishing than on net fishing, this is not at all certain because nets are perishable and sinkers are difficult to interpret as net or line sinkers. There was, however, a greater emphasis on the use of fishhooks for catching inshore fish than the use of lures for catching octopus; likewise, there was more exploitation of octopus by lures than surface trolling for pelagic fish.

Three additional artifacts for octopus lures ("coffee bean" sinkers) are obtained by breaking the sinkers down on a formal basis as is done in Table XI of Appendix D.

Fishhooks

Koaie fishhooks were almost all slender and "small" (as defined in Chapter III), indicating a primary emphasis on line fishing in shallow water. It is probable that many of the small hooks were used with fishing poles. Some of the fishhooks from Koaie fall within the "large" category, indicating some exploitation of the deeper benthic waters by hand line techniques.

Informant Interview:--A trip was made to Maui to interview Mr. Sam Po, an elderly Hawaiian who fished commercially for many years along the inshore leeward area of east Maui. The marine habitats of the section he consistently fished are similar to the Koaie marine habitats and his information provides a functional understanding of many of the Koaie fishhooks. Mr. Po was shown examples of the Koaie fishhooks and notes were taken on his observations of them as follows:

Small fishhooks were used to catch fish with small mouths, such as moi, po'o-pa'a, hīnālea, moano, weke, manini, kala, and 'a'awa.

Fishhook 0715 (Fig. 8, No. 7, Appendix G) was for 'a'awa, 'e'a, a'ua'u, or palani but not for manini, which was caught with a hook that was more open. [This small fishhook has a point only slightly incurved.]

Fishhook 2740 (Fig. 8, No. 14, Appendix G) could be used for 'ū'ū, kūpīpī, mamo, and humuhumu but 0715 would have been better. [2740 differs from 0715 primarily in being more incurved. Probably a jabbing-hook was best for these fish.]

Fishhook 2776 (Fig. 8, No. 9, Appendix G) has the shape used to catch ula (lobster) but is a little too small.

Fishhook 3082 (Fig. 8, No. 1, Appendix G) was used in kūkaula fishing as one of ten to fifteen hooks on one line to catch uku, ono, moi, and 'ula'ula. Hook 2143 (Fig. 8, No. 15, Appendix G) was also used in kūkaula fishing and would have been better than 3082 because it is a better shape to keep the fish hooked. [The difference lies in the greater curvature of the point for L-2143 and the presence of an inner barb on 3082.]

Fishhook 0340 (Fig. 9, No. 26, Appendix G) would have been good for catching po'o-pa'a, kūpīpī, and mamo.

Mr. Po did not recognize any two-piece hooks shown him, but he did recognize that their shapes when pieced together were similar to one-piece hooks he had used. He also stated that the size and shape of the fishhooks were the functional factors; not the material.

<u>Material</u>:--The overall artifact analysis by material is shown in Table VIII of Appendix D; 588 artifacts were

constructed of marine materials, making up 15 percent of the total. Of these 588, most were made of sea urchin spines (248), closely followed by coral (226), while the remaining artifacts were of shell (113), and sponge (1). All marine biota used for manufacturing artifacts were from the close inshore area and from quite shallow water. This again emphasizes the heavy use of the inshore area at Koaie.

Not all artifacts used for marine exploitation were constructed of marine materials; only 8 percent of the fishhooks were shell (Appendix D, Table XII) and only 50 percent of the sinkers were of coral (Appendix D, Table XIII).

Manufacturing Tools for Fishhooks:--An attempt was made to apply the analytic techniques of Semenov (1964) to use facets of sea urchin spine files on the assumption that these files were primarily used to manufacture bone fishhooks. Table X of Appendix D gives the results of this analysis based upon the microscopic examination of all sea urchin spine files. None but the "grooved" use facets were directly indicative of fishhook manufacture since all other use marks could have been the result of working other bone artifacts. The "grooved" facets, however, were the result of sharpening the tips of very pointed objects with the spines; most likely fishhook points but also possibly the bone picks for extracting shellfish from their shells. The same techniques applied to coral and stone abraders ("saws" and "files") was likewise inconclusive in correlating use facets with fishhook manufacture. It was interesting to find, however, that use patterns were discernible on sea urchin spines, coral, and stone artifacts when microscopically examined.

Midden Analyses

Shellfish

The overall midden analysis for Koaie is shown in Appendix D, Table IX. The largest midden component percentage is for shellfish (61%), but does not necessarily indicate a major emphasis upon shelling because of the high remains/low biomass weight problem covered earlier. The shellfish category is summarized in Figure 3 by excluding all entries of less than 1 percent of the total shell weight.

At the class level, the ratio between gastropods and pelecypods (bivalves) is 97:2 (1% unidentified to either), far higher than the usual ratio of 82:18 for Hawaiian waters. This is indicative of clear and unsilted marine conditions if the midden ratio is the same as the living ratio for the area. If the midden ratio is different from the living ratio it would indicate the degree of cultural preference for each shellfish type. The answer is unclear because the living ratio for Koaie is not known.

No reference to the use of cone shells for food was encountered in the literature but definitely they were exploited at Koaie. The 2 percent Cellana ('opihi) and 9

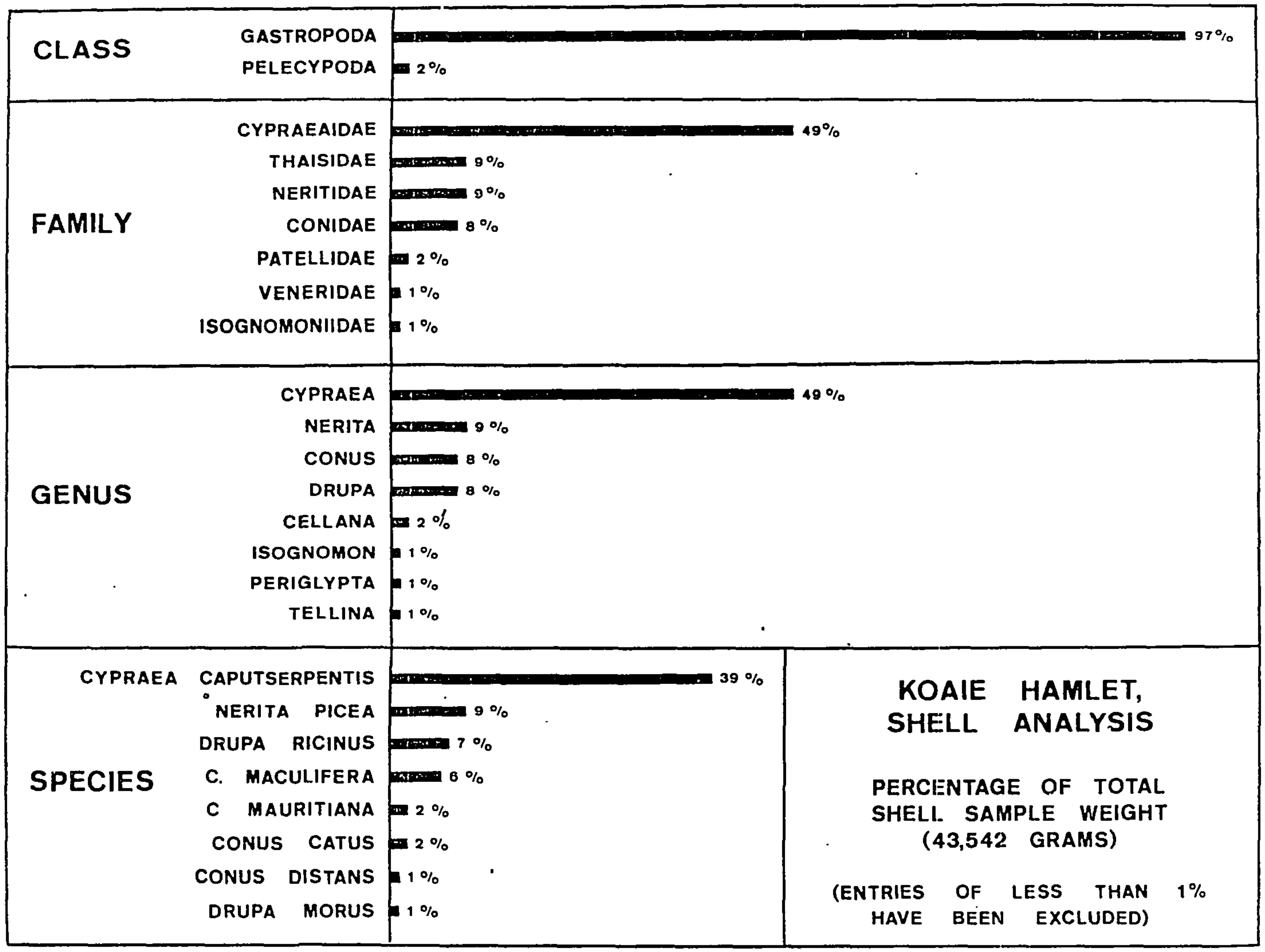

CLASS
GASTROPODA
97%
PELECYPODA
2%
FAMILY
CYPRAEAIDAE
49%
THAISIDAE
9%
NERITIDAE
9%
CONIDAE
8%
PATELLIDAE
2%
VENERIDAE
1%
ISOGNOMONIIDAE
1%
GENUS
CYPRAEA
49%
NERITA
9%
CONUS
8%
DRUPA
8%
CELLANA
2%
ISOGNOMON
1%
PERIGLYPTA
1%
TELLINA
1%
SPECIES
CYPRAEA CAPUTSERPENTIS
39%
NERITA PICEA
9%
DRUPA RICINUS
7%
C. MACULIFERA
6%
C MAURITIANA
2%
CONUS CATUS
2%
CONUS DISTANS
1%
DRUPA MORUS
1%
KOAIE HAMLET, SHELL ANALYSIS
PERCENTAGE OF TOTAL SHELL SAMPLE WEIGHT (43,542 GRAMS)
(ENTRIES OF LESS THAN 1% HAVE BEEN EXCLUDED)

Fig. 3

percent Nerita (pipipi) are most likely correlated with the leeward position of Koaie and the reduced supra-surge zone. The relative proportion of Cellana and Nerita midden remains, for example, was far greater at a shelter cave site on the windward side of Kalawao Peninsula, Molokai (Hirata and Potts n.d.). The high proportion of Cypraea remains at Koaie is quite different from the low proportion at this Molokai site; again, probably a direct result of the difference in geographic location in relation to swell action. Cypraea caputserpentis made up 39 percent of the total shell remains, and was the most heavily exploited shellfish at Koaie. This is surprising because there is no indication in the archaeological or historic literature of any cultural preference for C. caputserpentis. It is, however, one of the more common cowrys at Koaie today (H. Snider, University of Hawaii Marine Biologist, Personal Communication). Similarly, there is no indication of the exploitation of cone shells in the literature and the relative abundance of Conus catus is unusual because it seems to occur in the midden at Koaie at higher frequencies than would be expected in a living assemblage (H. Snider, University of Hawaii Marine Biologist, Personal Communication), indicating a distinct cultural preference for this particular cone shell.

In summary, the shellfish component of the Koaie midden substantiates the indications from other lines of evidence that the primary exploitative emphasis was on the near inshore area. Furthermore, the role of the leeward position of Koaie can be seen in the types of shellfish exploited, where the supra-surge zone shellfish make up only a minor part of the midden.

Fish

The fish analysis in Table IX of Appendix D shows that fish made up 1.4 percent of the total midden and 2.0 percent of the food remains. Although apparently a low percentage of fish remains for a coastal fishing settlement, it must be remembered that shellfish and sea urchin remains are not as perishable as fish bone; furthermore, fish is a low remains weight/high biomass midden component so straight comparisons by weight are skewed. Figure 4 provides a summary of fish remains on the basis of bone and scale count instead of weight.

No remains of pelagic fish were in the midden sample; only of inshore and possibly benthic types. This is apparently not the result of identification or preservation problems because Dr. Swerdloff stated that should pelagic remains have been present it would have been possible to identify them; similarly, pelagic fish bones would not decompose faster or more completely than the bones of inshore fish. This pointedly illustrates the lack of emphasis by Koaie residents on pelagic fishing and the primacy of inshore fishing.

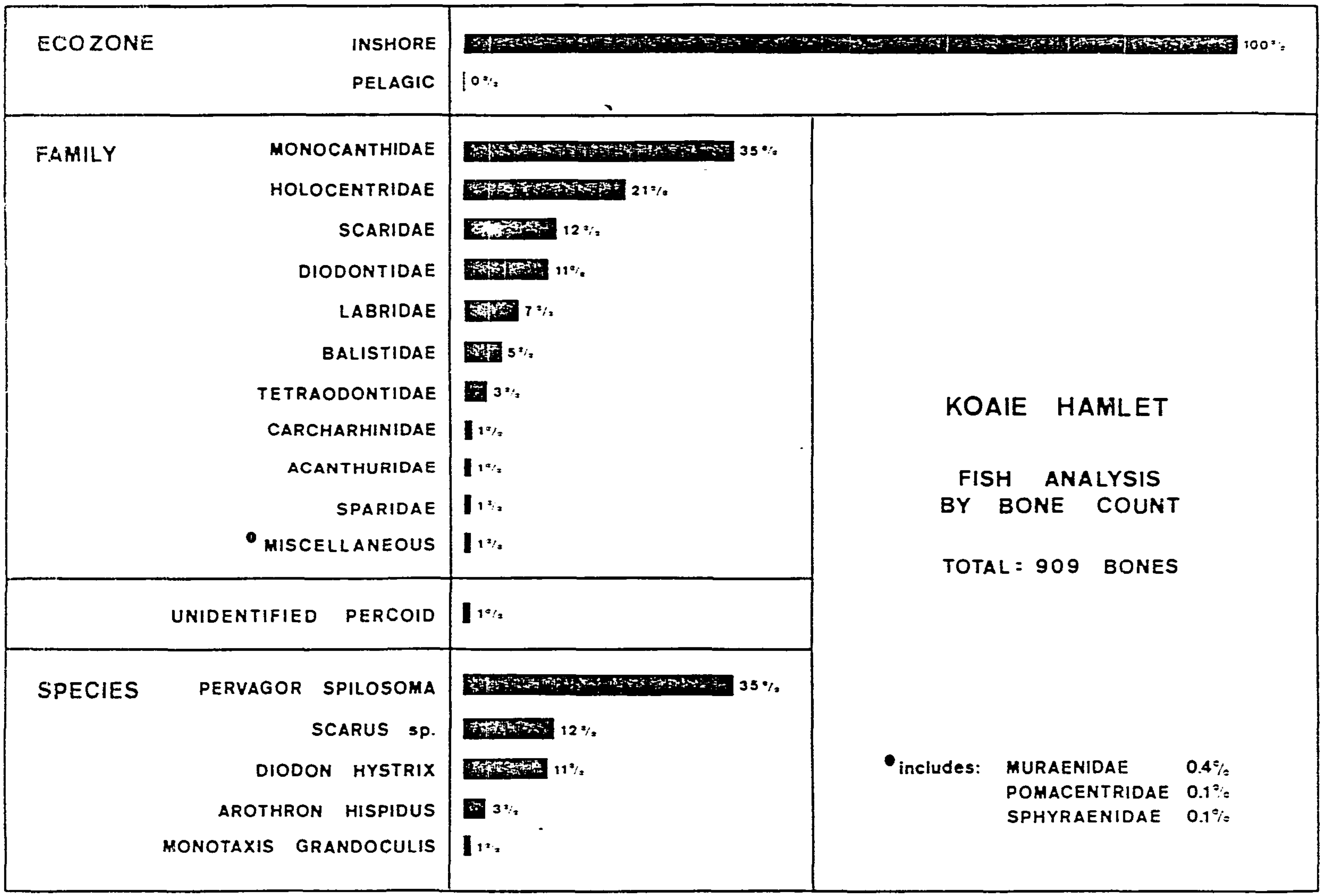

ECOZONE
INSHORE 100%
PELAGIC 0%
FAMILY
MONOCANTHIDAE 35%
HOLOCENTRIDAE 21%
SCARIDAE 12%
DIODONTIDAE 11%
LABRIDAE 7%
BALISTIDAE 5%
TETRAODONTIDAE 3%
CARCHARHINIDAE 1%
ACANTHURIDAE 1%
SPARIDAE 1%
• MISCELLANEOUS 1%
UNIDENTIFIED PERCOID 1%
SPECIES
PERVAGOR SPILOSOMA 35%
SCARUS sp. 12%
DIODON HYSTRIX 11%
AROTHRON HISPIDUS 3%
MONOTAXIS GRANDOCULIS 1%
KOAIE HAMLET
FISH ANALYSIS BY BONE COUNT
TOTAL: 909 BONES
• includes: MURAENIDAE 0.4%
POMACENTRIDAE 0.1%
SPHYRAENIDAE 0.1%

Fig. 4

The problem of transposing native and scientific taxonomic fish names was mentioned in Chapter III but a list of native names for the fish remains at Koaie is given in Appendix D, Table XIV. It is not certain if all these native named fish were represented, but at least the Koaie fish remains come from within this listing.

The direct correlation of midden remains with particular exploitative techniques was prevented by the inability of marine biologists to identify most Hawaiian fish below the family level on the basis of skeletal characteristics. Most Hawaiian fish identification keys are based upon soft body parts and not on skeletal features; skeletal features of Hawaiian fish have yet to be amassed into a complete identification key. Certain fish types, however, can be identified to genus and species on the basis of highly unique skeletal features.

This itself presents a definite problem in using the fish data developed here to discuss relative importance of individual fish types to the Koaie residents. Some comparatively rare fish may be more easily identified on the basis of unique skeletal parts while other quite common fish may well remain identified only to a much higher taxonomic level, thus skewing the relative percentages of fish types represented toward those more readily identified. There is no ready solution for the archaeologist and he must simply wait or press for definitive skeletal keys to be developed;

in the interim it is necessary to view these data with some caution. The family identifications, however, should be valid but do not correlate well with the exploitative practices of Appendix C, Table VI, because this table is based on lower taxonomic levels. It must be emphasized, however, that the lack of identifiable pelagic fish remains does not fall under this problem for sufficient skeletal identification information exists to allow their identification when represented.

Summary

The people of Koaie primarily depended upon the inshore area for maritime subsistence; some exploitation took place in the benthic zone but very little pelagic fishing was practiced. The most common exploitative techniques were: fishing with hook and line, bag and gill nets, poisoning, and hand collecting. Hook and line fishing using a pole was probably practiced extensively quite close to shore while the kūkaula technique was used in deeper waters of the inshore and benthic areas. It is possible that kākā fishing took place in the deep water areas, but the data are unclear here. Although some pā lure parts were present, the lack of pelagic midden remains makes it unlikely that this technique was commonly used. Octopus fishing with the cowry lure was of more importance than pelagic trolling, kūkaula, or kākā fishing, but of less importance than inshore pole fishing. Shellfish and other edible marine invertebrates were primarily exploited from the surge and sub-surge zones and not from the supra-surge zone. The most important shellfish was the cowry, which was over five times more prevalent in the midden than any other.

It is certain, however, that not all subsistence was obtained from the sea at Koaie--the extensive upland agricultural areas must also have contributed to the food supply. A rounded picture of subsistence for the whole Lapakahi area can only come after a consideration of land exploitation patterns.

CHAPTER V

HAWAIIAN LAND EXPLOITATION

Introduction

Hawaiian agriculture was based on root and tree crops; primarily taro, sweet potatoes, and breadfruit. Additional food was obtained from other domesticated plants such as arrowroot, sugar-cane, coconut, pandanus, and yams, but these were not as important in the diet. The primary farming implement was the digging stick, or 'ō'ō; a type of tool most often associated with extensive instead of intensive land exploitation (cf. Boserup 1965). In Hawaii, however, this simple tool was part of a sophisticated farming technology efficiently using natural resources such as surface water for irrigation, soil and/or rocks for banking both flooded and unflooded fields, dead vegetable matter for fertilizer, and field boundary vegetation for wind protection and water retention.

Sea exploitation demanded a diversified and complex artifact technology, but Hawaiian agriculture illustrated a simple digging stick interface with nature. This interface was backed by a highly developed native knowledge of environmental parameters, cultigen characteristics, and engineering design. A reconstruction of Hawaiian land exploitation must determine the knowledge lying behind native agriculture, rather than merely study portable artifacts. This research is not as concerned with Hawaiian portable artifacts as was the section with maritime exploitation; rather, the emphasis is to discover the natural factors limiting cultigens and practices brought by the Polynesian settlers.

Previous Analyses

Few analyses of Hawaiian farming have been made in terms of man-nature interaction; hence, little comparative data are available. A number of articles and books have described Hawaiian agriculture: MacCaughey (1917), Miller (1932), Handy and Pukui (1952), Sahlins (1958), Wichman (1965), Buck (1957), Kelly (1956), Barrere (1962) and Rohsenow (1967); to name only a few. The most important coverage of Hawaiian agriculture is The Hawaiian Planter by Handy (1940) which provides a detailed study of Hawaiian agriculture based on literary analysis and informant interviews.

Unfortunately, the same problems exist with these sources as with the general literature on maritime exploitation. No author considers the possibility of historic change in agricultural practices owing to European contact. Yet, the historic literature records the introduction of many new plants; herbivores such as cattle, horses, sheep, and goats; and European metal tools. New plants were quickly accepted by the Hawaiians and soon squash, melons, and pumpkins were being traded to ships provisioning in Hawaii (Holland 1969).

Historic Land Ecosystem Changes

The new animals increased in numbers to create a new hazard for the Hawaiian farmer who had to change his field design by building protective walls to keep them out of the crops. In addition, these animals caused large-scale changes in the floral cover, particularly in the forested areas above the agricultural fields.

> . . . grazing has affected more of the island's [Hawaii Island] vegetation than all other causes. Grazing, either by domestic or feral mammals has, with perhaps a few minor exceptions, affected to some degree all of the vegetation on the island. Some portions, particularly the dryer exposures, have undergone complete alteration, with many exotic plant species now firmly established over large areas (Robyns and Lamb 1939:289).

> With the arrival of Europeans came the introduction and semi-naturalization of cattle, sheep, and goats. . . . Some of these animals had taboos placed upon them; they multiplied rapidly and became naturalized in the hills and mountains. The animals completed the destruction of the original foothill vegetation, permitting the soil cover to be stripped from the lava rock, and causing the dry summer to be vastly more unfavorable for plant life. One can still find today, in isolated parts of arid Oahu, small patches of soil six feet or more in thickness, supporting a more mesic vegetation than that in the vicinity, and eroding rapidly at the margin--mute and vanishing evidence of past conditions.

> Within a relatively short period following European colonization, there was created a large area practically devoid of a closed vegetation, an unsaturated region ready to absorb any of dozens of pioneer species, be

> they introduced or native. The lowlands, being the sites of the ports, towns, gardens, and experimental stations, did receive a tremendous influx of foreign plants, some of which found favorable the barren unoccupied over-grazed lowlands. They are said to have spread over the island like an uncontrolled fire. Thus, lantana, opuntia, and klu (*Acacia farnesiana* (L.) Willd.) came to dominate the lower slopes while kiawe (*Prosopis chilensis* (Molina) Stuntz.) covered the dusty coastal plain with an evergreen verdure that transformed the face of the land (Egler 1942:18).

> Numerous writers have recorded the decimation of the native forests on the Hawaiian Islands by many agents such as sandalwood cutters, grazing cattle, and fire, and by lumbering for firewood, timber, or charcoal (St. John 1947:19).

These quotations illustrate documented shifts in vegetation type and distribution caused by the introduction of new plants and grazing animals by the Europeans. The vegetation shifts were generally toward more open forested conditions of the gradual elimination of lowland forests, especially on the leeward sides of the islands. The major exception is the kiawe (*Algaroba sp.*) succession on dry coastal lowlands which changed grassland into open forest.

Land Ecosystem Changes at Lapakahi

Many of the general changes noted above also occurred at Lapakahi and it is essential that the present ecosystem description be balanced by a study of past conditions. The general abiotic features of the Lapakahi land ecosystem would have been stable throughout the course of human occupation, except erosion of the small gullies; the same was definitely not the case for floral composition and distribution. Changes occurred in the floral cover as the result of demographic changes and owing to the increased number of grazing animals in the area.

Father Bond, the missionary stationed in the Kohala area, wrote in about 1860:

> As to the Southern and Western portions of the field, the question bids fair to have a speedy settlement in the extermination of the entire population. During the seven years preceding the recent census, the decrease in the population of the District was nearly one hundred per annum. This decrease, it scarcely need be said, was chiefly caused by removals and with few exceptions to Oahu. The total of Hawaiians now in the field is but 2,745. The decrease has almost entirely occurred in those parts of the field just referred to. The herds of cattle and horses belonging to natives themselves, suffered to run at large through the most ruinous negligence, had well nigh annihilated all possibility of cultivation; and thus commenced the work of expulsion ere foreigners with large herds of cattle came in to complete the process of depopulation. In that entire tract of country where formerly we had nine flourishing schools, but one insignificant, famine-stricken gathering of children is now to be found (Damon 1927:159).

Somewhat later, probably in 1864, Father Bond wrote:

> In 1841 the new parish [in West Kohala, including the Lapakahi area] had a population of 2500 souls at least, with 16 schools. Now the sparsely scattered people number less than 800, with 4 small schools . . . The entire tract of country is gradually filling with cattle and sheep belonging to foreigners, and the natives, as a matter of necessity, are rapidly leaving the district, chiefly for Oahu . . . (Damon 1927:207).

Historic Floral Changes at Lapakahi

Kiawe:--The most dominant feature of the Lapakahi coastal landscape today is the kiawe forest; yet this forest zone is a recent development. Kiawe was not introduced into Hawaii until 1838 (Egler 1947:413) and hence cannot have existed at

Lapakahi prior to that time. Kiawe was not a major floral cover in North Kohala until sometime after the end of the nineteenth century, to judge from an old photograph of Mahukona Harbor (Map 3). This photograph (Hansen 1963:16) of an area about one-half mile (.8 kilometer) north of Koaie shows no kiawe trees although Mahukona is heavily forested today. No date is given for the photograph but it shows tracks of the Hawaiian Railroad Company line which was built in 1880, so it is certain that the dense kiawe stand has developed since that time. In addition, an old local name for the point of land just to the south of Koaie is "Two Kiawe" and residents explained this was because only two kiawe trees grew there about the turn of the twentieth century.

The Mahukona photograph shows sparsely grassed hillsides in the background and it is reasonable to assume the same conditions at the time for Lapakahi. If this is the case, then the entire coastal kiawe belt would have been absent before the twentieth century and in its place would have been a cover of pili grass (Heteropogon contortus). The Lapakahi coastal area would have been completely devoid of shade or protection from the high velocity 'āpa'apa'a wind sweeping down the sloping terrain. The succession of kiawe from grassland at Lapakahi is also reasonable because it has been suggested that:

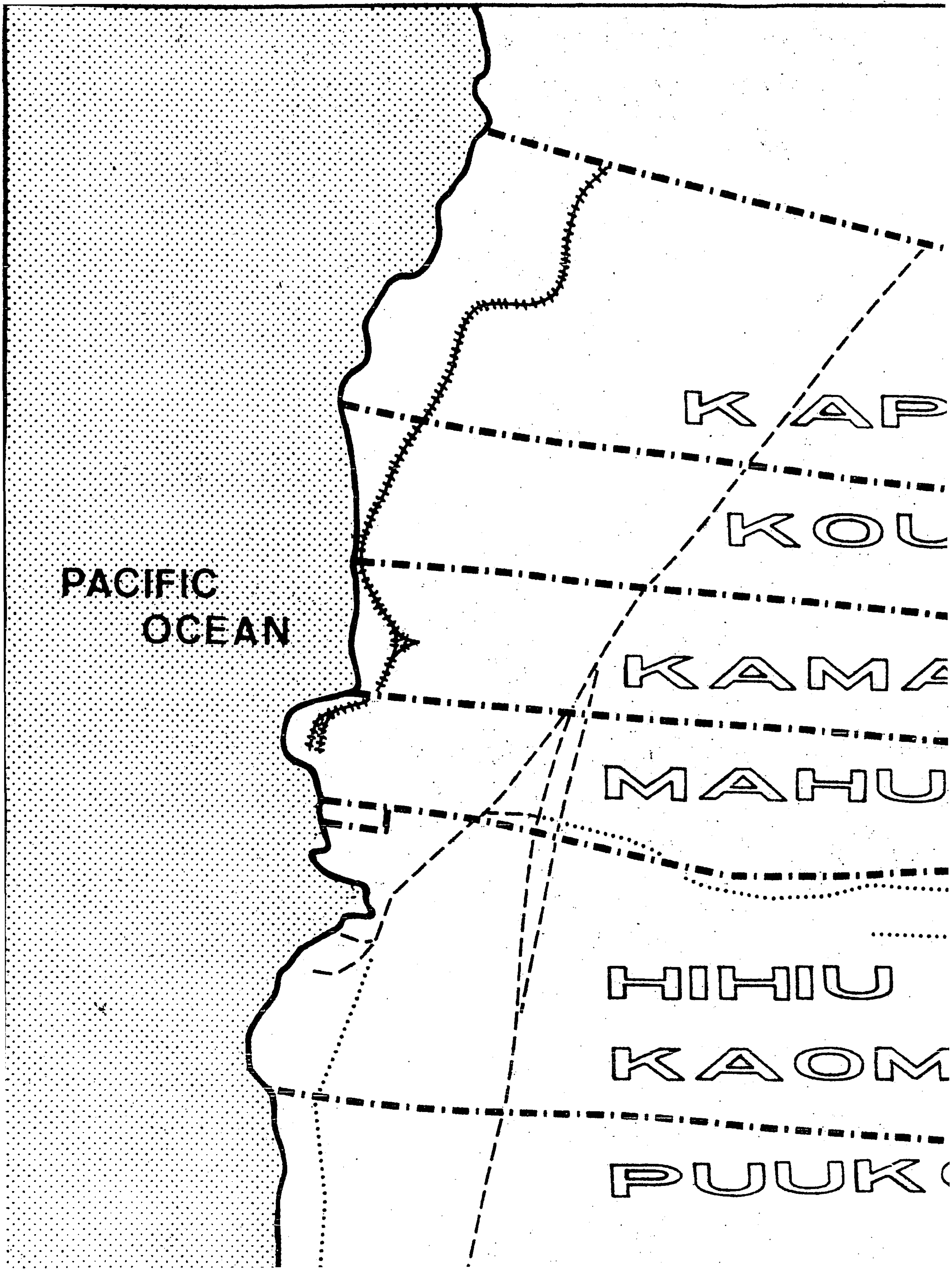
> . . . the bulk of the present kiawe forests originated under intensive overgrazing, on an essentially bare

> soil, under full light, by seeds excreted by animals and trampled into the ground during the wet season (Egler 1947:414).

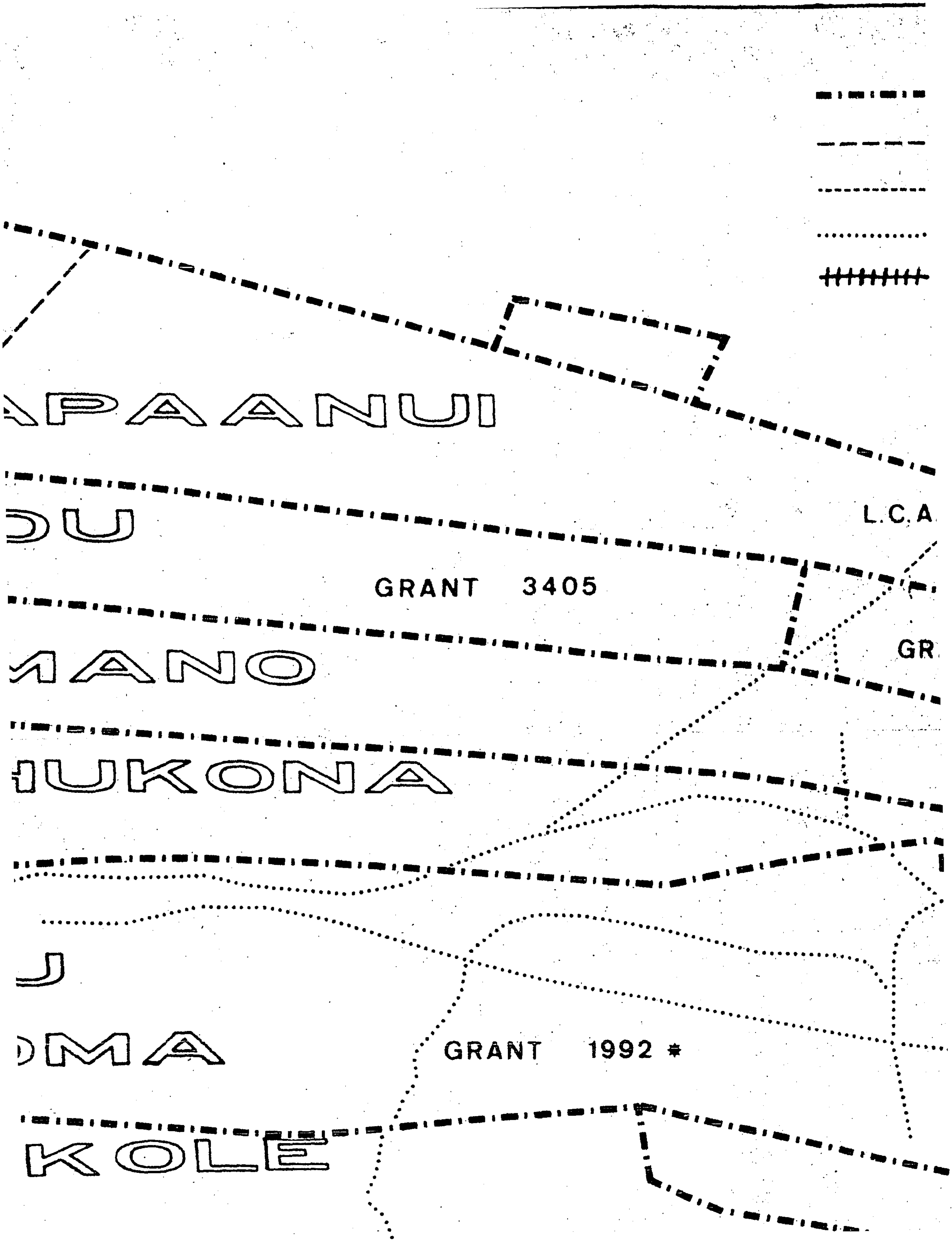
These data indicate that the kiawe succession was essentially post-nineteenth century in origin and probably correlated with the heavy use of the area by Parker Ranch for cattle grazing, particularly because kiawe beans are reputed to be valuable as cattle feed. In a letter to the Minister of the Interior of the Hawaiian Islands dated June 17, 1893, the Theo. H. Davies Company petitioned to lease lands in Puukole (a part of the Lapakahi area, see Map 11), and states:

> . . . we shall plant kiawe plants so as to establish as far as in our power a kiawe forest along the coast of the lands leased (letter in State Archives).

Pili Grass and Wiliwili Trees:--Kiawe forest cover was a non-native condition but the fact of pili grass being a dominant cover in the area needs further proof. Such proof can be provided for the area by reference to letters about the Lapakahi area on file in the State Archives. A letter from S. C. Wiltse, dated March 23, 1871, states that the lands of Koaie and Lapakahi consist mostly of pili grass. A land survey of numerous native tracts was conducted in the Kohala area by Father Bond (Damon 1927:180) and his survey reports include entries for areas in and near Lapakahi. The 1856 survey report by Bond for Grant 1992 (Map 11) covers portions of Mahukona, Hihiu and Kaoma and mentions pili grass and wiliwili trees (*Erythrina sandwicensis*). Another 1856 report, on Grant 2507, covers portions



PACIFIC
OCEAN
KAP
KOU
KAMA
MAHU
HIHIU
KAOM
PUUK


APAANUI
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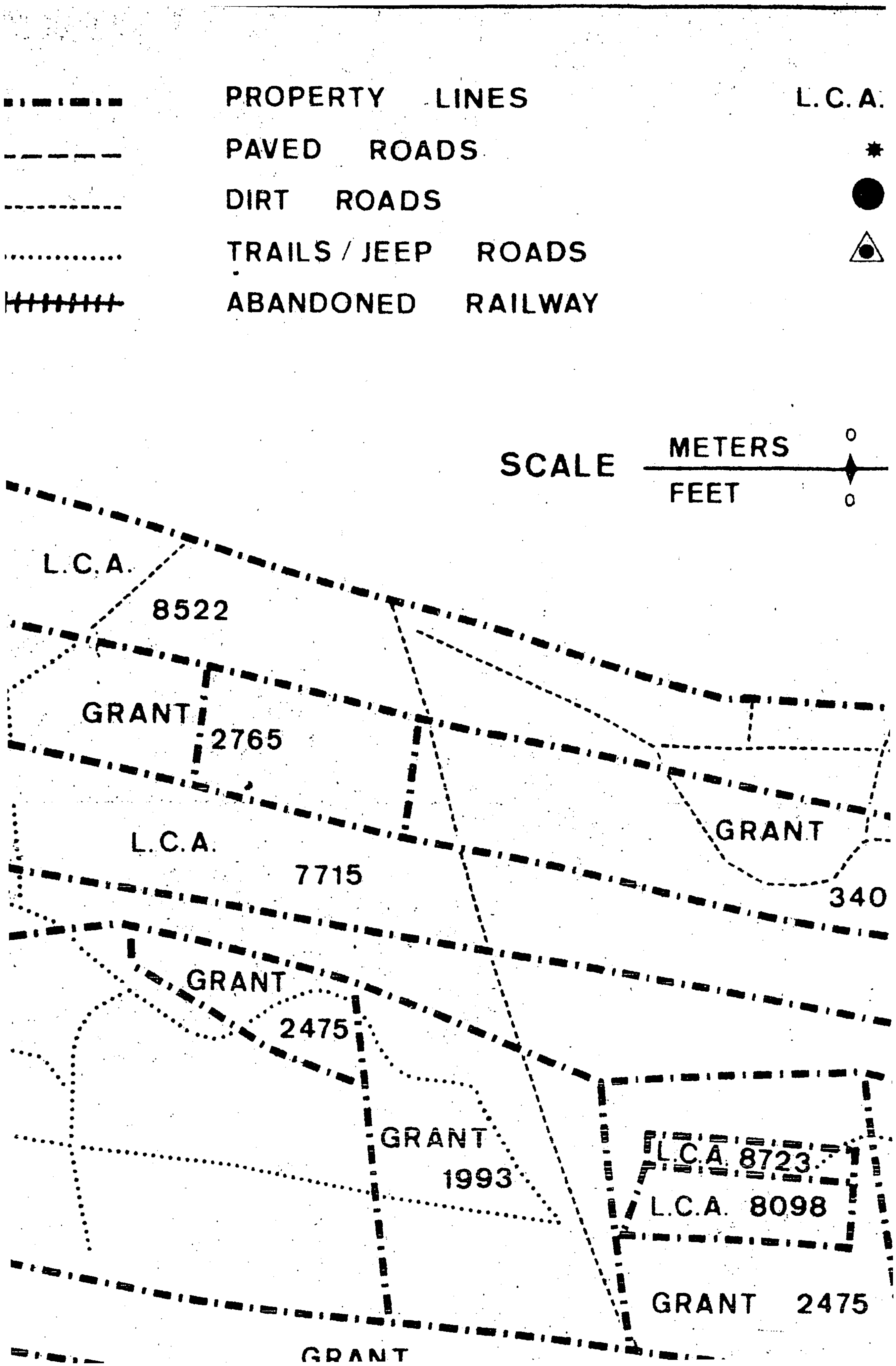

PROPERTY LINES
PAVED ROADS
DIRT ROADS
TRAILS / JEEP ROADS
ABANDONED RAILWAY
L.C.A.
SCALE
METERS
FEET
0
0
L.C.A.
8522
GRANT
2765
L.C.A.
7715
GRANT
340
GRANT
2475
GRANT
1993
L.C.A. 8723
L.C.A. 8098
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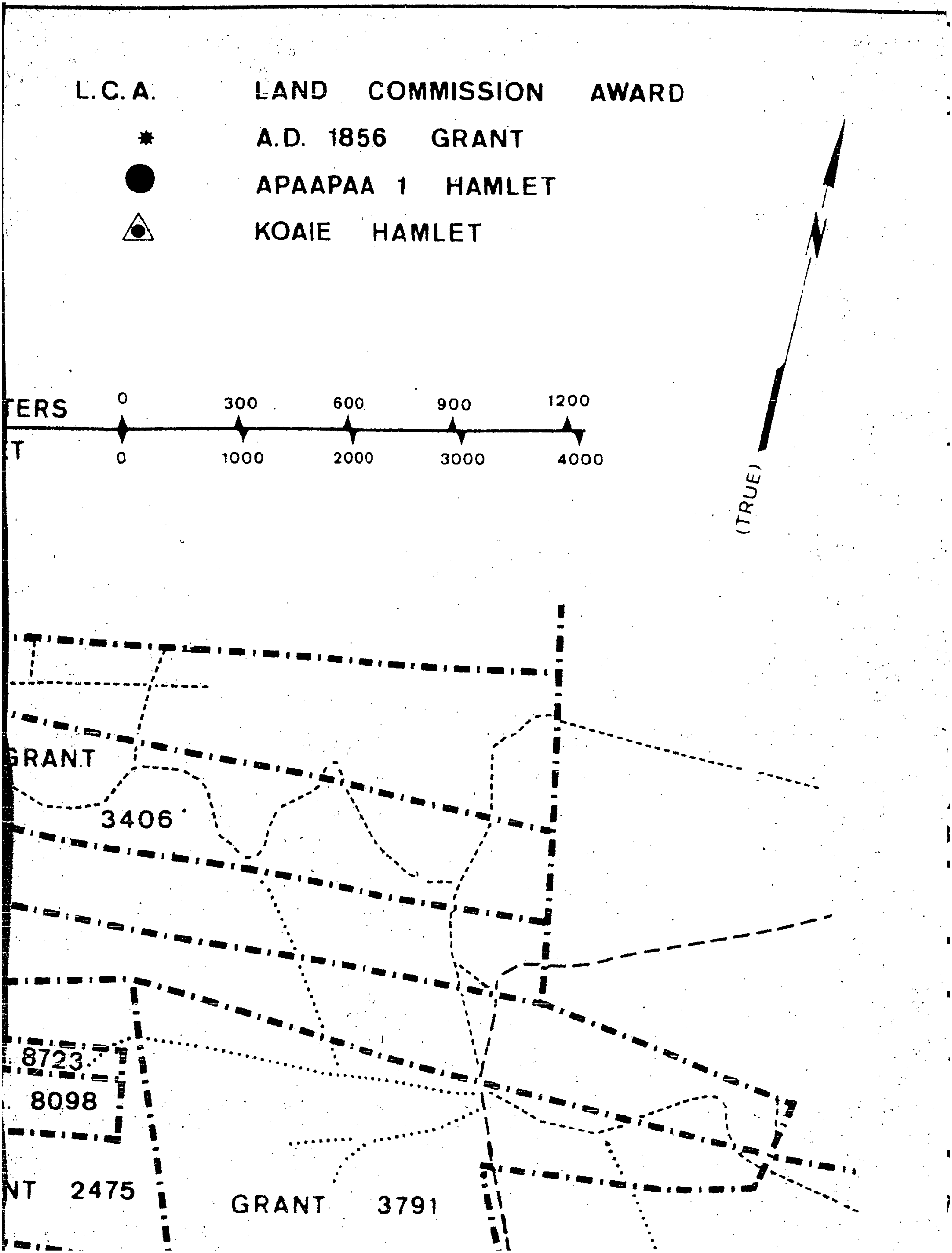

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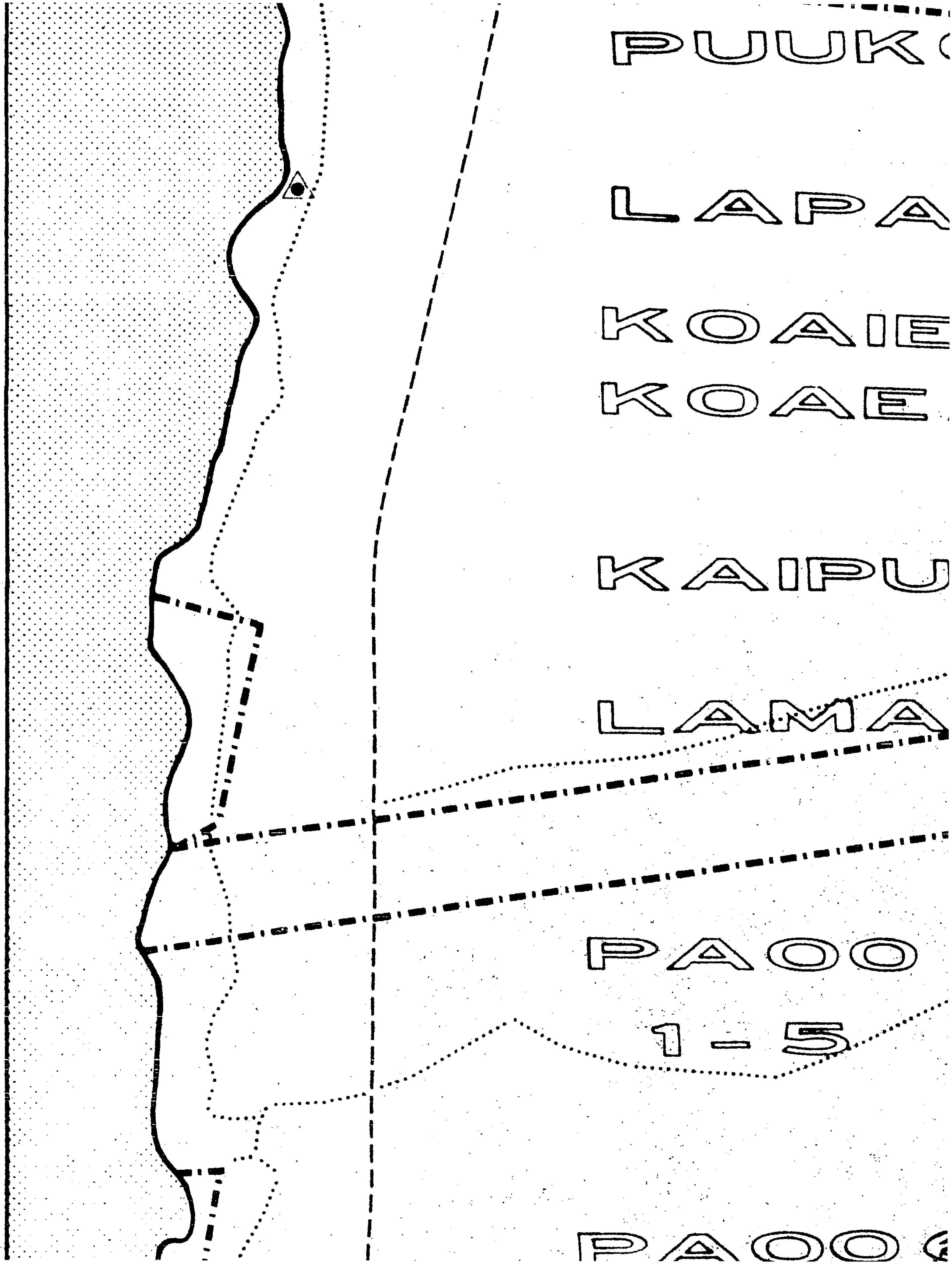
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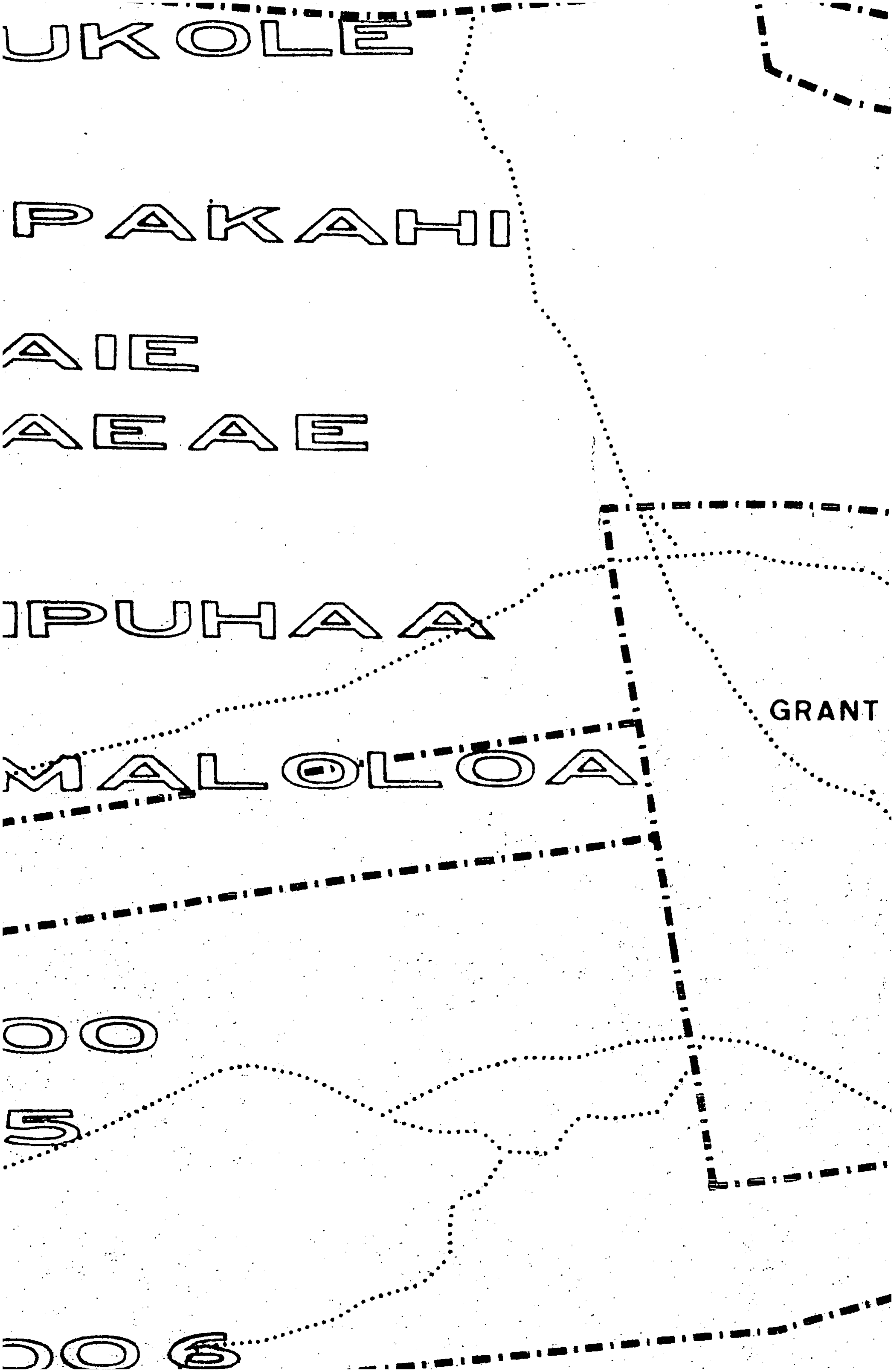
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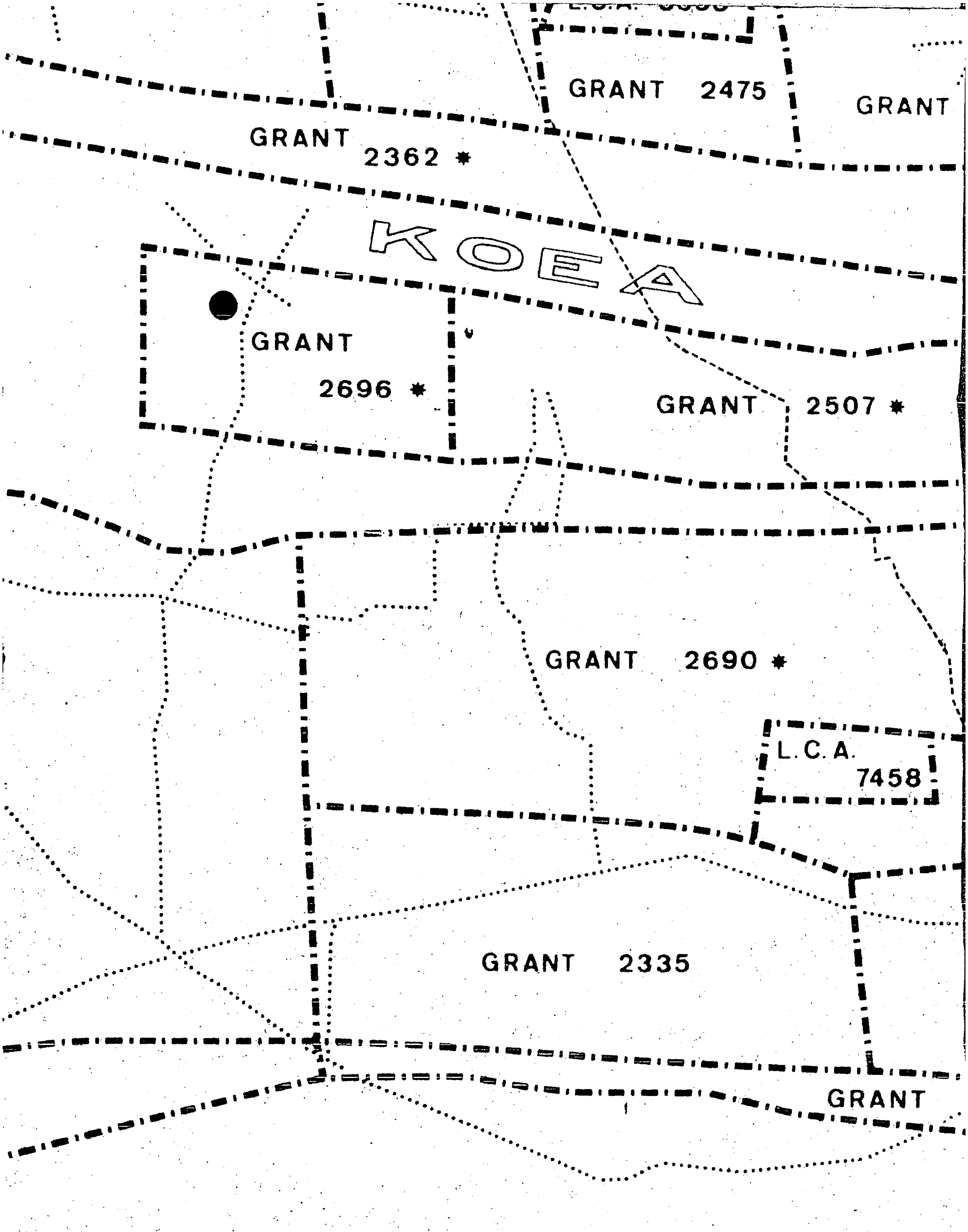
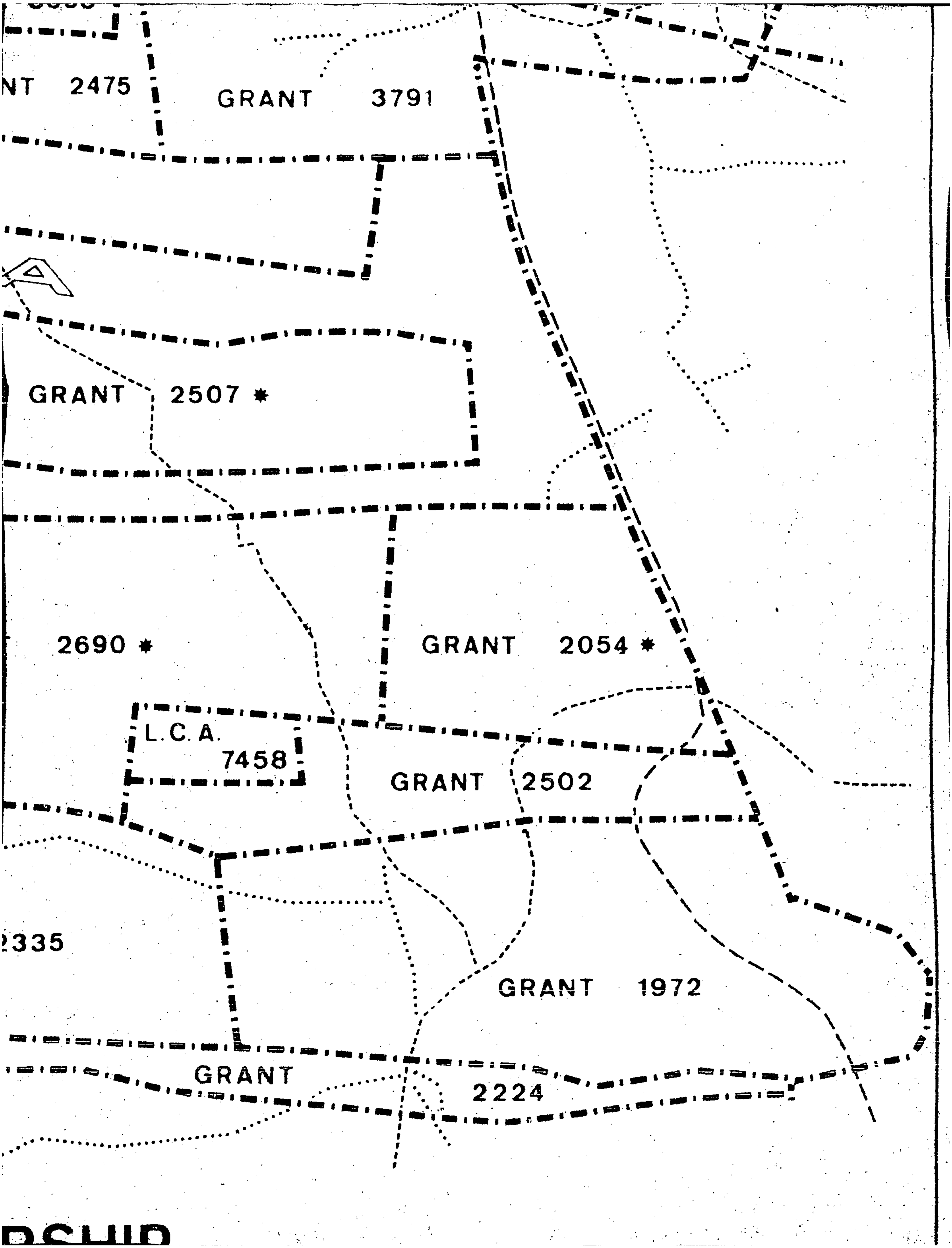


LAND OWNERSHIP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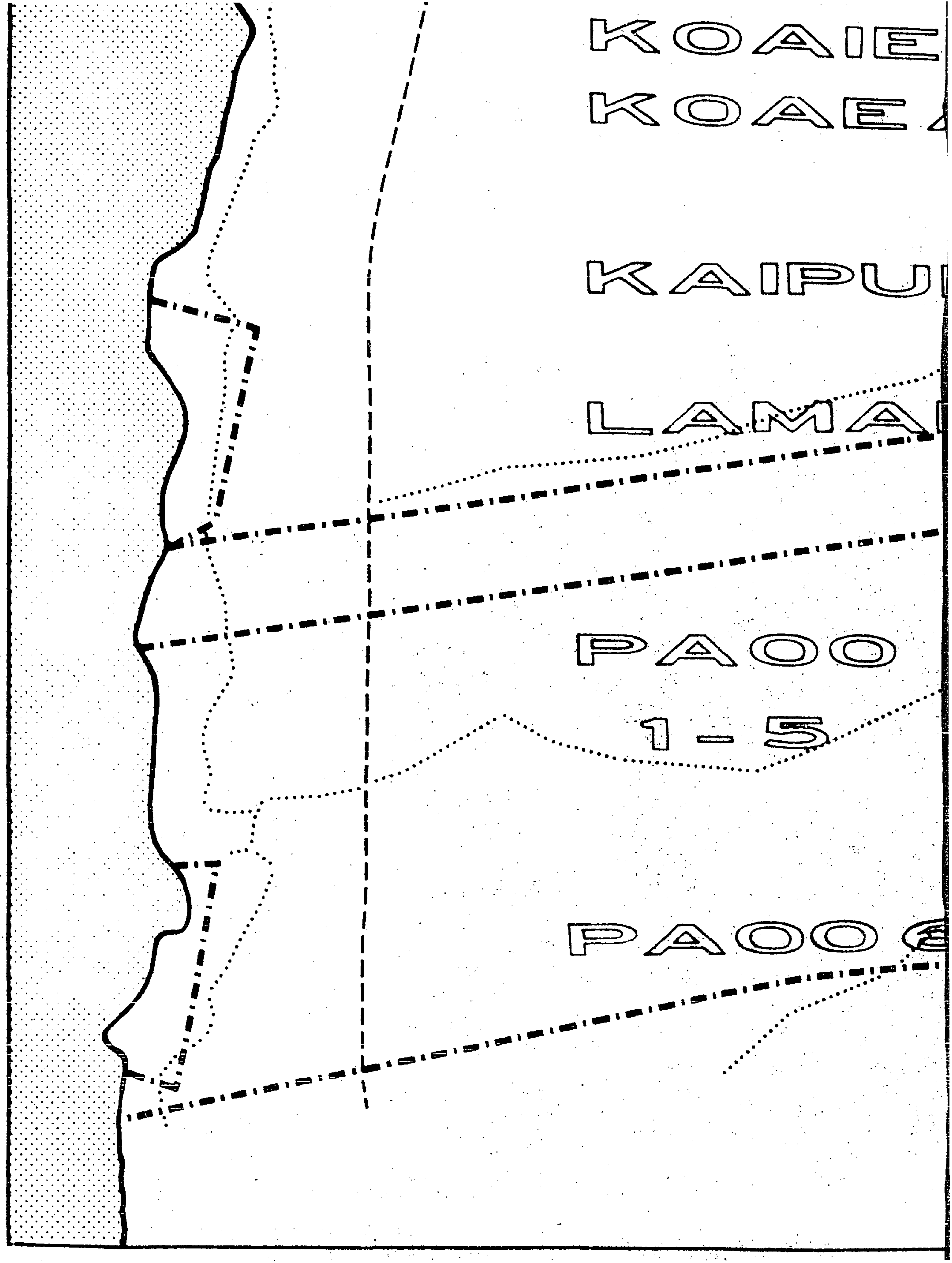
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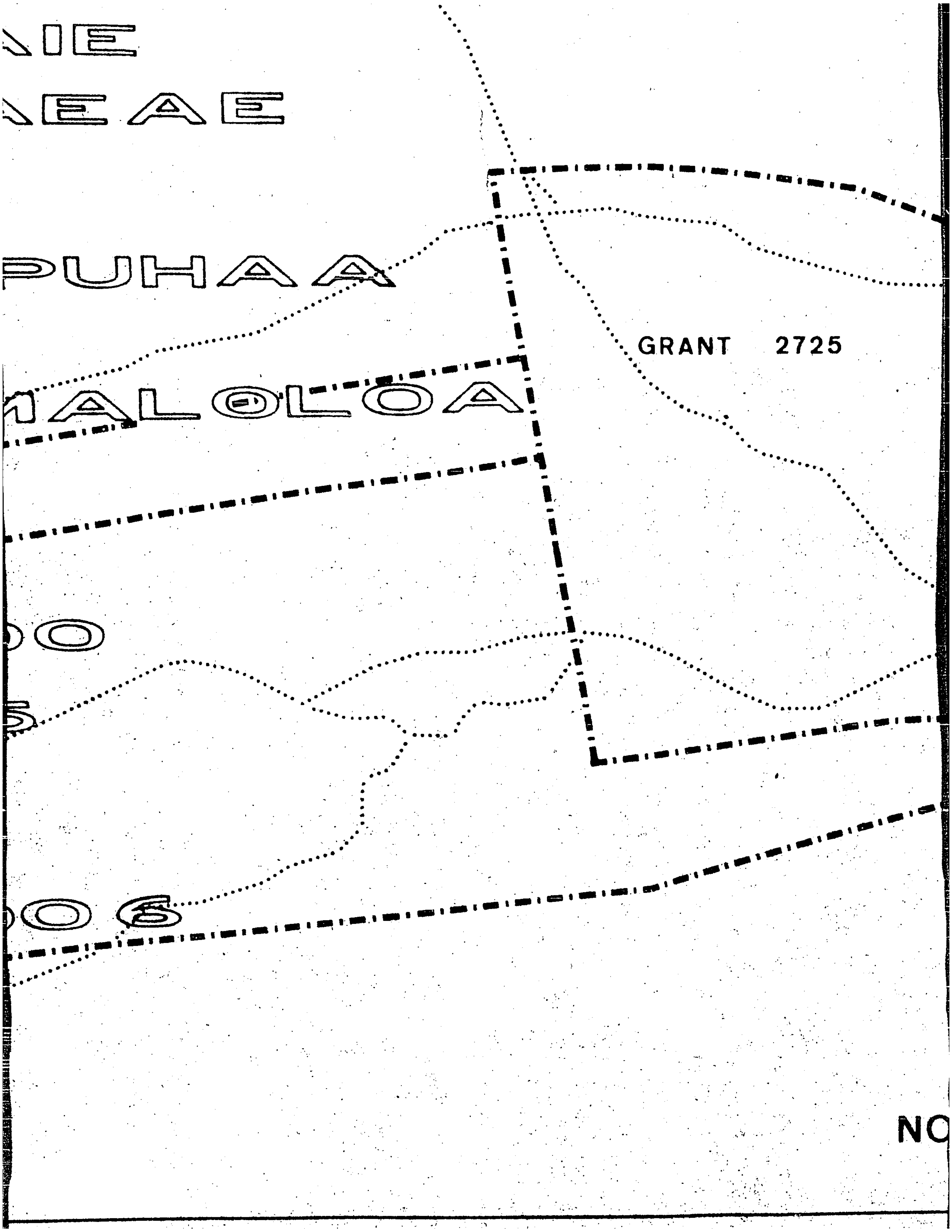
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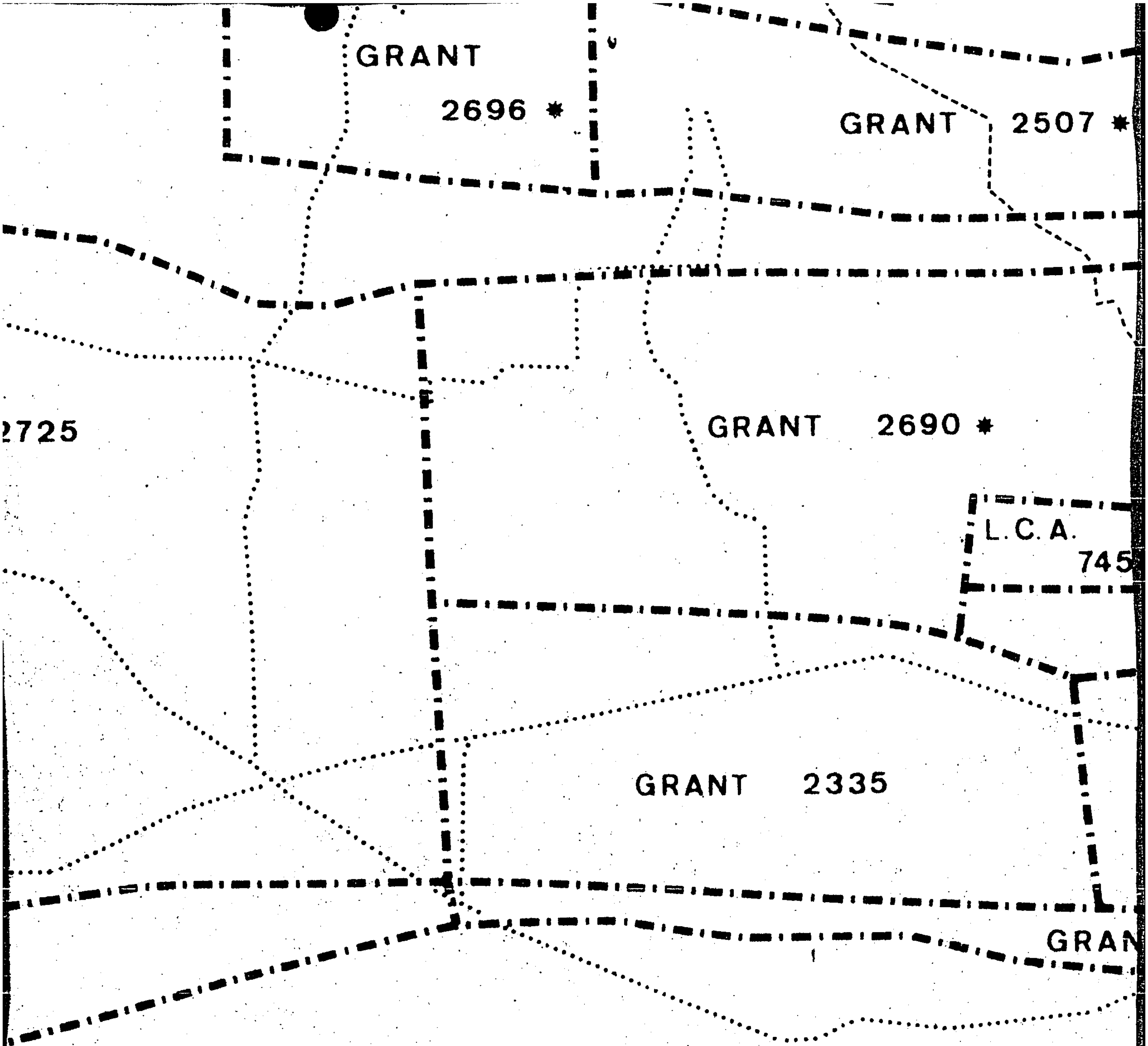
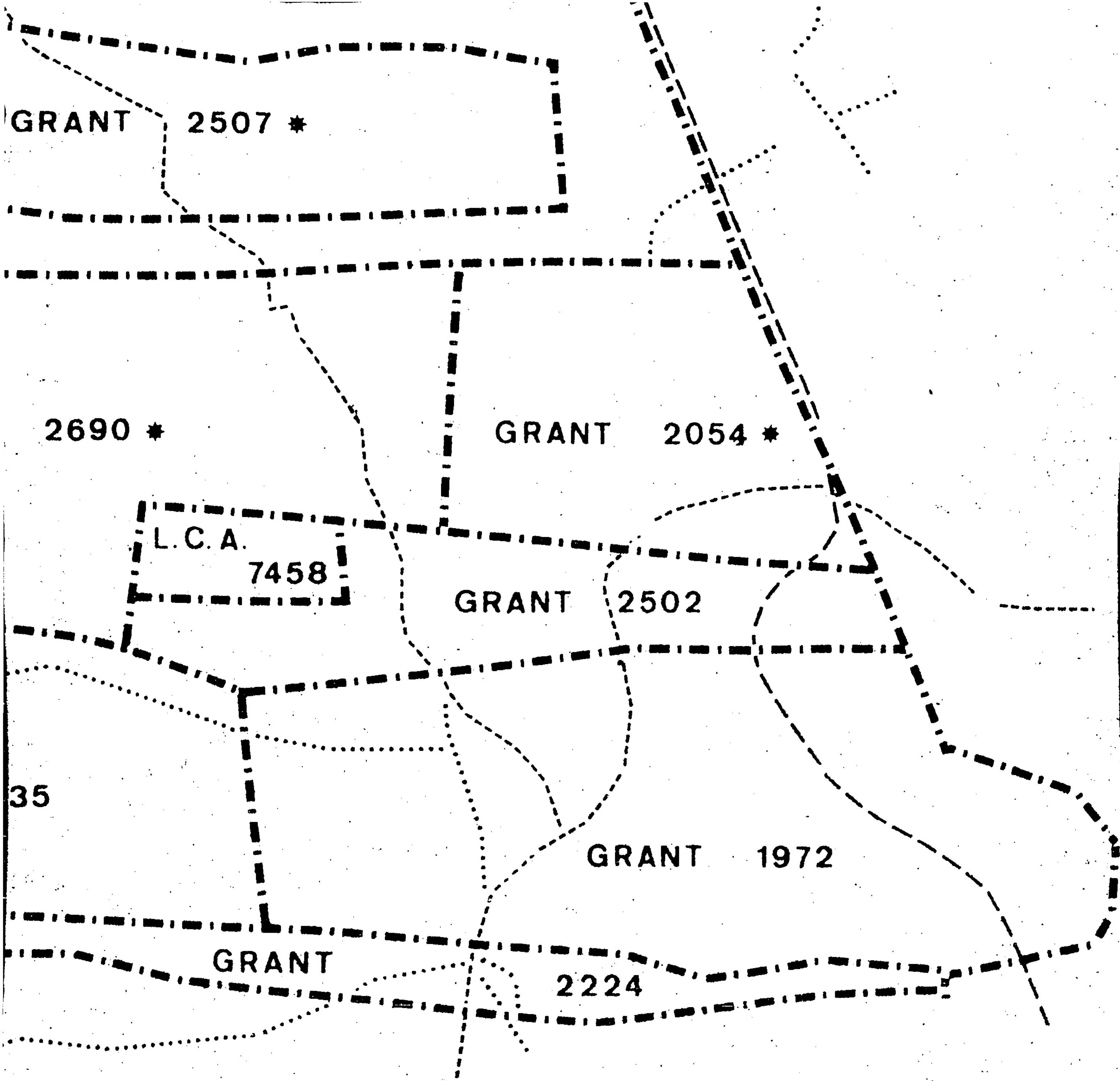


LAND OWNERSHIP

LAPAKAHI GENERAL AREA

NORTH KOHALA, – ISLAND OF HAWA



RSHIP

AREA

OF HAWAII

of the upper Lapakahi area and mentions wiliwili trees; these trees are depicted along the southern border of Grant 2507 toward the eastern end (reports on file at the State Archives) (Map 11). Wiliwili is generally found in dry regions, primarily along leeward sides of the Islands at altitudes from sea level to about 2,000 feet (Neal 1965:458). One may infer the same general dryness for the Lapakahi area since the wiliwili trees demarked in Grant 2507 were at about the 1,700 foot (520 meter) elevation.

This information on wiliwili habitat may be combined with that for pili grass which is found normally in open, dry, and sometimes rocky land (Neal 1965:80) to establish that dry conditions existed at Lapakahi during the nineteenth century. The existence of pili grassland may also indicate periodic burning for pili grass may be a pyrophytic, or fire-adapted plant (cf. Egler 1947:399). Its existence in the Lapakahi upland area may indicate periodic re-clearing by fire within the field system. The abandonment of exhausted fields to fallow for a number of years would probably have resulted in short-term grassland climax successions, explaining the pili grass distribution and prevalence in the area. It is reasonable to think that a pili grass succession was present on all fallow fields and in surrounding, un-cultivated dry areas throughout the time the field system was in use.

There is no direct evidence about forest distribution or history in the Lapakahi area but a reasonable suggestion would be that forests extended down to approximately the 1850 foot (550 meter) elevation. This is based on the general lack of discernible field boundaries above this elevation, although a few are present. No forest exists in Lapakahi today, however, and this may be due to cattle grazing, clearing for sugar cane, or other historic shifts in land use.

Whether or not deforestation occurred in historic times at Lapakahi, it is definite that historic shifts in succession and distribution of Hawaiian flora generally eliminated or reduced forested areas, causing whole series of changes in the Hawaiian land ecosystem. Some of these changes may be suggested on the basis of general studies on the effects of deforestation.

Effects of Deforestation

The most obvious change which occurs with deforestation, or forest reduction, is a shift in plant community constitution as new floral successions begin. A reduction of forest cover increases the amount of solar radiation reaching the soil; soil moisture is lowered (Thornthwaite 1956: 578; Albrecht 1956:651); soil chemistry is altered (Raikes 1967:77; Bartlett 1956:697); soil structure collapses (Blaut 1960:194); soil permeability is reduced, resulting in less retention of surface water, faster run-off, and a lower water table (Sears 1956:478-479; Raikes 1967:68). Topsoil is then carried off by sheet or gully erosion (Leopold 1956:639; Strahler 1956:623). This topsoil loss results in lowered nutritive levels of the soil and reduces the carrying capacity for the land (Albrecht 1956:672).

Micro-climatic Changes

Changes in micro-climatic conditions are also caused by deforestation, which increases wind velocity by removing surface friction and the superstructure that kept the winds aloft. Increased wind velocities decrease soil and atmosperic moisture, especially when coupled with increased surface temperatures resulting from greater solar penetration. The elimination of trees decreases the amount of moisture returned to the atmosphere through plant respiration; often a very substantial amount of water (Mangenot 1963:119). The direct interception of atmospheric moisture by trees is well documented in Hawaii (Ekern 1964) and this water source would be lost by deforestation. The role of Hawaiian vegetation and micro-climatic conditions is discussed by Egler as follows:

> Hosaka . . . writes that he has often observed the rain clouds sweep over the Koolau range at Waipio, disappearing at the native forest edge, except where they continue in a mile-long tongue out over the Eucalyptus plantations. In conclusion, it may be said that no meterologic data exist in Hawaii to indicate any influence of the vegetation on climate. In the opinion of the writer, however, and as indicated by Hosaka's observations, the influence of the vegetation on the absorption and retention of radiant energy, together with the influence of

> transpiration on the moisture content and temperature combine to determine whether or not oncoming currents of air will or will not lose the moisture which they bear. . . . Historic evidence of springs and of Hawaiian villages in areas now arid imply strongly that desiccation has occurred in the past . . . (1947:402).

These documented historic changes in the Hawaiian land ecosystem make imperative the same careful approach to the analysis of Hawaiian farming as was necessary with Hawaiian maritime exploitation. This is further necessitated by historic changes in traditional Hawaiian culture and population decimation in the face of increased European contact which resulted in agricultural technique and land utilization shifts.

The Approach

This section first establishes an historically documented body of information on Hawaiian demography and land utilization, then correlates these data with environmental factors to provide a synthesis of man-nature relationships at a known point in time. These syntheses are then correlated with recent archaeological work on Hawaiian farming.

The historical literature reveals that most of the changes listed above occurred after A.D. 1825. Traditional techniques were still in use after this time, but many formerly exploited geographical areas were abandoned while others received increased immigration. Techniques and crops increasingly changed to meet new cultural and environmental situations after 1825. For these reasons, it was decided to orient the historical analysis to the years 1778 to 1825.

A recurring theme in the literature of this period is one of regional and inter-island diversity in agricultural techniques, crops, and types of cultivated land; so this analysis concentrates on Hawaii Island to develop composite pictures of land exploitation. Additional work must be done with other islands to detect differences in cropping techniques, and types of lands utilized before a general summary of Hawaiian agriculture may be generated; this is beyond the scope of this paper.

Hawaii Island: 1823

The diary of Reverend William Ellis provides the best information source for Hawaii Island in 1823 (Ellis 1963). Ellis recorded observations during his two month trip around Hawaii Island--the first European to travel around one of the Hawaiian Islands other than by ship. Although replete with missionary-oriented interpretations and moralizing on social conditions, Ellis was highly objective in the sort of information needed in this study. His journal records detailed descriptions of native flora, crops, soils, climate, agricultural techniques, demography and settlement patterns.

The Route of Ellis

The route Ellis and his companions took in their journey around the island was reconstructed through the use of his journal, detailed modern maps, aerial photographs, and personal familiarity with Hawaii Island geography (Map 12). In a few cases, sufficient descriptive material was available to precisely reconstruct the route, but usually all that is known from the journal is that Ellis left one point and later arrived at another. In these instances the precise route cannot be reconstructed because Ellis may have followed land contours instead of a straight line--although such a straight line would approximate his path. The distances involved are generally short and along the coast, so that a major deviation from a straight line between two points is unlikely. It seems reasonable that the reconstructed straight-line route has a maximum error of about one-half mile (.8 kilometers). This paper, then, assumes Ellis travelled somewhere within a corridor about one mile wide on a straight-line between each pair of points.

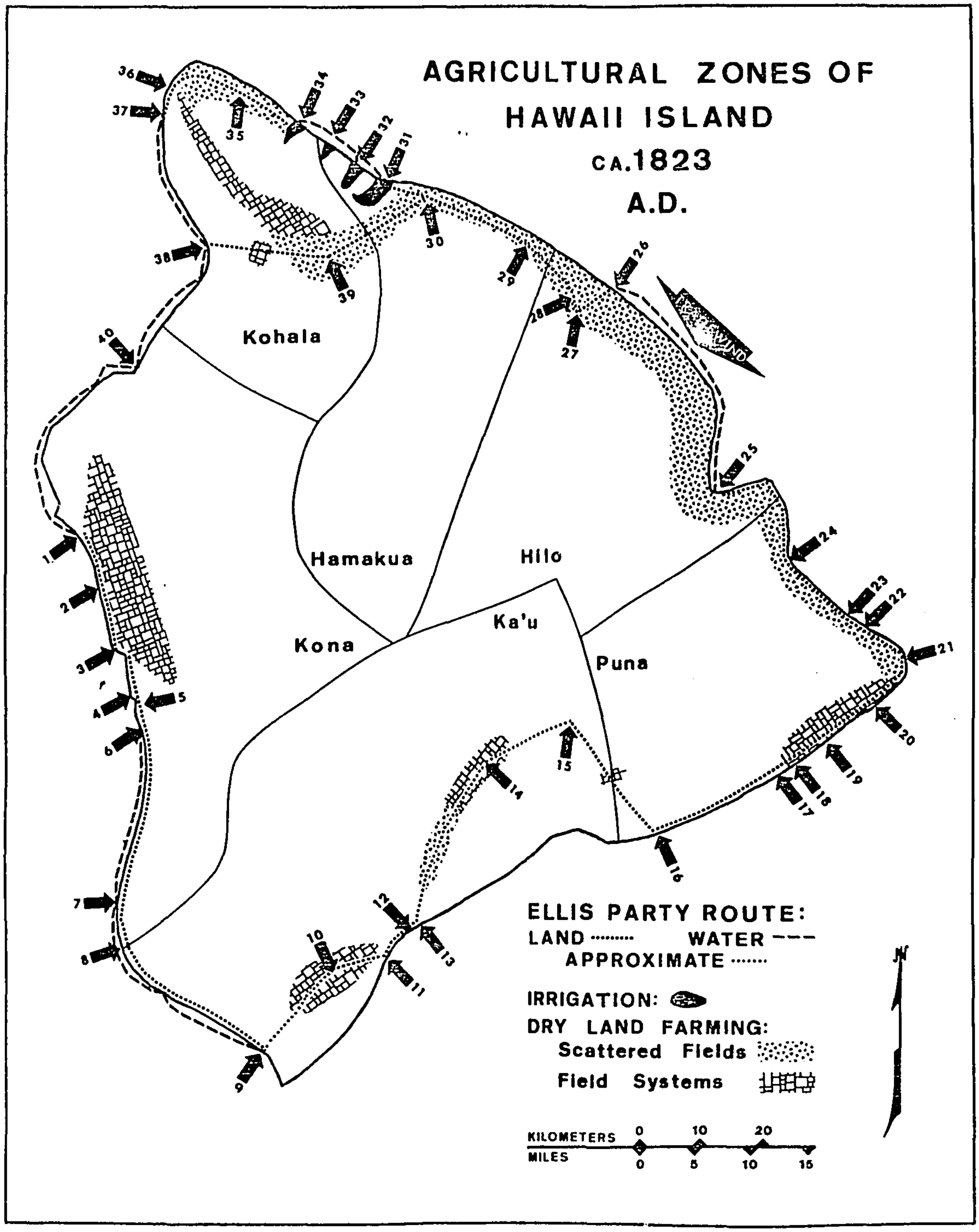
Spatial Limits of the Agricultural Areas

Spatial boundaries for the agricultural areas noted by Ellis were difficult to construct because Ellis did not always provide enough geographical information to draw inclusive boundaries. When Ellis described fields near Kailua, for example, it is not clear whether the fields were only

MAP 12

ELLIS PARTY ROUTE

1. Kailua
2. Keauhou
3. Kaawaloa
4. Honaunau
5. Keokea
6. Kalahiki
7. Kapua
8. Kaulanamauna
9. Kailikii
10. Waiohinu
11. Honuapo
12. Hilea
13. Punaluu
14. Kapapala
15. Kilauea Volcano
16. Kealakomo
17. Kalapana
18. Kaimu
19. Kamaili
20. Keahialaka
21. Kapoho
22. Kahuwai
23. Honolulu
24. Keaau
25. Waiakea (present city of Hilo)
26. Laupahoehoe
27. Humuula
28. Kaula Valley
29. Manienie
30. Kapulena
31. Waipio Valley
32. Waimanu Valley
33. Honokane
34. Polulu Valley
35. Halawa
36. Awalua
37. Mahukona
38. Kawaihae
39. Waimea (also called Kamuela)
40. Kiholo


AGRICULTURAL ZONES OF
HAWAII ISLAND
CA.1823
A.D.
Kohala
Hamakua
Hilo
Kona
Ka'u
Puna
ELLIS PARTY ROUTE:
LAND
WATER
APPROXIMATE
IRRIGATION:
DRY LAND FARMING:
Scattered Fields
Field Systems
KILOMETERS 0 10 20
MILES 0 5 10 15
N

MAP 12

near Kailua or extended southward to the next point where he again mentions fields.

Another set of information was brought into the study, therefore; information gleaned from aerial photos of potential agricultural areas. It was possible to establish geographical boundaries for native agricultural areas in West Kohala, East Kohala valleys, and along the Kona coast from Kailua to Honaunau. No evidence of other native agricultural areas was visible in the airphotos. All agricultural zones described by Ellis and not located on the airphotos were delimited as precisely as possible through the use of Ellis' comments. The results are illustrated on Map 12.

Correlation of Environmental Characteristics

All references made by Ellis to Hawaiian agriculture, soils, water resources, botany and demography were methodically extracted and correlated with these specific areas along his route (Appendix H). The same modern environmental characteristics were checked for each agricultural area noted by Ellis: soil (series, type, depth, texture, color, parent material, degree of stoniness), drainage, slope, clime, mean annual rainfall, elevation, wind direction and wind velocity. All data were extracted from Baker, et al. (1965) by using the aerial photos in the volume to trace the route of Ellis and to determine the land classifications of each agricultural area described by Ellis. Fifty sets of data about the thirteen environmental variables were produced.

Analytic Problems

Several major problems confront any such analysis. One difficulty is the assumption that traces of aboriginal agricultural areas on aerial photographs will provide a reasonable basis for delimiting agricultural zones seen in 1823 by Ellis. Another problem covered earlier is the imprecision in reconstructing the path of Ellis so that generally his path is known only to have been within a one mile (1.6 kilometer) wide corridor. This corridor width and the size of the hypothetical agricultural zones encompasses a large number of diverse micro-environmental zones. Thus, both the corridor and the agricultural zones may encompass data that would not be included if the exact path of Ellis was known or if the agricultural zones derived from airphoto analysis had been delimited precisely by Ellis himself. The analysis should also take into account the relative frequency of each variable over the route of Ellis, or within the agricultural zones delimited by aerial photos. If Ellis' path carried him through a narrow set of environmental characteristics for one quarter of a mile (.4 kilometers) and then the next mile (1.6 kilometers) was characterized by a different set of variables, then obviously the second set should receive more weight than the first in summarizing agricultural environmental variables.

In practice, however, these problems have not detracted to any great extent from the validity of the study because other historical sources and some archaeological data support the zones proposed here, as will be shorn later. In addition, the general range of variables within the route corridor and the agricultural areas is quite similar. The modern data on environmental characteristics for areas on Hawaii Island are so precise that lands have been classified as unique although they cover only several thousand square feet.

One additional problem, however, presented a formidable obstacle to the logical validity of this study. This major problem is that of applying modern environmental data to observations made almost a century and a half ago, when it has been demonstrated that major environmental changes occurred after European contact in 1778 A.D. As shown earlier, herbivores such as cattle, horses, goats, sheep, and deer were introduced and these caused large scale floristic changes, and in turn affected soil erosion patterns; exotic flora achieved a virtual climax in many areas, causing the displacement of species prevalent at the time of Ellis. Modern cultural demands have changed the water table and surface streams; volcanoes have continued to spew forth streams of lava which have since covered some agricultural areas described by Ellis. Most of these changes occurred after 1823, so it was possible to avoid this problem entirely by eliminating certain environmental variables from consideration. The changes that have occurred since 1823 have been primarily concerned with flora, and to a lesser extent, with soil erosion and water resources. Only the variables which should be virtually the same now as in 1823 were used in this study; considerations of floral distributions, erosion, and ground water have been eliminated from this portion of the analysis.

Environmental Parameters of Hawaii Island Agriculture: 1823

Generalizations were developed about the environmental parameters of Hawaii Island agricultural zones in 1823, through an analysis of data on environmental variables specific to the areas described by Ellis:

Clime: Virtually always humid or sub-humid; generally sub-humid.

Annual Mean Rainfall: 20 to 150 inches (.5 to 4 meters); generally 40 to 80 inches (1 to 2 meters).

Elevation: Sea level to 2,500 feet (750 meters); Windward (eastern) zones vary generally from 200 to 1,000 feet (60 to 300 meters); Leeward (western) zones generally vary from 1,000 to 2,500 feet (300 to 750 meters).

Slope: 0 to 35 percent; usually from 0 to 20 percent.

Drainage: Almost all lands are well drained.

Soil Parent Material: Almost always volcanic ash.

Soil Type: Generally alluvial, reddish brown, humic latosol or hydrol humic latosol, although reddish prarie and lithosol may have been included.

These agricultural lands lie as a band around the lowland sections of the Island. The interior sections and much of the lowland non-agricultural areas are expanses of barren lava, completely unsuited for agriculture. Although Hawaii Island is the largest of the Hawaiian Islands, it had little land that was well suited for aboriginal agriculture.

These agricultural lands encompass a variety of different sub-types. Differences in agricultural lands and the accompanying cultural practices appear to be closely correlated with differences in the type, duration, amount, and periodicity of moisture. These aspects of moisture are, in turn, controlled by three broad sets of variables: elevation, topography, and geographical location in relation to the prevailing northeastern trade wind (or lowland-upland; valley-tableland; and windward-leeward). Virtually all other ecological factors such as flora, climatology, soils, and topography are a function of these three sets of variables; hence Hawaii Island agriculture was primarily limited by considerations of moisture.

Hawaii Island Agricultural Zones: 1823

These broad variables, the environmental characteristics of each agricultural area, and cultural information derived from Ellis were synthesized into a tentative classification system for ordering the agricultural zones on Hawaii Island in 1823. The initial division is made geographically between valleys and tableland areas, and culturally between irrigated and dryland farming.

Irrigation

1. Location: Eastern Kohala in the Waipio, Waimanu, Honokane, and Pololu valleys (and possibly small areas in the little valleys along the Hamakua coast from Waipio to Hilo).
2. Demography: Greater population density than occurs with other areas but a rather low total population in a clustered settlement pattern.
3. Crops: Irrigated taro; bananas; sugar-cane.
4. Distinctive Agricultural Practice: Irrigation of taro.
5. Physical Setting: Valley topography, windward location, near 0° slope, alluvial soils, 0 to 100 foot (0 to 30 meter) elevation.

Dryland Farming

1. Location: Tableland areas along the lower slopes of Hawaii Island.

2. Demography: Lower population density than in valleys or in major coastal fishing villages; settlement pattern was apparently a generally dispersed arrangement of single family dwelling areas; there was little or no clustering into concentrated villages in the agricultural areas themselves, although such clustering did occur with associated coastal fishing villages.
3. Crops: Unirrigated taro, sweet potatoes, bananas, yams, breadfruit, olonā (a fiber plant), sugar cane, and the paper mulberry.
4. Distinctive Agricultural Practices: Sweet potato and unirrigated taro cropping.
5. Physical Setting: Tableland topography, 100 to 2,500 foot (30 to 762 meter) elevation.

Tableland dry farming areas may be further refined by a division into areas of scattered and somewhat isolated farms, primarily in the windward regions and areas of patterned and contiguous fields making up cohesive systems (generally to leeward).

Scattered Fields

1. Location: Northeast Kohala, Hamakua coast from Waipio to Hilo, the Puna coastal strip from Hilo to Kapoho, sections north of Punaluu, and inland on the Ka'u-Puna district boundary.

2. Demography: Less concentration of population in the agricultural areas than occurred with areas of field systems, and with few fishing villages on the coast (except possibly for parts of the Puna area). The settlement pattern was characterized by scattered fields or gardens with isolated small villages or family habitations.
3. Crops: Same as the general dry land-farming type.
4. Distinctive Agricultural Practices: Scattered fields, gardens and habitations; generally less intensive cultivation of available land. No major field systems occur.
5. Physical Setting: Tableland topography, generally windward location, 100 to 2,500 foot (30 to 750 meter) elevation.

Field Systems

1. Location: West Kohala, an area to the west of Waimea, the Kona coast from Kailua to Honaunau, the Ka'u area to the west and another to the north of Punaluu, and possibly portions of the Puna coast southwest of Kapoho.
2. Demography: Fairly dense population along the coast, particularly in fishing villages associated with inland agricultural field systems. The density was greater in both the coastal villages and the inland agricultural areas than

occurred with the scattered farm area (generally to windward) but probably less dense than in the valleys where irrigated agriculture was practiced.

3. Crops: Same as the general dry land farming category.
4. Distinctive Agricultural Practices: Massive field systems in contradistinction to the scattered fields generally found to windward. The Kohala system, for example, measures about 2 by 13 miles (3.2 to 21 kilometers) while the Kona system measures about 3 by 18 miles (4.8 to 29 kilometers). No remains of the Ka'u and Puna field systems are visible in aerial photography, but were reported by Ellis.
5. Physical Setting: Tableland topography, generally leeward location, 1,000 to 2,500 foot (300 to 750 meter) elevation.

Conclusions

This research provides a general outline of the environmental factors characteristic of Hawaiian agricultural zones for A.D. 1823. An initial classification of Hawaii Island agriculture was developed and the geographical distribution of each agricultural zone is plotted on Map 12. Certain other conclusions of a more general nature may also be drawn from these data:

1. The agricultural zones seem to have been larger and contributed to a greater population in areas of field systems.
2. The particular crops grown in an area were most dependent upon the type of moisture available, its quantity, and periodicity. These factors, in turn, were dependent upon the geographical location of the area in terms of three pairs of variables: windward-leeward location; lowland-upland elevation; and tableland-valley topography.
3. The geographical areas most intensively cultivated in 1823 are not those most intensively cultivated today. Leeward areas with massive field systems were the largest agricultural areas in 1823 but today the West Kohala and Ka'u areas are pasture lands while the Kona system is only partially under coffee cultivation. On the other hand, the leading sugar cane cultivation in the entire state today lies between Waipio Valley and Hilo where only scattered fields were present in 1823. The controlling factor seems to be the ability of modern farming to use machinery and provide the necessary fertilizers to supplement the water-rich but leached windward soils. The Kona system lies in an area that is difficult to cultivate with modern mechanized methods and has been

agriculturally abandoned except for coffee, a non-machine crop.

4. Habitation settlements mentioned in the Ellis account and those known from personal inspection to exist in the agricultural areas were virtually always located on non-agricultural ground. In the West Kohala area, for example, the habitation areas were in places too steep or rocky for good cultivation, while in Waipio Valley, Ellis noted the villages to be scattered along the sides of the valley (1963:256).
5. The impression is given by the general literature on Hawaiian farming that large scale irrigation systems existed over the State and that there was a primary dependence upon irrigated taro. Very few sources even mention non-irrigated farming. However, the most important agricultural areas of Hawaii Island in 1823 were not those that were irrigated, but rather the leeward field systems. Irrigation may have been dominant on the other Islands, but Hawaii Island must be exempted from this generalization.

Kohala: 1825-1833

Additional information on the Kohala area comes from later reports by other missionaries and these must be mentioned since this was the area in which most field work was done for this study.

The Rev. A. Bishop, missionary from Kailua, visited North Kohala in 1825 and recorded:

> Set out at 2:00 A.M. for Kohala in our double canoe. Reached Mahukona at sunrise, twenty miles, commenced our journey on foot. For about four miles in our ascent the country was stony and barren; we then came to a fertile region presenting a very beautiful sloping landscape, upon which grew the taro, banana and sugar cane in abundance. At twelve o'clock arrived at the table land, and caught sight of the ocean on the north side of the island (In Damon 1927:52).

In an 1833 letter to the Board of Commissioners for Foreign Missions, the missionaries located at Waimea, Hawaii Island described Kohala as follows:

> It [Kohala] is one of the largest districts on Hawaii; occupying the N.W. corner of the Island extending 20 miles or more from N to S & not far from the same extent from E to W. The population as enumerated in 1832 was 8,014--many of these live along the western shore where is a good fishing ground, a still greater number along the line of cultivation which commences two or three miles inland. Over all the interior & also the eastern part of the district, the population is more uniformly scattered.
>
> The soil of Kohala is good. In different parts anything can be cultivated, that is cultivated in any part of the Islands such as taro, sweet potatoes, yams, bananas, corn, melons, &c. Sugar cane, bread fruit grows (Answers by the Sandwich Islands Missionaries to the Questions in the Circular of March 15, 1833 sent to Missionaries of the American Board of Commissioners for Foreign Missions; copy in the Hawaii Mission Children's Society Library, dated 1833).

Hawaii Island Agriculture: 1792-1794

Data Source

Archibald Menzies, surgeon and naturalist with Captain George Vancouver, provided excellent descriptions of Hawaii Island agricultural zones for the years 1792-1794 (Menzies 1920). Menzies was able to observe and describe most agricultural areas of Hawaii Island because Vancouver completely circumnavigated the Island in the course of his several voyages. Menzies was the first European to make extensive inland trips, other than a short penetration inland at Kealakakua Bay by members of Captain Cook's crew in 1779. Menzies traveled inland almost to the Waimea plateau above Kawaihae; up Hualalai behind Kailua, up the slopes of Mauna Loa from Kealakekua Bay, and from the vicinity of South Point overland to a point southwest of Kilauea before climbing to the summit of Mauna Loa.

Hawaii Island Agricultural Zones: 1792-1794

The reconstruction of Hawaii Island agriculture for 1823 was found to be fully accurate for 1792-1794 also, with the addition of a small leeward irrigated area and information on the distribution of breadfruit trees.

Irrigated agriculture was noted by Menzies at Ki olu ku village, somewhere on a line between Point 10 and Point 14 on Map 12. This indicates that at least one inland valley on the southern flank of Mauna Loa had sufficient surface water to allow localized leeward irrigation. The agricultural zones shown on Map 12 near Points 10 and 14 were connected as an inland band of rather intensive agriculture. It is most probable that these fields were present in 1823, but that Ellis did not report them because he proceeded from Point 10 to the shoreline at Punaluu and thence to Point 14 (Map 12).

Although Ellis mentioned breadfruit trees, at no time was it possible to include them as a dominant or even important crop. Menzies, however, notes their dominance in the Kona Field System (p. 75) and in the vicinity of Hilo (p. 141), evidently at fairly low altitudes.

The Kona Field System

Menzies provides excellent descriptions of what is here termed the Kona Field System, which extends from inland of Point 1 to Point 4 on Map 12. Menzies made several trips across the Kona Field System from the coast to its upper limits, at both the northern and southern ends.

Northern Portion

Menzies and his party left Kailua (Point 1, Map 12) to ascend Hualalai and he noted:

> We commenced our march with a slow pace, exposed to the scorching heat of the meridian sun, over a dreary barren track of a gradual ascent, consisting of little else than rugged porous lava and volcanic dregs, for about three miles, when we entered the breadfruit plantations whose spreading trees with beautiful foliage were scattered about that distance from the shore along the side of the mountain as far as we could

> see on both sides. Here the country began to assume a pleasant and fertile appearance, through which we continued our ascent for about two miles further, surrounded by plantations of the esculent roots and vegetables of the country, industriously cultivated, till we came to the uppermost village consisting of a few scattered huts . . . (p. 154).

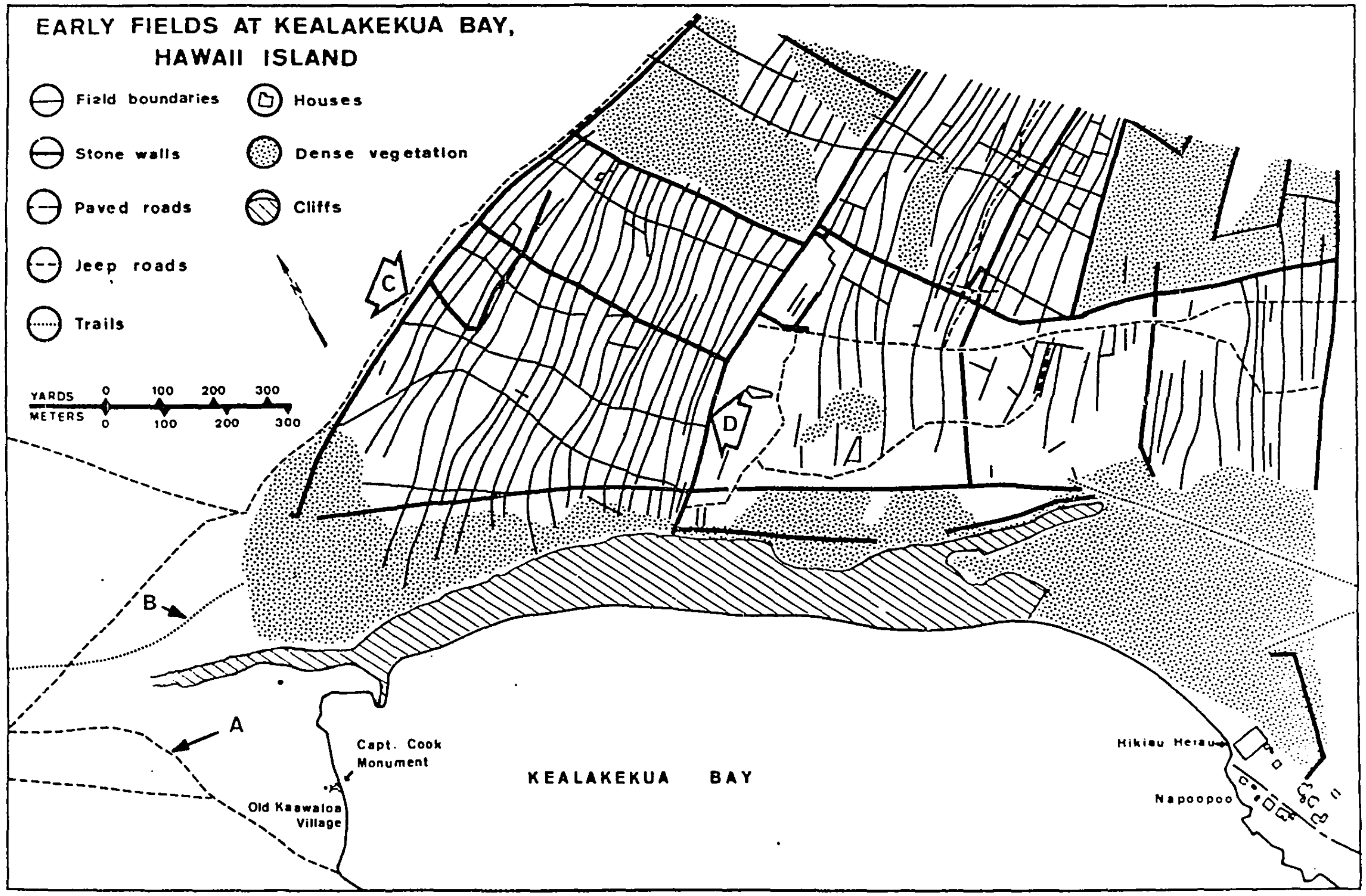
After reaching the summit of Hualalai, Menzies and his group angled south directly toward Kaawaloa, Kealakekua Bay (Point 3, Map 12) instead of returning to Kailua. Descending out of the forest, he noted:

> . . . we found the lower edge of it [the forest] as in other places, adorned with rich plantations of plantains and bananas (p. 167).

Southern Portion

The most extensive description of the Kona Field System comes from a similar trip by Menzies at Kealakekua Bay. After leaving Kaawaloa (Point 3, Map 12; Map 13), Menzies observed:

> The forenoon was far spent in arranging and equipping the party before we left the village [Kaawaloa], and as our route lay directly back from it, over a dry barren rocky country, up a steep ascent, in the scorching heat of the day, the first part of our journey was rather fatiguing, before we gained the summit of the eminence over the bay, where we met a refreshing breeze, and had an extensive prospect of the country and villages to the southward of us. The tract which extended along shore, if we might judge from its appearance and our knowledge of that which we had already traveled over, we were ready to pronounce a dreary naked barren waste, if we except a few groves of cocoa palms here and there near the villages. But that which stretched higher up along the verge of the woods from the manner it was industriously laid out in little fields exhibited a more pleasing and fertile appearance.
>
> On leaving this station, we soon lost sight of the vessels, and entered their bread-fruit plantations,


EARLY FIELDS AT KEALAKEKUA BAY,
HAWAII ISLAND
Field boundaries
Houses
Stone walls
Dense vegetation
Paved roads
Cliffs
Jeep roads
Trails
YARDS 0 100 200 300
METERS 0 100 200 300
C
D
B
A
Capt. Cook Monument
Old Kaawaloa Village
KEALAKEKUA BAY
Hikiau Heiau
Napoopoo

MAP 13

the trees of which were a good distance apart, so as to give room to their boughs to spread out vigorously on all sides, which was not the case in the crowded groves of Tahiti, where we found them always planted on the low plains along the sea side. But here the size of the trees, the luxuriancy of their crop and foliage, sufficiently show that they thrive equally well on an elevated situation. The space between these trees did not lay idle. It was chiefly planted with sweet potatoes and rows of cloth plant [wauke]. As we advanced beyond the bread-fruit plantations, the country became more and more fertile, being in a high state of cultivation. For several miles round us there was not a spot that would admit of it but what was with great labor and industry cleared of the loose stones and planted with esculent roots or some useful vegetables or other. In clearing the ground, the stones are heaped up in ridges between the little fields and planted on each side, either with a row of sugar cane or the sweet root of these islands (Dracena ferrea, Linn) [ti] where they afterwards continue to grow in a wild state, so that even these stony, uncultivated banks are by this means made useful to the proprietors, as well as ornamental to the fields they intersect.

The produce of these plantations, besides the above mentioned, are the cloth plant (morus papyriferus, Linn.) [wauke], taro, and sweet potatoes. The latter are here planted three or four feet apart and earthed up around their stems much in the same manner as the common potatoes are treated in England. When they dig up any, we remarked that, after stripping off the potatoes, they carefully put the old plant back again in the ground for the ensuing crop. But the taro, being naturally an aquatic plant, required in this dry soil a very different treatment. There were generally two or three of them planted together in a hole about nine inches below the surface of the ground. These holes were about four feet apart, and as the plants grew up, the earth is gathered round their stems in the form of a basin to retain the water, either from rain or otherwise, about their roots. The whole field is generally covered with a thick layer of hay, made from long, coarse grass or the tops of sugar cane, which continually preserves a certain degree of moisture in the soil that would otherwise be parched up by the scorching heat of the solar rays. In this way they rear up these roots to very great perfection even on a dry elevated situation.

> The land here is divided into plantations, called ili, which take their rise at the sea side and proceed up the country, preserving a certain breadth without any limitations, or as far as the owner chooses to cultivate them, and without the protection either of high walls or gates. (p. 77)

> After breakfast, we pursued our course onward with a fair prospect of a fine day and soon after entered the wood by a well trodden path, on both sides of which were luxuriant groves of plantains and bananas reared up with great industry in the neatest order of cultivation. These being tender vegetables, required a sheltered situation and good soil to bring them to perfection. (p. 80)

Menzies continued inland above the field system and returned to the coast at Honanunau (Point 4, Map 12), just south of Kealakekua Bay.

Menzies' Route

Menzies must have left Kaawaloa in a northerly direction, approximately along the route of the modern "jeep trail" shown at Point A on Map 13. This would have been necessary because the cliff behind Kaawaloa is quite steep and would have been scaled only with difficulty. Slightly north, however, the cliff becomes lower and much less difficult to climb; in fact, an old Hawaiian trail (Point B on Map 13) was located during a survey in 1968 (Soehren and Newman 1968). This trail leads up the cliff from Kaawaloa and then angles eastward into the field system; it is likely that Menzies followed this trail. Menzies' description eliminates the entire area shown on Map 13 north of the fields because this area is entirely barren lava. Furthermore, his observations indicate that he most likely travelled northeast in the fields somewhere between Points C and D on Map 13. The entire field area shown on the map was probably the area of breadfruit, sweet potatoes, and wauke described by Menzies.

Modern land data from Baker, et al. (1965) show a major change in land type at about the top of Map 13 and this probably also marked the end of the breadfruit trees.

Continuing inland, or to the northeast and off Map 13, Menzies would have passed just north of the location of the present town of Captain Cook. He continued his north-easterly direction and apparently exited the field system at approximately 2,500 feet (750 meters) in elevation, although the plantains and bananas may have been somewhat higher.

Kona Field System Sub-zones

The route of Menzies was first plotted, his observations matched to specific land areas, and the observations and the areas were analyzed according to modern environmental data to determine the characteristics controlling the agriculture. Again, the data from Baker, et al. (1965) were used and the route of Menzies was traced on the airphotos in the volume. The following sub-zones for the Kona Field System were developed:

Breadfruit/Sweet Potato/Wauke Zone

Elevation: 500 to 1,000 feet (150 to 300 meters)

Rainfall: 30 to 60 inches (.8 to 1.5 meters)

Crops: breadfruit trees with sweet potatoes and wauke planted between them.

All fields shown on Map 13 are in this sub-zone.

<u>Sweet Potato/Dry Land Taro Zone</u>

Elevation: 1,000 to 2,500 feet (300 to 750 meters)

Rainfall: 60 to 80 inches (1.5 to 2.0 meters)

Crops: no breadfruit trees; sweet potatoes in the lower part, dry land taro in the upper part. Field boundaries planted with ti and sugar cane.

<u>Plantains and Banana Zone</u>

Elevation: 2,000 to 3,000 feet (600 to 900 meters)

Rainfall: 80 to 100 inches (2.0 to 2.5 meters)

Crops: bananas and plantains planted just below and within the climax rain forest.

The soil is classed as "smeary" and dries irreversibly; clouds commonly hang low to the ground and the area is in what is often termed the "fog belt."

Discussion

This classification divides the Kona Field System into three sub-zones on the basis of crop type. All environmental variables are relatively constant for the sub-zones except those of elevation and rainfall, demonstrating the regulating effect of these two variables on agriculture in the Kona Field System. These divisions are not to be construed as clear-cut but rather show a gradual change from one sub-zone to the next, correlated with steady increases in elevation and rainfall.

Kona Field System Sub-zones:
Classification by J. Holland

Jerald Holland, a geographer with the University of Hawaii, has proposed a system of four sub-zones for the Kona area, based upon historic accounts prior to 1825:

Coastal Zone (Ko Kaha Kai)

Elevation: Sea level to 750 feet (0 to 225 meters)

Rainfall: Below the 50 inch (1.2 meter) isohyet

Crops: small gardens of sweet potatoes and coconut trees.

In general the area was hot, dry, and generally barren of vegetation. Holland regards this zone as agriculturally insignificant and primarily the "living zone" (Holland 1969:8-10).

Seaward Slope (Ko Kula Kai)

Elevation: 750 to 1,800 feet (225 to 550 meters)

Rainfall: Above the 50 inch (1.2 meter) isohyet

Crops: Predominantly breadfruit (Holland 1969: 10-11).

Upland Slope (Ko Kula Uka)

Elevation: 1,000 to 2,500 feet (300 to 750 meters)

Rainfall: Not stated

Crops: Sweet potatoes, taro, wauke; breadfruit not present

This zone overlaps the Seaward Slope area in places and was the most extensive agricultural sub-zone of the Kona Field System (Holland 1969:12-13).

Upland Jungle (Wao)

Elevation: 2,500 to 4,000 feet (750 to 1,200 meters)

Rainfall: Approximately 100 inches (2.5 meters)

Crops: Plantains and bananas only (Holland 1969: 13-14).

Discussion

The differences between this analysis and that of Holland concern the elevation and rainfall limits of the sub-zones. Both, however, illustrate the basic division between a lower elevation, drier area with breadfruit trees, sweet potatoes, and wauke; a middle zone of sweet potatoes and taro with fields bounded by planted sugar cane and ti; and an upper area where bananas and plantains were grown. The differences between the two classification systems are minor because the Kona Field System gradated from one sub-zone to the next without truly sharp divisions.

The Kohala Field System

Menzies also was the first European to report the field system spread across the upland region of West Kohala:

> From the north-west point of the island [Upolu Point], the country stretches back for a considerable distance with a very gradual ascent, and is destitute of trees or bushes of any kind. But it bears every appearance

> of industrious cultivation by the number of small fields into which it is laid out, and if we might judge by the vast number of houses we saw along the shore, it is by far the most populous part we had yet seen of the island (Menzies 1920:52).

This reference is especially interesting in that it substantiates the reconstruction of nineteenth century floral cover in the Lapakahi area made earlier in this chapter. Furthermore, the reference to numerous houses along the coast provides settlement pattern data for 1793, well before any known changes began in the Kohala area owing to European contact. Finally the reference to population size indicates a sizable population in the Kohala area, as would be expected from the extent of the field system although the population decreased dramatically in the nineteenth century.

Summary

The reconstruction of Hawaii Island agriculture for 1823 was found to also accurately reflect agriculture back to 1792-1794. Indications of small scale and localized irrigation in a valley on the southern slope of Mauna Loa came from Menzies. The first historic data on agriculture, settlement patterns and demography for West Kohala were recorded by Menzies in 1793. The importance of breadfruit as an agricultural crop came out clearly from Menzies. As well as authenticating the broad picture of Hawaiian agriculture present in 1823 as being also present in 1792-1794, it was possible to make a detailed analysis of the Kona Field System.

Hawaii Island Agriculture: 1779

The picture of Hawaii Island agriculture derived from an analysis of journals kept on Captain Cook's third voyage substantiates the general reconstruction for 1792-1823. The impression is given, however, that more of the windward Hamakua coast was under cultivation than in the later period, and the Kohala Field System noted for 1792-1823 was not observed. Radiocarbon dates from the Lapakahi fields, however, demonstrate a pre-contact date for the Kohala system so this was likely an oversight. These radiocarbon dates will be discussed in the section on archaeological evidence.

Kona Field System: 1779

A party of Cook's crew went inland from the area where the present town of Napoopoo is located (Map 13) and some detail is available to authenticate the nature of the Kona Field System for 1779, the time of contact. Menzies went inland from Kaawaloa on the north side of Kealakekua Bay while the Cook party went inland from a point on the south side of the Bay, and did not climb the bluff as did Menzies. The route of the Cook party is not illustrated on Map 13 beyond the starting place near Napoopoo. A member of the party, Ledyard, described the trip as follows:

> Our course lay eastward and northward from the town . . . about two miles without the town [present Napoopoo] the land was level, and continued of one plain of little enclosures separated from each other by low broad walls: Whether this circumstance denoted separate property, or was done solely to

> dispense with the lava that overspread the face of the country, and of which the walls are composed, I cannot say, but probably it denotes a distinct possession. Some of these fields were planted, and others by their appearance were left fallow: In some we saw the natives collecting the coarse grass that had grown upon it during the time it had lain unimproved, and burning it in detached heaps. Their sweet potatoes are mostly raised here, and indeed are the principal object of their agriculture . . . We saw a few patches of sugar cane interspersed in moist places, which were but small . . . we also passed several groups of plantain-trees.
>
> These enclosed plantations extended about 3 miles from the town, near the back of which they commenced, and were succeeded by what we called the open plantations. Here the land began to rise with a gentle ascent that continued about one mile when it became abruptly steep. These were the plantations that contained the bread-fruit-trees.
>
> After leaving the bread-fruit-forests we continued up the ascent to the distance of a mile and a half further, and found the land thick covered with wild fern. . . . It was now near sun-down, and being upon the skirts of those woods that so remarkably surrounded this island at a uniform distance of 4 and 5 miles from the shore, we concluded to halt . . . (Ledyard 1963:118-120)

Additional detail about the lower agricultural area near the present town of Napoopoo comes from King:

> We fix'd upon a field of sweet potatoes close to the Morai [Hikiau heiau, Map 13] . . . (King 1967:507)

King also described the area immediately behind (northeast) of Napoopoo:

> I was never myself above 3 miles into the body of the Country; for the first 2 1/2 miles it is compos'd of burnt loose stones, & yet almost the whole surface beginning a little at the back of the town [Napoopoo], is made to yield Sweet potatoes & the Cloth plant [wauke]. One then comes to breadfruit trees which flourish amazingly. The ground was very uneven & although there was a

tolerable Soil about the trees, yet there was constant breaks in the land & large bare, burnt rocks; in the bottoms that these made were planted the Sweet Potatoe roots with earth collected about them (King 1967:520-521).

King was not a member of the inland exploring party but summarized their findings:

They travelld 3 or 4 miles & found the Country as above represented, after which were the regular & very extensive plantations. The Plantain trees are mixed amongst the breadfruit trees & did not compose any part of the plantation except some in the Walls: these walls seperate their property & are made of the Stones got on clearing the Ground; but they are hid by the sugar cane being planted on each side, whose leaves or stalk make a beautiful looking edge. The Tarrow or Eddy root [taro] & the sweet Potatoe with a few cloth plants [wauke] are what grow in these cultivated spots.

. . . to the NW a continuation of Villages by the Sea shore & to the left [southeast toward Ka'u] a thick wood, to the right [north toward Kailua] cultivated ground as far as they could see, & a thick wood on their back. The Potatoes and Tarrow are planted 4 feet from each other, the former is cover'd except the tops with about a bushel of light Mould, the latter is left bare to the roots, & the mould surrounding made in the form of a bason, in order to preserve the rain as this root is fond of & requires much humidity, it should be noted that the Tarro of these Islands is the best we have ever tasted (King 1967:521).

King also says of this inland trip:

Before they enter'd the first Wood, they also observ'd Arms or branches stretchg towards the Sea side, in a direction at right Angles to the Main wood, & that these reach within a Mile or two of the beach, these Arms seperated the great Plantations which has been observ'd to be 4 or 5 miles broad, & which are again divided into Small fields by stone hedges. The Soil was good, the Space that seperated these Plantations from the entire Lava, or burnt Cindery surface, which extends two or three miles inland from the beach, is Planted with Breadfruit trees & Plantain; Wild or horse Plantains grow some distance into the first Wood.

> The prevaling productions of the above Plantations is Tarro (Eddy) & which in all other Islands is only plant'd in very wet ground, & where a great part is always covered with water. These can only be water'd from the heavens, the Earth about them is so contriv'd as to retain about their roots whatever moisture falls; they are the best tasted tarrow we have seen. The Sweet Potatoe grows anywhere, a great part of the ground about the Villages yield them (King 1967:608).

Kona Field System Sub-zones: 1779

The data fit nicely with those of Menzies by adding a Sweet Potato/Wauke Zone below the Breadfruit/Sweet Potato/ Wauke Zone. This zone extends from sea level to about 500 feet (0 to 150 meters) with a quite seasonal rainfall of 30 to 50 inches (.8 to 1.2 meters). It is suspected that the only reason this Sweet Potato/Wauke zone was observed in production by Cook's crew is because they arrived in mid-winter--the only time of the year in the Kona area where sufficient rainfall would have been available for crops in this coastal area. Only a fast maturing crop, such as sweet potatoes, could have been raised before the dry summer season set in. The remainder of the zones established on the basis of descriptive materials in Menzies are validated for 1779.

Summary

These data for 1779 are especially important because any agricultural zones or techniques observed at this time of first contact may be assumed to be native Hawaiian techniques. The existence of the Kona Field System and its sub-zones has been validated as present at the time of contact. The general description of Hawaii Island agriculture developed for 1823 and 1792-1794 is seen to have also been valid for 1779. Furthermore, the following were native techniques because of their presence in 1779: field fallowing; field clearing by burning; field mulching by applying cut grass; and construction of rock and earthen field borders planted with ti, sugar cane and plantains.

Historic Summary for Hawaii Island Agriculture: 1779-1823

Agricultural zones for Hawaii Island, environmental parameters, crops, and techniques have been reconstructed for 1779, 1792-1794, and 1823. The general reconstruction for 1823 has been validated back to the time of contact in 1779. A refinement of the Kona Field System into sub-zones has been made for the period of 1779-1794, and was very likely substantially the same up to at least 1823.

Archaeological Evidence for Agriculture: Hawaii Island

It is necessary to limit this discussion to Hawaii Island because inter-island agricultural diversity in crops, areas used, and techniques were evident in the review of historic literature. Reconstructions must be made on an island by island basis.

The archaeological evidence for Hawaii Island agriculture consists of a surface survey of the lower section of the Kealakekua Bay fields, a part of the Kona Field System (Soehren and Newman 1968) and surface surveys and excavations in the Lapakahi area of North Kohala, a section of the Kohala Field System. This limits the correlation of archaeological and historic evidence to that concerning field systems; irrigated and scattered dry land agriculture cannot be handled at this time.

Kealakekua Bay Fields

The survey area is marked by a network of elongated rectangular fields with boundaries highly visible on aerial photography (Map 13). These fields are oriented lengthwise on a northeast to southwest axis and also lie along a sea to mountain axis. The major field boundaries (the long sides) lie perpendicular to the topographic contours and parallel to the terrain slope, while random short cross-boundaries run parallel to the contours. Although the survey area encompassed two different native land tenure units (ahupua'a), there is no discernible change in field symmetry between the two areas. Individual fields vary in size from about 50 feet (15 meters) long and 30 feet (9 meters) wide to some that are over 1,000 feet (300 meters) long and up to 150 feet (45 meters) wide. There is no apparent correlation between field length and width: some long fields are quite wide and others narrow; some short fields also have varied widths. During efforts to compute average field dimensions, it quickly became apparent that there is no such thing as an "average" field. The dimensions vary so widely as to make this a useless exercise in quantification. Rather, the field dimensions appear to be related to topography. A field may widen to take in a feature such as an outcropping--or it may narrow to go around one. Certain fields continue practically throughout the entire survey area while others may end with a short cross-boundary and not resume on the other side.

The system was inspected on the ground after the air-photo interpretation. The field boundaries were difficult to see and it was virtually impossible to detect patterning on the ground, although both are readily visible in the aerial photography. The field boundaries which formed the symmetrical patterning in the aerial views were found to be earthen mounds and low stone walls. Some walls are well constructed of stacked stone while others are merely piles of rock lining the field borders. These walls vary in height from about 2 to 4 feet (.6 to 1.2 meters). The earthen mounds vary from about 1 to 3 feet (.3 to .9 meters) in height and are quite rounded. The width of these field boundaries ranges from about 3 feet (1 meter) for well constructed stone walls to about 8 feet (2.5 meters) for the rounded earthen mounds.

There was no evidence of irrigation as shown by traces of water diversion or by terracing; the mounds and walls were for rainfall retention, boundary markers and depositories for field rocks. In addition, the upslope orientation of the fields rules against their use for holding surface water, indicating that water was limited to rainfall as noted by Menzies.

The general symmetry of the Kealakekua fields, and of the whole Kona Field System, is well designed to take advantage of the Kona environment. The orientation maximizes the available sunlight and exposure to periodic rainshowers. The alignment would have made the crops susceptible to high velocity trade winds but for the protection of Mauna Loa. Summer on-shore winds are generally light so physical damage or excessive plant evapo-transpiration would not have been a crucial factor in field alignment.

Correlation With the Historic Evidence

It is quite apparent that the area on Map 13 is that described by Menzies during his inland trip as being covered with breadfruit trees, interspersed with sweet potatoes and wauke. It is not clear from the account of Menzies that the raised field boundaries were found in the breadfruit groves, but the archaeological information definitely indicates this since the field boundaries extend almost to the sheer bluff overlooking Kealakekua Bay. These borders were certainly planted with sugar cane, ti, or perhaps plantains, although it was probably too dry for plantains.

Menzies specifically mentions 'ilis as being elongated and bordered fields extending inland from the coast, and Map 13 illustrates these.

The heavier lines for "stone walls" on Map 13 are almost certainly historic property lines and walls to control cattle. A reconstruction of this area for 1779 would delete these walls, leaving the dominant 'ili boundaries running inland from the coast. The short cross boundaries probably delimit particular individual fields within each 'ili and this could explain their seemingly "random" occurrence. On the basis of environmental variables it is probable that the top of Map 13 marks the inland limit of the breadfruit tree distribution. The area between Points "C" and "D" on Map 13 was most likely the agricultural area supporting the settlement at Kaawaloa.

Summary

It was possible to correlate the surface survey information for the fields above Kealakekua Bay with the data from Menzies. The area on Map 13 was most likely the Breadfruit/Sweet Potato/Wauke Zone observed by Menzies. The field borders have been plotted to a lower elevation on the basis of archaeological evidence than was possible with the information from Menzies. The remainder of the Kealakekua Bay fields may still be seen today in airphotos, although they do not show on Map 13.

Kohala Field System: Lapakahi Section

The Kohala Field System (shown on Map 12, points 36 to 39) is the only other field system studied on Hawaii Island. This study was part of the 1968 Lapakahi Project and is based upon aerial photography, ground surveys, and trenching by power machinery in the Lapakahi field area.

Map 4 Construction

The R. M. Towill Corporation of Honolulu, under the s pervision of Mr. Peter Miles, produced the basic photogrammetry for Map 4. Two separate flight paths were flown by the Towill aircraft: one at 6,000 feet (1,800 meters) above terrain to produce photography for map construction, and another flight at 3,000 feet (900 meters) above terrain using color infra-red film to produce airphotos for archaeological interpretation. Archaeological features were marked on enlargements of the higher altitude photos and the Towill Corporation plotted these and geographic features on a base map at a scale of 1:1000. The airphotos were again methodically studied to ensure that all pertinent features had been plotted; if any were missed or were plotted erroneously, changes were made on the base map through the use of proportional dividers. A final reduction was made to the finished Map 4.

This mapping procedure proved highly effective in mapping the general characteristics of the entire Lapakahi area; a task that would have been prohibitive in both time and funds if ground surveys had been attempted. It should be emphasized that this map provides a general overview of an area measuring about 1 by 4 miles (1.6 to 6.4 kilometers) and does not replace small area ground surveys for specialized research. Archaeological features measuring less than about 10 feet (3 meters) across or less than 3 feet (1 meter) high cannot always be seen on these airphotos, even under stereoscopic inspection. This eliminated the plotting of small features on Map 4. Furthermore, the finest printed line on Map 4 represents about 10 feet (3 meters) of ground area; this again prohibited the plotting of small features.

Archaeological features labelled as "burial areas," "stone features," "stone walls," and "trails" on Map 4 were assigned these designations primarily on the basis of airphoto interpretation, although some were field checked. On the other hand, those features labelled "animal pens," "garden areas," "habitation areas," and "water catchments" were assigned these functions on the basis of both airphoto interpretation and field inspection (except for the habitation area shown in Kilometer 94 and the water catchment shown in Kilometer 4 which were based on airphoto analysis only). The "stone features" plotted along the coast in Kilometers 1 and 11 are the result of an intensive coastal site survey conducted under the supervision of Roger Green for the 1969 Lapakahi Project, and did not stem from airphoto analysis because of heavy forest cover.

Map 4 provides a synthesis of both airphoto analysis and field surveys and was quite important in this analysis in that it plots the distribution and nature of the major archaeological features within the entire Lapakahi area, from the inland field system to the coastal fishing habitations.

Lapakahi Field Pattern

The field borders in the Lapakahi area are shown on Map 4 as thin lines usually oriented on an approximate north-south axis. The fields which these borders surround are generally elongated and rectangular with the long sides parallel to the terrain contours and perpendicular to the ground slope (fall line). This orientation places the long sides of the fields parallel to the coastline instead of perpendicular to it as was the case with the Kealakekua Bay fields (Map 13). Interspersed in the network of rectangular fields are a number of rocky areas, usually near the lee summit of small hills and often surrounded by stone walls. Numerous stacked stone wall enclosures are found in the field area, most with dense vegetation inside.

Types of Agricultural Areas:--Airphoto analysis and ground inspections revealed that several types of agricultural features were to be found:

Rectangular Fields: These are the dominant agricultural feature and are highly visible in the airphotos but much less noticeable on the ground. It is this type of agricultural feature that creates the pattern of long narrow fields oriented parallel to the coast and to the general land contour, as discussed above. The field borders are made of earth and piled rocks, varying in height from about 2 to 3 feet (.5 to 1 meter) and in width from 3 to 9 feet (1 to 3 meters). Field borders above about 1200 feet (350 meters) in elevation are generally earthen with few rocks, although this may be the result of clearing operations since this is prime grazing land (actual bulldozed areas are coded on Map 4 with a circled "8"). Below this elevation the borders are usually made of a mixture of rocks and earth, although in some areas only rock borders exist. These borders, rocky or earthen, produce a slight cupping to the field surface, as shown in Appendix F, Figure 7, A and B.

A sub-type of the general rectangular field category is one with numerous rock cairns scattered within the field itself and distinct from the borders. These cairns are 3 to 6 feet (1 to 2 meters) in diameter and about 1 to 2 feet (.25 to .5 meters) in height. This field type is generally found in the more rocky, lower elevation areas. A surface profile of this field type is shown in Appendix F, Figure 7, B. It is most likely that these rock piles served a special agricultural purpose, perhaps to prevent gourds from rotting owing to soil contact. Their symmetry and distribution argue against being the result of clearing rocks from within the field.

<u>Knoll Gardens</u>: These are scattered below the 1,300 foot (400 meter) elevation, generally just below the tops of small knolls on the leeward side. Often these areas are enclosed by stacked stone walls although some without walls were noted in the lower sections of the agricultural area. Knoll gardens are always exceedingly rocky, with boulders up to 3 feet (1 meter) in diameter often covering major portions of the surface and with much exposed basal rock. The boulders are generally symmetrically arranged into rough circles and it appears that sections of naturally fractured basal rock have been removed, in both cases making irregular depressions surrounded by large rock masses. Stone cairns are also scattered throughout many of the knoll gardens.

These are definitely not habitation areas and from the luxuriant modern growth of vegetation would appear to make excellent growing areas. Not only are these garden areas protected from the high 'āpa'apa'a wind by their leeward location on knoll shoulders, but evidently the proximity of basal rock and boulders affects plant growth. This may be the ability of impervious basal rock to hold rainfall at a higher level where plant roots can reach it continuously, as opposed to the porous soil of the main system, or perhaps it is a function of wind protection and the elimination of excessive evapo-transpiration. Another possibility is that the exposed rock masses may absorb heat, creating higher soil temperatures. Soil temperature has proven to be an important variable to commercial sugar cane growers in the North Kohala area (Ed Norum, Kohala Sugar Company, personal communication 1970) and may have also been important in Hawaiian agriculture. To judge from the types of plants growing today, these areas are ideally suited for tall willowly plants with shallow roots, such as bananas and wauke. Points 5 and 14 on Map 4 illustrate this type of area.

Small Enclosures: Small enclosures built of stacked rock occur throughout the area and are of various shapes: round, rectangular, square, or asymmetrical. The walls are generally about 3 feet (1 meter) high and the area enclosed is most often less than 500 square feet (150 square meters). Larger enclosures are present in the area but these appear to have been animal pens or knoll garden walls. The smaller enclosures appear to have been associated with agricultural purposes instead of penning animals because there is more flat facing to the outside of the walls than on the inside; the larger enclosures tend to have the reverse facing. Often the windward walls are higher than those to leeward. Dense vegetation is usually found within these enclosures, demonstrating the effectiveness of the walls either protecting the plants from animal browsing or from wind damage and excessive evapo-transpiration.

Trenches in the Field Area

A series of trenches was excavated in the central portion of the field area near Apaapaa 1 to allow analysis of field profiles. Approximately 800 lineal feet (250 meters) of trench was opened to depths in excess of 3 feet (1 meter) through the use of a diesel backhoe donated by the Kohala Sugar Company. The primary trenches excavated are located as Points 12 and 13 on Map 4. Secondary trenches are marked on Map 4 with the symbol shown in the map legend. Each trench was aligned perpendicular to the field borders and extended until a minimum of two field borders were exposed in cross-section. A thorough analysis of Trench 1 (Point 12 on Map 4) was made by this author and Edwin Murabayashi, a land classification specialist with the Land Study Bureau; only a surface profile was drawn for Trench 2 (Point 13 on Map 4) because the two trenches were quite similar in cross-section. A detailed study of Trench 1 soils is to be found in Murabayashi (1969).

Trench 1:--The Trench 1 profile is shown in Appendix F, Figure 7, A. The archaeological features exposed were scattered charcoal lens, a few bits of bone, several shells, and an apparent cultural disturbance in the upper 1 foot (.3 meter) of the soil.

All bone, shell, and charcoal was located within the disturbed level. The entire length of Trench 1 was hand troweled to define the lower limits of the disturbed layer.

The interface between this layer and the culturally sterile layer below was marked by a sudden soil compaction and a very slight soil color change. Although the interface was irregular the depth below the surface was generally consistent. That this is a cultural level is indicated by the change in compaction as well as the presence of charcoal, bone, and particularly by shells at the interface. The unevenness of the interface could be explained by the use of the Hawaiian digging stick, or 'ō'ō for turning the soil. Radiocarbon dates: A large charcoal sample was taken at the interface just downslope from the field boundary near Point A (Appendix F, Fig. 7, A) and in close association with *Drupa* and *Cypraea* shells. This proximity with shells eliminates the possibility of dating the result of a natural fire from lightning or volcanics. The sample was submitted to Isotopes, Inc. and the date received was 405 ± 95 years B.P. or A.D. 1545 ± 95 at one standard deviation (Sample Number I-4184). This date correlates closely with another sample taken from the bottom of an imu, or steam oven, exposed in a nearby gully. This imu was within the field system and the date processed by Isotopes, Inc. was 305 ± 110 years B.P. or A.D. 1645 ± 110 at one standard deviation (Sample Number I-4054). These two dates provide the first archaeological evidence for a prehistoric field date on Hawaii Island, since both dates are pre-contact even at the upper limit of one standard deviation.

Irrigation

No evidence for irrigated fields was found in the trenching, surface inspection, or airphoto analysis. Rather, it is certain that irrigation was not practiced in the Lapakahi area because of a lack of soil mottling in the exposed trench profiles, the lack of surface water in the area, no features for water channeling, the porosity of the field boundaries, and especially the fact that the field boundaries do not necessarily follow the contour. Although the fields parallel the general terrain contour, in a great many instances specific fields were constructed oriented up and down slope when this differed from that of the general terrain contour.

Reasons for the Field Pattern

Since considerations of irrigation were not factors in the field pattern design, reasons must be sought elsewhere. Murabayashi presents detailed evidence that the field pattern is located in the optimum growing area at Lapakahi (1969). The lower limit of the field zone occurs at the transition from vegetation zone B to vegetation zone A. The upper limit is less clear but the fields appear to have extended into vegetation zone C_2. Murabayashi notes that at the lower limit of the field zone there would have been a 5 to 7 month dry period when farming could not have been consistently successful. Conversely, there would have been a 1 to 3 month dry period for the fields higher in vegetation zone B. Year round farming could take place in vegetation zone C.

Murabayashi suggests a crop of sweet potatoes would mature in 5 months during the winter if planted in the lower portions of the field zone as well as hypothesizing that:

> Over the study area as a whole, the cropping probably shifted uphill and downhill, with the lower areas being used principally during the wettest period, and gradually shifting uphill as the lower areas dried up. Also, it is likely that the short-term crops that could be planted, matured and harvested in the shortest time were planted in the lower areas since these areas dried up sooner. The longer-term crops were probably planted successively uphill where more moisture was available for longer periods (1969:22).

Thus, it is probable that the fields were established where they were primarily because of rainfall, a major determinant for the different vegetation zones.

The role of orographic rainfall in the area has already been covered in Chapter II; this is the major rainfall source for the upper field zone, while low pressure kona storms probably supplied most of the rainfall in the lower sections of the field zone. Soil temperature and sunlight levels may have been important in defining the upper limits of the field zone since temperature decreases with elevation, and cloud cover increases upslope owing to orographic clouds. These factors indicate the reasons why the Hawaiians located their field system where they did, but do not explain why the fields are oriented on a general north-south axis.

The 'Āpa'apa'a Wind:--The overall orientation of the fields along a north-south axis appears correlated with the high velocity trade wind sweeping down slope from the Kohala summit for the long sides of the fields are perpendicular to the wind. This wind, called 'āpa'apa'a, has been strong enough to cause tree deformation and to have affected floral distribution. Trees in the agricultural area are generally lopsided to leeward, both by trunk inclination and top shape. Dense groves of trees and brush occur only in protected areas such as gullies, inside abandoned enclosures, or in the Knoll Gardens. Otherwise there is no vegetation in the exposed areas except grasses, low shrubs, and an occasional kiawe tree. Some eucalyptus trees have been planted along the dirt road that angles across the Lapakahi area in Kilometer 96 but none grow in the main portion of the agricultural zone.

It is probable that the long field borders were planted with high vegetation, such as sugar cane and ti, that acted as a windbreak for crops planted in the fields. This is consistent with what Menzies observed at Kealakekua Bay where sugar cane and ti were planted along the field borders. Such plantings along the Lapakahi field borders would have produced a series of floral windbreaks at about 30 to 60 foot (10 to 20 meters) intervals, perpendicular to the 'āpa'apa'a wind. The surface wind would be effectively pushed aloft to roughly the level of the floral windbreaks with only lower velocity burbles or vortices sweeping to the ground between the windbreaks. The elimination of the high velocity trade wind at the crop level would stop physical wind damage to plants, decrease plant evapotranspiration, raise the soil temperature, and decrease soil drying. No empirical evidence exists to support this hypothesis other than the correlation of field alignment perpendicular to the wind. However, it is significant that very slight variations in field alignment noted during ground surveys were correlated with micro-changes in wind direction owing to local terrain features.

Although there has been a reported shift in trade wind direction within the twentieth century, the shift appears cyclical within an azimuth from northeast to east (Wentworth 1949). Such variation in trade wind direction would be insufficient to degrade the windbreak effectiveness.

Moisture Collection by the Windbreaks:--The windbreaks would have also acted to collect moisture from the blowing rainshowers that periodically sweep down from the summit area. This phenomenon has been studied in Hawaii for forested areas and significantly increases the moisture near areas of high vegetation (Ekern 1964).

Plantings of sugar cane perpendicular to the trade wind along field boundaries were observed at Waimea (Point 39 on Map 12). David Fullaway, Forester with the Hawaii State Tree Nursery near these fields, was asked why the cane was planted in this fashion. After some research with the local farmers in the Waimea area, Mr. Fullaway wrote that the sugar cane was definitely used as a windbreak and was selected because of its rapid rate of growth and strong resistance to the wind. However, he indicated that moisture collection from fog might not be an adequate explanation for the existence of cane rows because windbreaks in the Waimea area do not collect as much water as the cane transpires (Fullaway, Personal Communication, 1969). However, conditions at Lapakahi are slightly different from the Waimea plateau which often has fog in that actual rainshowers move across Lapakahi. This hypothesis must be further considered and tested for Lapakahi before it can either be substantiated or discarded.

Enclosures, Exclosures, and Grazing Animals

Agricultural Area:--The historic documentation for West Kohala mentioned the increase of horses, cattle, and sheep in the area and the problems of cultivation that resulted. Many of the stone walls in the Lapakahi area may date from this mid-nineteenth century period as an attempt to keep animals out of the crops or inside corrals.

Virtually all of the larger enclosures were built after the field system, as demonstrated by walls built over the field boundaries (e.g., Points "5" on Map 4). Many water catchment areas were enclosed with stone walls with the flat facing outside, indicating an exclosure function (e.g., Point 15 on Map 4). Of those features built over the older field system, some functioned as exclosures while others functioned as enclosures.

The large enclosure immediately north of Apaapaa 1 (Point 11 on Map 4), for example, was undoubtedly an animal enclosure, probably for cattle and horses because of its size. This functional assignment is based upon the enclosure having been constructed after the field system; general flat facing to the inside portions of the walls; and a lower ground level inside the walls than outside. Most important is the fact that small internal exclosures within the large enclosure have been carefully constructed with flat faced walls on the outside and sloping walls facing their interior, indicating small agricultural areas within a large animal pen. Additional detail on this large enclosure, which was sectioned by the backhoe for profile analysis, is included in the report by Murabayashi (1969).

It appears every effort was made to prevent horses, cattle, and sheep from ruining crops by penning them within enclosures or providing exclosures around garden areas. It is quite likely that the main field system was abandoned at about this time because there is no evidence of attempts to wall in major sections of the rectangular fields, although some small areas do have surrounding walls. Grazing animals would have probably ruined the floral windbreaks, if these were present, and this would have further degraded the agricultural area by increasing wind velocity at ground level and thus, increased plant evapo-transpiration, physical damage, soil drying, and decreased rainfall collection.

Most likely the population responded by shifting the focus of their agriculture to small garden areas that could be enclosed by rock walls, and abandoned the entire system of rectangular fields. This would have occurred during the middle of the nineteenth century. The lower portion of the field system was probably abandoned first since it was agriculturally the most marginal. Furthermore, it is quite likely that settlement also shifted inland during the nineteenth century because almost all land awards given in the area during the mid-nineteenth century were for inland portions of the field system; none were given for the lower portion (cf. Map 11).

Koaie Hamlet:--These data on late wall building are especially interesting in that only the "great wall" depicted on Map 9 at Koaie hamlet was prehistoric in date; all other walls at Koaie are demonstrably historic. The "great wall" is a massive structure that is footed almost at the bottom of the lowest cultural level (Appendix F: Fig. 5, Profile H, Area 6; Fig. 6, Profile P, Area 4). Furthermore, a wooden implement thought to be a short digging stick (Appendix G, Fig. 10, No. 1) was found inside the wall where it was breached to record Profile P. A section cut from this artifact was radiocarbon dated by

Isotopes, Inc. at 310 $\pm$ 90 years B.P. or A.D. 1640 $\pm$ 90 years (Sample I-4696). Given this date for the digging stick, the wall must be at least this old unless the central portion of an old tree was used to construct it or the artifact was kept for many generations after manufacture. However, the stratigraphic evidence of the wall being footed in the lowest cultural level with no historic artifacts plus this radiocarbon date, indicate pre-contact construction of the wall.

The question is then why such a huge wall should have been constructed in a settlement which at that time consisted only of house platforms and no other walls? The answer must surely lie with the strong 'āpa'apa'a wind for the wall is aligned exactly perpendicular to the normal wind flow. Furthermore, it is known that in the nineteenth century the coastal area was barren except for pili grass and hence unprotected from this high wind.

The answer to the proliferation of walls at Koaie hamlet in historic times is intriguing. The logical possibilities are that the walls were designed to delimit property, to separate areas of diverse function, to prevent entry, or to prevent exit. The data on wall facings are contradictory: some are flat faced to the outside, others to the inside; some are flat faced on both sides. Many of the walls were built along earlier platform edges while others crossed over them.

The solution that takes into account the most data is that some internal walls were designed to pen domestic animals, probably pigs and dogs, while the peripheral walls were constructed to prevent entry by horses and cattle into the central compound.

The historic wall building activity and the wealth of nineteenth century artifacts and midden debris combine to indicate a middle nineteenth century florescence of Koaie into a nucleated complex. Quite likely this was correlated with the degradation of the inland agricultural system by grazing animals and the loss of the hypothesized floral windbreaks.

Native Land Divisions

It was mentioned earlier in the text that it was uncertain if Lapakahi was an ahupua'a (a large native land division) that included smaller land divisions ('ili) called Puukole, Koaie, Koaeae, and Koea; or if each of these land divisions were also an ahupua'a (see Map 11). Apparently Koae was an 'ili since it is smaller than the others, terminates inland without extending to the coast, and because historic documents refer to it as an 'ili. In a letter dated 1876 to the King, Mrs. Apikaila Maikai wrote:

> The 'Ili 'aina of Koea, situate in Kohala, Island of Hawaii, was given by Kamehameha III and acquired by Kealoha, my father, it was with him right down to me (letter in the State Archives).

The other land divisions are larger and might, however, have been ahupua'as. An undated letter from E. Bond (probably written around 1860) speaks of the "ahupua'a" of Kaoma (Map 11) which is about the same size as the land divisions in the Lapakahi area (letter in the State Archives). Similarly, another letter from E. Bond in 1856 describes Puukole (Map 11) as an ahupua'a (letter on file in the State Archives). Tax records for 1855 list Koaie, Kaoaeae [Koaeae?], Puukole, and Lapakahi as ahupua'as but also list Koea as an ahupua'a, although other lines of evidence suggest that it was an 'ili (Tax records on file in the State Archives). The evidence is contradictory as to whether or not the land divisions in the Lapakahi area are ahupua'as or 'ilis, but it seems most likely that Koea was an 'ili within the ahupua'a of Lapakahi, while Puukole, Koaie, and Koaeae were each a separate ahupua'a.

Archaeological Evidence for Land Divisions

Map 4 shows five distinct and two less distinct boundaries running counter to the general north-south field pattern. These boundaries are of earth and stone; sometimes of stone walls alone, and often have trails closely paralleling them. These boundaries run upslope and downslope, or from the inland area toward the coast through the field zone. Trails visible on the aerial photos continue through the barren terrain of Kilometers 1, 2, 3, 11, 12, and 13 (Points 10 and 17 on Map 4). The long sides of the rectangular fields abutt perpendicularly to these east-west boundaries, quite often in a discontinuous fashion. That is, the long field borders often do not continue in the same alignment across these east-west boundaries, but terminate at them. Each field system between these perpendicular boundaries is internally consistent, but there is a definite "mismatch" of the field borders at their intersection with these east-west boundaries. There is nothing in the terrain features that demand readjustment of field provenience at these junctures; the reasons must have been cultural. These east-west boundaries most likely are the native boundaries to the land divisions of Kaoma, Puukole, Lapakahi, Koea, Koaie, and Koaeae (Map 11).

By starting with where Koea is shown on the tax maps (Map 11) and observing that it did not extend to the sea, it was possible to match this traditional land area with the archaeological features shown on Map 4. Working out from Koea, it proved possible to correlate Kaoma with Area 18; Puukole with Area 19; Lapakahi with Areas 20 and 21; Koaie with Area 22 and the northern half of Area 23; and Koaeae with the southern half of Area 23, all on Map 4. Area 24 was certainly Kaipuhaa, the land division just to the south of the study area.

This correlation of ground areas with traditional land divisions puts both Koaie hamlet on the coast and the inland settlement of Apaapaa 1 in the land of Koaie, not Lapakahi (unless Koaie is an 'ili within Lapakahi ahupua'a). This was established by extending the distinct east-west boundaries in the field area through the barren middle section to the coast on the basis of trails visible on the airphotos.

Summary

Archaeological data on the Kealakekua Bay portion of the Kona Field System were correlated with the historic information from Menzies. The information on the Lapakahi portion of the Kohala Field System was refined through archaeological and ecological work undertaken during the 1968 Lapakahi Project. The nineteenth century role of cattle, sheep, and horses in altering patterns of cultivation and demography at Lapakahi came from a study of the historic and archaeological evidence. Native land divisions were correlated with particular land areas on the basis of archaeological and historic analyses.

The net result of this entire chapter has been to reconstruct native patterns of land exploitation for the time of contact at Hawaii Island, and hence representative of immediate pre-contact times. The correlation of archaeological and historical evidence prepares the groundwork for future studies of prehistoric land exploitation on Hawaii Island which may now extrapolate backwards in time on the basis of the correlations.

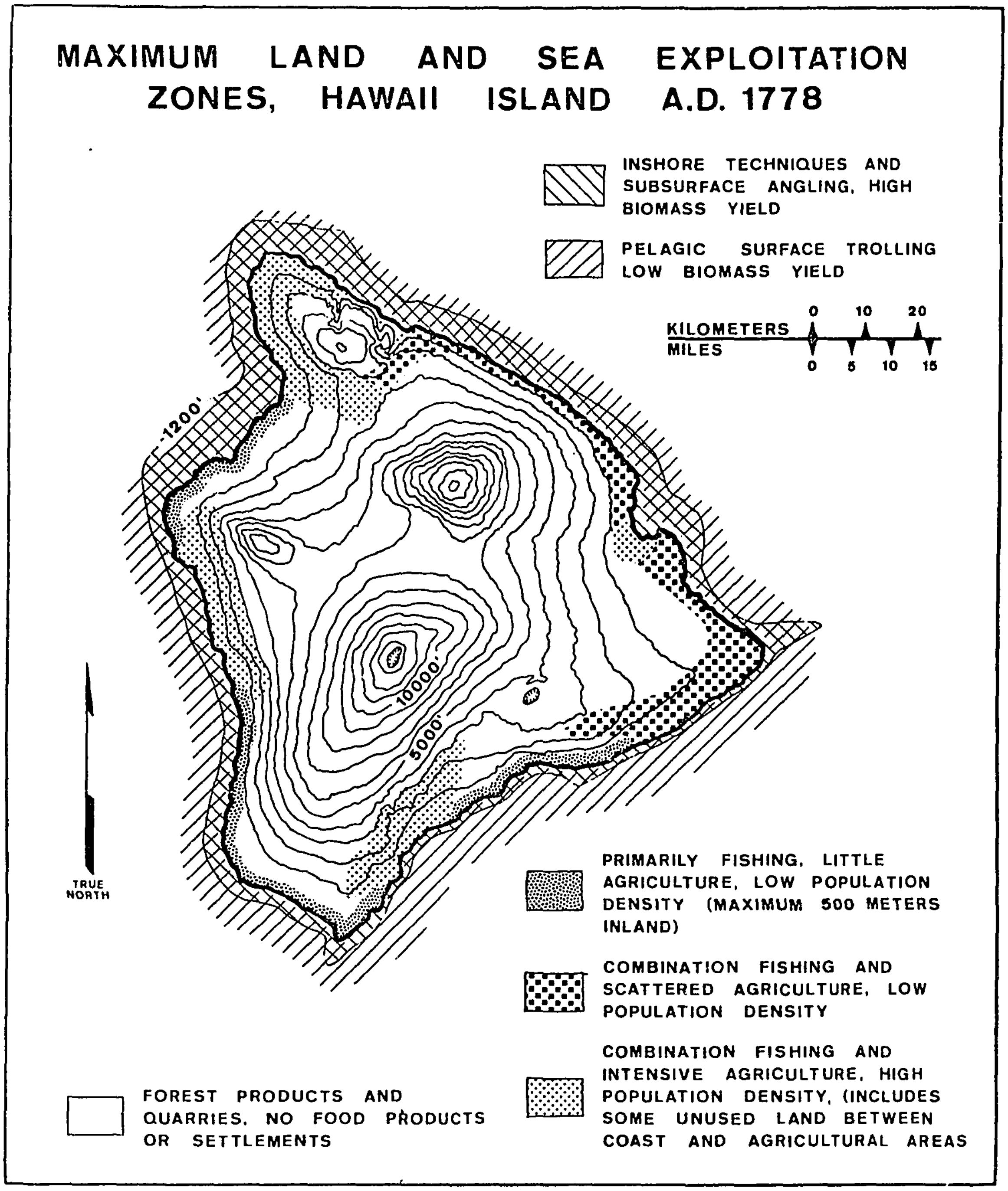
CHAPTER VI

MAKAI--MAUKA: FISHING AND FARMING ON THE ISLAND OF HAWAII IN A.D. 1778

The preceding chapters have partially reconstructed Hawaiian fishing and farming practices, demography, and the limiting factors of the Hawaiian ecosystem for the post-European period of Hawaii Island. The historical approach has been used to differentiate between native and introduced patterns of land and sea exploitation, while an ecological approach has indicated the environmental limiting factors. All have been correlated with the available archaeological data in an application of the direct historical approach in archaeology to reconstruct Hawaiian land and sea exploitation patterns truly native and pre-European. A synthesis of all these approaches is presented on Map 14 which shows the maximum land and sea exploitation zones for Hawaii Island in A.D. 1778, the year of first European contact in the Hawaiian Islands.

Fishing

Hawaiian exploitation patterns were apparently well adapted to tapping specific marine biota and habitats. Technology was carefully designed to meet specific conditions of the general Hawaiian marine ecosystem.



MAXIMUM LAND AND SEA EXPLOITATION ZONES, HAWAII ISLAND A.D. 1778
INSHORE TECHNIQUES AND SUBSURFACE ANGLING, HIGH BIOMASS YIELD
PELAGIC SURFACE TROLLING LOW BIOMASS YIELD
KILOMETERS
0 10 20
MILES
0 5 10 15
1200'
10000
5000
TRUE NORTH
PRIMARILY FISHING, LITTLE AGRICULTURE, LOW POPULATION DENSITY (MAXIMUM 500 METERS INLAND)
COMBINATION FISHING AND SCATTERED AGRICULTURE, LOW POPULATION DENSITY
COMBINATION FISHING AND INTENSIVE AGRICULTURE, HIGH POPULATION DENSITY, (INCLUDES SOME UNUSED LAND BETWEEN COAST AND AGRICULTURAL AREAS
FOREST PRODUCTS AND QUARRIES, NO FOOD PRODUCTS OR SETTLEMENTS

MAP 14

The maximum depth to which the Hawaiians are known to have fished was 1,200 feet (366 meters); Map 14 shows the extent of waters surrounding Hawaii Island that are shallower than this. Within this zone Hawaiians collected shellfish, sea urchins, sea cucumbers, and seaweed by hand. Fishing was done by hand and with nets, baited hooks, artificial lures, poisons, basket traps, spears, and snares. This zone seemed to be the area of primary sea exploitation in 1778.

The most intensive use of marine resources on Hawaii Island was apparently along the leeward shoreline, from Awalua to Kapoho (Map 12). This was probably the direct result of a biomass differential between the leeward and windward sides of Hawaii Island plus the difficulty of fishing in windward areas exposed to the strong northeast trade wind swell system.

The suggested maximum extent of pelagic fishing in the offshore area is indicated on Map 14; this was the area primarily exploited by surface trolling, although bag nets were sometimes used. Pelagic fishing was most likely secondary to the inshore area in terms of both yield and exploitation intensity, primarily because of the unpredictability of pelagic resources. Probably the heaviest use of pelagic resources was along the leeward coastline from Kailikii to Kapoho (Map 12), for here the inshore area was small indeed.

Farming

Hawaiian farming practices and demography were apparently closely correlated with certain critical environmental factors, particularly those concerned with moisture.

Irrigation was of minor importance on Hawaii Island because it was restricted to areas with flowing surface streams, a rarity on the geologically young Hawaii Island. Irrigation was present in the East Kohala valleys, in the narrow stream bottoms of the windward coast, and inland on Mauna Loa. This was intensive agriculture with great expenditure of energy per cultivated area, but had the advantage of producing highly predictable food supplies. Population densities were probably higher in these areas of irrigated agriculture than elsewhere on Hawaii Island, although the total population supported was relatively small.

Intensive agriculture was also present in many leeward areas in the form of field systems. The Kohala and Kona Field Systems were intensively farmed, but individual fields were probably fallowed for a number of years before re-use. In all areas of intensive, but unirrigated agriculture, portions of the field system most likely lay fallow while other parts were in crops. Population density in areas of intensive agriculture seemed to be the highest on Hawaii Island, except for the small valleys having irrigated agriculture. The overall population numbers were apparently greater in these intensive dryland agricultural areas than anywhere else on Hawaii Island. Intensive agricultural areas generally had associated coastal fishing establishments to further support the large population.

Scattered dryland agriculture and some emphasis upon fishing was predominant along the windward tableland areas of Hawaii Island. The resultant population seemed quite low in density and in total numbers. The windward areas appear to have been the most marginal areas for environmental exploitation; here nature seems to have closely limited the population that could be supported, the crops that could be raised, the seasons in which they could be planted and harvested, and the types of sea exploitation that could be successfully practiced.

Certain areas had little agriculture and here the people were primarily fishermen, living in straggling hamlets along the shoreline from Kawaihae to Kailua; from Honaunau to Kailikii; and from Punaluu to Kealakomo (Map 12). Some marginal agriculture was practiced where possible, but environmental conditions were too harsh to allow much dependence upon crops. The overall population density in these areas was probably the lowest of occupied areas on Hawaii Island, and the total population was small.

Unused Lands

Map 14 illustrates the point made in Chapter II that very little land area on Hawaii Island was usable for farming. Most of the Hawaii Island interior was incapable of economically feasible agricultural exploitation under Hawaiian culture. It would appear that nearly all usable land was under the most intense cultivation possible, given the limitations of environment and culture. In fact, one wonders if the population present on Hawaii Island in A.D. 1778 might not have been near the maximum that the Island ecosystem could support under Hawaiian culture.

Man's Affect on Nature

The Hawaiian and his culture demonstrably affected many aspects of the Hawaiian ecosystem through the interaction of his culture; particularly technology and exploitation patterns. Fields were constructed over wide areas of the leeward sloping lands and floristic succession was controlled through the use of fire and clearing. Water courses were channeled and diverted to the use of man's demands in areas where irrigated agriculture was found.

Even micro-climatic changes might have been generated through the astute use of floral windbreaks which could have changed wind flow patterns, soil temperatures, and available moisture.

Probably the effect of Hawaiian exploitation on the marine ecosystem was minimal, although some of the shallow water areas may have been occasionally over-exploited. Man, in substantially the role of predator and carnivore might have affected the population numbers of certain types of sea creatures, although probably not to any great extent in deeper water or pelagic areas.

Nature's Affect on Man

The affect of nature on Hawaiian and Hawaiian culture is evident throughout this analysis. Both fishing and farming were closely limited by the ability of the Hawaiian to adequately exploit the Hawaiian ecosystem with his specific culture and biology. Fishing was limited to waters less than 1,200 feet (366 meters) deep and farming was limited to elevations less than about 3,000 feet (914 meters). Population density and distribution were closely correlated with the carrying capacity of an Hawaiian ecosystem exploited by Hawaiian techniques. Items of technology and exploitation patterns were expressly adapted to specific parts of nature. Hawaiian fishhooks, nets, poisons, digging sticks, irrigated fields, and field systems, for example were well adapted to exploit specific portions of the Hawaiian environment; under different environmental conditions they might not have been as successful.

Summary and Prospect

Exploitation patterns limiting environmental factors, and the relationships between man and nature in Hawaii at the point of contact have been partially reconstructed. It is hoped that the interplay of man, culture, and environment shown in this paper will amplify the many existing summaries of Hawaiian culture by pointing to the role of the environment in shaping Hawaiian culture.

The focus of this paper has been on reconstructing fishing and farming patterns at the time of European contact in Hawaii; yet every attempt has been made to correlate these historical data with available archaeological evidence. It seems possible that sufficient background has been prepared to allow future workers to extrapolate from this base to the other Hawaiian Islands, and back into prehistory to further amplify Hawaiian fishing and farming.

APPENDIX A

HAWAIIAN MARINE BIOTA*

'A'ALA'IHI (See 'ALA'IHI)

'A'AWA; (Spotted Wrasse)
Labridae; Bodianus bilunulatus
Zones: Sub-surge

'AHA; 'AHA'AHA (Young); A'UA'A; (Needle Fish)
Belonidae; Ablennes hians; Strongylura gigantea

'AHA'AHA (See 'AHA)

'AHI; (Yellowfin Tina)
Scombridae; Thunnus albacares
Zones: Pelagic; Benthic (?)

'AHI PĀLAHA; (Albacore)
Scombridae; Thunnus alalunga
Zones: Pelagic (generally below surface)

ĀHOLE; ĀHOLEHOLE (Young; lower reaches of streams); (Mountain Bass)
Kuhliidae; Kuhlia sandvicensis
Zones: Supra-surge; Surge; Reef-protected

ĀHOLEHOLE (See ĀHOLE)

'ĀHULUHULU (See KŪMŪ)

'AKI-LOLO; HĪNĀLEA 'I'IWI; (Wrasse)
Labridae; Gomphosus varius
Zones: Sub-surge

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*Hawaiian names were checked wherever possible for spelling in Pukui and Elbert (1965).
Zones are primarily based on definitions and data from Gosline and Brock (1965) and Gosline (1965).
Hawaiian and scientific names are from Gosline and Brock (1965), Pukui and Elbert (1965), Titcomb (1952), Cobb (1902), Doty (1968), Kay (1967, 1969), Hiatt (1954) and Hawaii Department of Fish and Game (n.d.).

AKU; (Skipjack Tuna)
Scombridae; _Katsuwonus pelamis_
Zones: Pelagic

AKULE; HAHALALŪ or HALALŪ (Young); (Big-eyed Scad)
Carangidae; _Trachurops crumenophthalmus_
Zones: Inshore Pelagic (Neritic)

'ALA'IHI; 'A'ALA'IHI (Young); HĪNĀLEA LAU-WILI; (Squirrelfish)
Holocentridae; _Holocentrus lacteoguttatus_
Zones: Supra-surge; Surge; Reef-protected; Sub-surge

'ALALAUĀ (See 'ĀWEOWEO)

'ALALAUWĀ (See 'ĀWEOWEO)

'ĀLO'ILO'I; (Damselfish)
Pomacentridae; _Dascyllus albisella_
Zones: Sub-surge

'AMA'AMA; 'ANAE (full size 'AMA'AMA); (Mullet)
Mugilidae; _Mugil cephalus_
Zones: Brackish water ponds; estuarine

'ANAE (See 'AMA'AMA)

'ANANALU (See 'E'A)

'AO'AO-NUI (See KŪPĪPĪ)

'API; (Surgeonfish)
Acanthuridae; _Acanthurus guttatus_
Zones: Surge

'ĀPU'UPU'U (See HĀPU'U)

A'U; (Sailfish; Marlin)
Istiophoridae
Zones: Pelagic

A'UA'U; (Needlefish)
Belonidae _Strongylura gigantea_

A'U-LEPE; (Sailfish)
Istiophoridae; _Istiophorus orientalis_
Zones: Pelagic

AULIULI (?)

AWA; (Milkfish)
Chanidae; _Chanos chanos_
Zones: Brackish water ponds; Inshore sandy bottom areas

AWA-'AUA (See AWAAWA)

AWAAWA; AWA-'AUA; (Ten Pounder; Tarpon)
Elopidae; <u>Elops hawaiiensis</u>
Zones: Brackish water ponds

'ĀWELA (See HOU)

'ĀWEOWEO; 'ALALAUWĀ or 'ALALAUĀ (Young); (Red Bigeye)
Pricanthidae
Zones: Surge

CATFISH
<u>Clarias fuscus</u> (?)
Zones: Fresh Water

CRAB, KONA
Crustacea; <u>Ranina serrata</u>

CRAB, KUAHONU; (White Crab)
Crustacea; <u>Portunus sanguinolentus</u>

CRAB, MO'ALA; (Red Crab)
Crustacea; <u>Podophthalmus vigil</u>

CRAB, PĀPA'I
Crustacea; (Unclassified)

CRAB, SAMOAN
Crustacea; <u>Scylla serrata</u>

'E'A; HINALEA; (Wrasse; Hawaiian "generic" name)
Labridae
Zones: Supra-surge; Surge; Reef-protected; Sub-surge; Benthic

HAHALALŪ (See AKULE)

HALALŪ (See AKULE)

HANANUE (?)

HĀ-NUI (See MAMAMO)

HĀPU'U; HĀPU'UPU'U or 'ĀPU'UPU'U (Young); (Grouper)
Serranidae; <u>Epinephelus quernus</u>
Zones: Benthic

HĀPU'UPU'U (See HĀPU'U)

HĀ'UKE'UKE; (Sea Urchin)
Echinodermata; <u>Colobocentrotus atratus</u>

HĀULIULI; HĀULIULI-PŪHI; (Snake Mackerel)
Gempylidae; _Gempylus serpens_

HĀULIULI-PŪHI (See HĀULIULI)

HE'E; (Octopus)
Mollusca; Octopoda

HĪHĪMANU; (Ray)
Dasyatidae; Myliobatidae

HĪHĪ-WAI; (Freshwater limpet)
Mollusca; Gastropoda

HILU (See 'ŌPULE)

HILU LAUWILI; (Wrasse)
Labridae; _Coris lepomis_

HĪNĀLEA 'I'IWI (See 'AKI-LOLO)

HĪNĀLEA (See 'E'A)

HĪNĀLEA LAU-WILI (See 'ALA'IHI)

HONU; (Green Turtle)
Reptile; _Chelonia mydas_

HOU; 'ĀWELA; 'ŌLANI, 'ŌLALI (Young); PALAE'A (Young)
Labridae; _Thalassoma purpureum_

HULUHULU (See KŪMŪ)

HUMUHUMU; (Triggerfish; Hawaiian "generic" name)
Balistidae
Zones: Sub-surge; Benthic

HUMUHUMU MĀNEONEO (See MĀNEONEO)

'IAO; I'IAO; (Silverside)
Atherinidae; _Pranesus insularum_

I'A-'ULA'ULA; (Goldfish)
Carassius auratus
Zones: Fresh water
Introduced

I'A-'ULA'ULA ULI; (Carp)
Cyprinus carpio
Zones: Fresh water
Introduced

I'A-PĀKĒ; (China fish; Snake head; Panchon)
Ophiocephalus striatus
Zones: Fresh water
Introduced

IHEIHE; (Halfbeak)
Hemiramphidae; _Hemiramphus depauperatus_, _Euleptorhamphus viridis_

'I'I (See MĀ'I'I'I)

I'IAO (See 'IAO)

ILIKIKI (?)

'INA; (Sea Urchin)
Echinodermata; _Echinometra mathaei_, _E. oblonga_
Zones: Surge

KĀHALA; PUAKĀHALA (Young); (Amberjack)
Carangidae; _Seriola dumerilii_

KAKAKĪ (See KALA)

KĀKŪ; (Barracuda)
Sphyraenidae; _Sphyraena barracuda_
Zones: Pelagic

KALA; PAKALAKALA or PAKAOA (Young); KAKAKĪ; (Surgeonfish)
Acanthuridae; _Naso unicornis_

KALANOHO (?)

KALEKALE (See 'ŌPAKAPAKA)

KALIKALI; (Pink Snapper)
Lutjanidae; _Pristipomoides sieboldii_

KAMANU; (Hawaiian Salmon)
Carangidae; _Elagatis bipinnulatus_

KAWAKAWA; (Little Tuna)
Scombridae; _Euthynnus yaito_
Zones: Inshore Pelagic (Neritic)

KAWALE'Ā; KAWELE'Ā; (Japanese Barracuda)
Sphyraenidae; _Sphyraena helleri_

KAWELE'Ā (See KAWALE'Ā)

KIHIKIHI; (Moorish Idol)
Zanclidae; _Zanclus canescens_
Zones: Reef-protected

KIHIKIHI MĀNEONEO (See MĀNEONEO)

KĪKĀKAPU; (Butterfly fish)
Chaetodontidae; _Chaetodon ornatissimus_

KOA'E; (Snapper)
Lutjanidae
Zones: Benthic

KO'I (See 'ULA'ULA)

KOLE; (Surgeonfish)
Acanthuridae; _Ctenochaetus strigosus_
Zones; Sub-surge

KOLEPALA (?)

KONA CRAB (See CRAB, KONA)

KUAPA'A; (Chiton)
Mollusca; _Acanthochiton viridis_

KUAHONU (See CRAB, KUAHONU)

KŪMŪ; 'ĀHULUHULU or HULUHULU (Young); (Red Goatfish)
Mullidae; _Parupeneus porphyreus_
Zones: Surge; Reef-protected; Sub-surge

KŪPĪPĪ; 'AO'AO-NUI (Young); (Damselfish)
Pomacentridae; _Abudefduf sordidus_
Zones: Supra-surge; Surge; Reef-protected

KŪPOUPOU; (Mongoose fish)
Labridae; _Cheilio inermis_
Zones: Reef-protected

LAE; LAI; (Leatherback)
Carangidae; _Scomberoides sancti-petri_

LAE-NIHI; (Razor fish)
Labridae; Genera _Iniistius_ and _Hemipteronotus_
Zones: Benthic (Sandy)

LAI (See LAE)

LĀ'I-PALA; LAU'Ī-PALA; LAU-KĪ-PALA; PALA; (Yellow Tang)
Acanthuridae; _Zembrasoma flavescens_
Zones: Sub-surge

LĀ'Ō; 'ŌHUA (Young); PA'AWELA;
Labridae; _Halichoeres ornatissimus_
Zones: Sub-surge

LAU-HAU; (Butterfly fish)
Chaetodontidae; _Chaetodon quadrimaculatus_

LAUIA; (Parrot fish)
Scaridae

LAU'Ī-PALA (See LĀ'Ī-PALA)

LAU-KĪ-PALA (See LĀ'Ī-PALA)

LAU-WILIWILI
Chaetodontidae; _Chaetodon miliaris_
Zones: Surge; Reef-protected; Sub-surge; Benthic

LEHI; (Snapper)
Lutjanidae; _Aphareus rutilans_
Zones: Benthic

LEHO; (Cowry; Hawaiian "generic" name)
Mollusca; Gastropoda; Cypraeaidae

LELO (?)

LIMU (Seaweed; Hawaiian "generic" name)

LOLI (Sea Cucumber; beche de mer)
Echinodermata; Holothuroidea

LOLO
Labridae; _Coris gaimardi_

LOLO-'OAU; (Flying Gunard)
Dactylopteridae; _Dactyloptena orientalis_
Zones: Benthic

LOULU
Monocanthidae; _Alutera monoceros_

MAHIMAHI; (Dolphin fish)
Bramidae; _Coryphaena hippurus_
Zones: Pelagic

MAHUKIA (?)

MA'I'I'I; I'I; (Surgeonfish)
Acanthuridae; _Acanthurus sp._

MAIKO; MĀIKOIKO; (Surgeonfish)
Acanthuridae; _Acanthurus nigroris_, _A_. _Leucopareius_
Zones: Surge; Reef-protected; Sub-surge

MĀIKOIKO (See MAIKO)

MAKA-'Ā
Malacanthidae; _Malacanthus hoedtii_

MAKIAWA; MIKIAWA; (Sardine)
Dussumieriidae; _Etrumeus micropus_

MĀLAMALAMA
Labridae _Coris rosea_

MĀLOLO; PUHIKI'I (Young); (Flying fish)
Exocoetidae; _Parexocoetus brachypterus_; _Oxyporhamphus micropterus_
Zones: Pelagic

MALU; (Goatfish)
Mullidae; _Parupeneus pleurostigma_
Zones: Sub-surge

MAMAMO; MAMO; MAOMAO; HĀ-NUI
Pomacentridae; _Abudefduf abdominalis_
Zones: Surge; Reef-protected

MAMAMU; MŪ
Sparidae; _Monotaxis grandoculis_

MAMO (See MAMAMO)

MAMOA WAA (See MOA)

MANALOA (See NENUE)

MĀNEONEO; HUMUHUMU MANEONEO; KIHIKIHI MANEONEO
Balistidae; Zanclidae

MANINI; (Surgeonfish; Convict Tang)
Acanthuridae; _Acanthurus sandvicensis_
Zones: Supra-surge; Surge; Reef-protected; Sub-surge

MANŌ; (Shark; Hawaiian "generic" name)
Squalidae

MANŌ-KIHIKIHI; (Hammerhead Shark)
Sphyrnidae; _Sphyrna lewini_, _S_. _zygaena_

MAOMAO (See MAMAMO)

MAUMAU (?)

MIKIAWA (See MAKIAWA)

MOA; MAMOA WAA; OOPAKAKU; (Trunkfish)
Ostraciontidae; *Ostracion lentiginosus*
Zones: Surge; Reef-protected; Sub-surge

MO'ALA (See CRAB, MO'ALA)

MOANO; (Goatfish)
Mullidae; *Parupeneus multifasciatus*
Zones: Reef-protected; Sub-surge

MOELUA; (Red Goatfish)
Mullidae; *Mulloidichthys pflugeri*

MOI; MOI-LI'I; (Threadfin)
Polynemidae; *Polydactylus sexfilis*

MOI-LI'I (See MOI)

MŪ (See MAMAMU)

MŪHE'E (True Squid; Cuttlefish)
Mollusca; Decapoda; *Sepioteuthus artipinnis*
Zones: Sub-surge

MUNU; (Goatfish)
Mullidae; *Parupeneus bifasciatus*
Zones: Sub-surge

NA'ENA'E; (Surgeonfish; Orange-spotted Tang)
Acanthuridae; *Acanthurus olivaceus*
Zones: Sub-surge

NEHU
Engraulidae; *Stolephorus purpureus*
Zones: Brackish water

NENUE; (Rudderfish)
Kyphosidae; *Kyphosus cinerascens*

NOHU; (Hawaiian "generic" name)
Scorpaenidae; *Scorpaenopsis cacapsis*, *S. gibbosa*
Zones: Surge; Reef-protected; Sub-surge; Benthic

NOHU-PINAO
Scorpaenidae

NŪNŪ; (Stick fish; Trumpet fish)
Aulostomidae; *Aulostomus chinensis*
Zones: Reef-protected

'OAU (See 'ŌKUHE)

'ŌHUA (See LĀ'Ō)

'Ō'ILI; (File fish; Hawaiian "generic" name)
Monacanthidae (except Alutera monoceros)
Zones: Sub-surge; Benthic

'Ō'ILI-LEPA; (File fish)
Monacanthidae; Alutera scripta; Amanses sandwichiensis

'Ō'ILI-'UWĪ'UWĪ; (File fish)
Monacanthidae; Pervagor spilosoma
Zones: Sub-surge; Benthic

'Ō'IO; (Bonefish)
Albulidae; Albula vulpes

'ŌKUHE; 'OKUHEKUHE (Young); 'OAU
Eleotridae; Eleotris fusca

'ŌKUHEKUHE (See 'ŌKUHE)

'ŌLALI (See HOU)

'ŌLANI (See HOU)

'ŌLEPE; (Clam; Hawaiian "generic" name)
Mollusca; Pelecypoda; Venerupis

'ŌMAKA; (Herring)
Carangidae; Labridae; Caranx mate, Stethojulis axillaris
Zones: Surge; Reef-protected; Sub-surge

'ŌMILU; 'ŌMILUMILU; ULUA 'ŌMILU; (Blue Crevally)
Carangidae; Caranx melampygus

'ŌMILUMILU (See 'ŌMILU)

ONO; (Wahoo)
Scombridae; Acanthocybium solandri
Zones: Pelagic

OOPAKAKU (See MOA)

'O'OPU; (Hawaiian "generic" name)
Esp. Gobiidae; also Eleotridae (Eleotris sandwichiensis)
Zones: Fresh water and marine

'O'OPU-HUE; (Swellfish; Puffer; Globefish)
Tetradontidae; Diodontidae; Arothron hispidus,
Chilomycterus affinis

'O'OPU-KAI (See PO'O-PA'A)

'O'OPU-PĀO'O (See PĀO'O KAUILA)

'ŌPAE; (Shrimp; Hawaiian "generic" name)
Crustacea

'ŌPAKA (?)

'ŌPAKAPAKA; PAKA (Young); KALEKALE (Young); (Snapper)
Lutjanidae
Zones: Benthic

'ŌPELU; 'ŌPELU-MAMA; (Mackerel Scad)
Carangidae; *Decapterus pinnulatus*, *D. maruadsi*
Zones: Inshore Pelagic (Neritic)

'OPIHI; (Limpet)
Mollusca; Gastropoda; Patellidae
Zones: Supra-surge

'ŌPULE; HILU; (Spotted Wrasse)
Labridae; *Anampses cuvieri*
Zones: Surge; Reef-protected; Sub-surge

PĀ; (Pearlshell)
Mollusca; Pelecypoda; *Pinctada goltsoffi*

PA'APA'A ULUA (See PA'OPA'O)

PA'AWELA (See LĀ'Ō)

PAKA (See 'ŌPAKAPAKA)

PAKAIKĀWALE
Lutjanidae

PAKALA (See KALA)

PAKALAKALA (See KALA)

PĀKI'I; PĀKIKI; (Flounder)
Bothidae
Zones: Reef-protected; Benthic

PĀKIKI (See PĀKI'I)

PĀKOLE; (Surgeonfish)
Teuthis olivaceus

PAKU (See 'UĪ'UĪ)

PĀKU'IKU'I; (Achilles Tang)
Acanthuridae; *Acanthurus achilles*

PALA (See LĀ'Ī-PALA)

PALAE'A (See HOU)

PALAMI (?)

PALANI; (Surgeonfish)
Acanthuridae; Acanthurus dussumieri

PALAPALA (See PUALU)

PĀLUKALUKA (Parrot fish)
Scaridae

PĀNUHUNUHU (See UHU)

PĀO'O; (Rockskipper)
Blenniidae; Istiblennius zebra
Zones: Supra-surge

PĀO'O KAUILA; 'O'OPU-PĀO'O
Blenniidae; Exallias brevis
Zones: Sub-surge

PA'OPA'O; PA'APA'A ULUA; (Yellow ulua)
Carangidae; Gnathanodon speciosus

PĀPA'I (See CRAB, PĀPA'I)

PĀPAUA (Clam)
Mollusca; Pelecypoda; Isognomom

PĀ'Ū'Ū; (Squirrelfish)
Holocentridae; Myripristis chryseres

PĪHĀ; (Small Round Herring)
Dussumieriidae; Spratelloides delicatulus

PILI-KO'A; (Hawk fish)
Cirrhitidae; Paracirrhites forsteri, P. arcatus, P. cinctus
Zones: Surge; Sub-surge

PO'O-PA'A; 'O'OPU-KAI
Cirrhitidae; Cirrhitus alternatus
Zones: Surge; Sub-surge

PŌ'OU
Labridae; Cheilinus rhodochrous

POOUPOU (?)

PUA 'I'I (?)

PUALU; PUWALU; PALAPALA; (Surgeonfish)
Acanthuridae; Acanthurus xanthopterus, A. mata

PUAKĀHALA (See KĀHALA)

PUAUU (?)

PŪHI; (Eel; Hawaiian "generic" name)
Muraenidae
Zones: Surge; Reef-protected; Sub-surge; Benthic

PUHIKI'I (See MĀLOLO)

PŪHI-LAU-MILO (Eel)
Muraenidae; Gymnothorax undulatus
Zones: Sub-surge

PŪHI-WELA; (Eel)
Muraenidae; Gymnothorax pictus

PU'UILI
Belonidae; Hemiramphidae; Ablennes hians, Strongylura gigantea, Euleptorhamphus viridis, Hemiramphus depauperatus

PUWALU (See PUALU)

UHU; PĀNUHUNUHU (Young); 'ŌMALEMALE (Young); (Parrot fish)
Scaridae
Zones: Reef-protected; Sub-surge

UHU 'ULA; (Parrot fish)
Scaridae

'UĪ'UĪ; PAKU; (Flounder)
Bothidae; Bothus mancus, B. pantherinus
Zones: Reef-protected; Benthic

UKU; (Gray Snapper)
Lutjanidae; Aprion virescens
Zones: Benthic

ULA; (Lobster)
Crusteacea; Panulirus japonicus, P. penicillatus

'ULAE; (Lizard fish)
Synodontidae; Synodus dermatogenys

ULA-PĀPAPA; (Slipper Lobster; Gray Crayfish)
Crustacea; Parribacus antarcticus

'ULA'ULA; KO'I (Young); (Red Snapper)
Lutjanidae; Etelis marshi
Zones: Benthic

'ULA'ULA KOA'E; (Red Snapper)
Lutjanidae; Etelis carbunculus
Zones: Benthic

ULUA; (Jack Crevally; Hawaiian "generic" name)
Carangidae

ULUA KIHI-KIHI; (Thread Crevally)
Carangidae; Alectis ciliaris

ULUA 'ŌMILU (See 'ŌMILU)

UMAUMALEI (?)

UOUOA; (False Mullet)
Mugilidae; Neomyxus chaptalii

'UPĀPALU; (Cardinal fish)
Apogonidae
Zones: Surge; Reef-protected; Sub-surge; Benthic

'Ū'Ū; (Squirrelfish)
Holocentridae; Myripristis argyromus; M. berndti

UUKANIPO; (Squirrelfish)
Holocentridae

WALU; WOLU; (Oilfish; Ruvettus)
Gempylidae; Ruvettus pretiosus
Zones: Benthic

WANA; (Sea Urchin)
Echinodermata; Echinothrix diadema, E. calamaris, Diadema paucispina
Zones: Surge; Sub-surge

WEKE; WEKE-'A'Ā; (Goatfish)
Mullidae; Mulloidichthys samoensis
Zones: Surge; Reef-protected

WEKE-'A'Ā (See WEKE)

WEKE-PAHULU; WEKE-PUEO
Mullidae; Upeneus arge

WEKE-PUEO (See WEKE-PAHULU)

WEKE-'ULA; (Red Goatfish)
Mullidae; *Mulloidichthys auriflamma*
Zones: Reef-protected

WELE'Ā; (Lizard fish)
Snyodontidae; *Trachinocephalus myops*
Zones: Benthic

WOLU (See WALU)

APPENDIX B

LAPAKAHI GRID SYSTEM

01	02	03	04	05	06	07	08	09	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	00

The grid system designed for the Lapakahi excavations is perhaps somewhat unusual in that it was specifically established to aid settlement pattern studies and the analysis of a large aboriginal field system spread over many square kilometers. It was also necessary to design a grid system that could be used to record horizontal provenience in a format that could be processed by computer. A further consideration was that the grid system be capable of accurately locating archaeological and geographic features at any level of feature size, from a fishhook within an excavated square to a field system of several square kilometers.

It was not necessary to develop an entirely new system for one that fits all design criteria has been in existence for many years. This is the square metric area system and although most people are familiar with square kilometers and square meters, few are familiar with hectares, much less with ares so it is necessary to go into some detail describing this system.

The metric area system forming the basis of the Lapakahi coordinate scheme begins with the square meter, or Centare. An area comprising one hundred Centares is called the Are (not Acre) and each individual Centare within the Are is numbered in rows and columns of ten, arbitrarily beginning in the northwest corner with Centare 01 and ending in the southeast corner with Centare 00 which stands for the 100th Centare to keep all designations to two digits. The Hectare is an area of 10,000 square meters, or 100 Ares. The Ares in the Hectare are arranged in ten rows and columns of ten Ares each, numbered in exactly the same fashion as the Centares are within the individual Are. The square Kilometer contains 100,000 square meters, 1,000 Ares, or 100 Hectares. Each Hectare is numbered in the same fashion as the Ares and Centares and arranged in rows and columns of ten Hectares each. It can be seen that this is a logically simple system, completely consistent at all levels of size in terms of dimensions and numbering. In the maps drawn for this report abbreviations are used as follows: K = Kilometer; H = Hectare; A = Are; and C = Centare.

It is necessary to pin this theoretical grid system to known points on the ground and this was done by adjusting the northwest corner of Kilometer 01 to the Mahukona Light, a Coast Guard installation of precise known geographical location. The alignment was made along true azmuths and the latitude and longitude for Mahukona Lighthouse was computed in terms of Universal Transverse Mercator Grid Coordinates which may be converted to conventional latitude and longitude should the need ever arise. The resultant grid system with its datum tied to Mahukona Light was then drawn onto the Lapakahi area map derived from aerial photogrammetry.

The aerial photogrammetry was produced by the R. M. Towill Corporation of Honolulu under the supervision of Mr. Peter Miles. Two special flight plans were flown by Towill aircraft, one at approximately 6,000 feet above terrain to provide the basic photogrammetric information, and the other at about 3,000 feet above terrain using special infra-red color film to produce prints designed to aid in interpretation of archaeological features. Using photogrammetric techniques the entire Lapakahi area was mapped at an original scale of 1:1000 to provide large scale field maps; a contour interval of 20 feet was established, keyed to points of known ground elevation. The original map was then reduced after airphoto interpretation of archaeological features and appears as Map 4. Although the accuracy of the Lapakahi area original map at a scale of 1:1000 is within standard mapping accuracy criteria it is not as accurate as ground surveyed maps of small areas such as an individual site, if for no other reason than the fact that all lines on Map 4 are approximately two meters in thickness when transferred to the ground. There is an error factor of at least ±1 meter under optimum locating conditions and the error increases in direct proportion to the ability of the ground party to transfer a site location to its proper position on the map, which, in turn, is greatly dependent upon the amount of map detail available. In the agricultural field system the accuracy should be close to the ±1 meter but below Kilometers 94 and 04 the error factor will increase because of the lack of map detail as a rather barren terrain and increasing vegetation ground cover prevented plotting of many terrain features. Along the coast the accuracy will vary with the ability of the ground party to determine feature location on the map and airphotos while under a fairly heavy tree cover.

The excavation grids established for Koaie and Apaapaa 1 were based upon the photogrammetric map grid and were fixed to the ground through the use of the airphotos and map. Once the ground point was established the remainder of each site grid system was surveyed in with ground instruments and surveyors tape; stakes were placed at each Are corner in areas to be excavated. Centare stakes were put in by either tape or instrument as needed for excavation.

The net result of this grid system and area mapping was the development of a map of greater accuracy than could have been produced at a comparable cost by ground survey methods; a map of an entire native land tenure unit with archaeological features plotted by airphoto interpretation for later ground checking; a grid system for recording horizontal provenience at any level of magnitude from a square meter to a square kilometer; and a numerical format logically consistent and appropriate for computer processing.

APPENDIX C

MARITIME EXPLOITATION TABLES

TABLE V

PRE-TWENTIETH CENTURY MARINE EXPLOITATION TECHNIQUES

	Hook and Line	Surface Trolling	Sub-surface	Long Hand Line	Octopus Lure	Seine/ Bag Net	Gill Net	Cast Net*	Bag Net	Basket Trap	Snare	Hands	Spear
'a'awa	x		x			700	x						
'aha						x							
'ahi	15,722	x	x										
āhole	x		x			1,200	x						
aku	200,492	x											
akule	258,454		x			11,400	16,109	18,136	x				
'ala'ihi						x		14,075	x				
'ālo'ilo'i	x					x	x	x	x				
'ama'ama						3,900	x	1,800	x				
'api						x							
a'ua'u	x		x			x							
awa						x	x						
awaawa	x		x			x	x						
'aweoweo	x		x				x						

Numbers = 1900 commercial catch for Hawaii Island (In Pounds) Entries of less than 500 pounds have been excluded

X = Technique used but no quantitative data

*Introduced technique

TABLE V (continued) PRE-TWENTIETH CENTURY MARINE EXPLOITATION TECHNIQUES

	Hook and Line	Surface Trolling	Sub-Surface	Long Hand Line	Octopus Lure	Seine/ Bag Net	Gill Net	Cast Net *	Bag Net	Basket Trap	Snare	Spear	Hands
'e'a	944		x			x	800	1,132		x			
hananue	x		x	x									
hāpu'u	x		x	x									
hāuliuli	27,020		x				7,200						
he'e	3,142		x		x							12,674	1,600
hihimanu	x											1,172	
honu												800	x
hou	1,040		x			x	x						
humuhumu	13,010		x				1,400						
'iao						1,500							
iheihe	x		x			7,300	1,100		x				
ilikiki	x		x	x									
'ina													620
kāhala	40,486		x	x									
kākū	x		x				500						
kala						680	2,900	x	x	819			
kalanoho						x							
kawakawa	44,723					2,600							
kawele'ā	x					1,600							
kihikihi						x							
koa'e	x		x	x									
kole						x							
kolepala									x				

*Introduced technique

TABLE V (continued) PRE-TWENTIETH CENTURY MARINE EXPLOITATION TECHNIQUES

	Hook and Line	Surface Trolling	Sub-surface	Long Hand Line	Octopus Lure	Seine/ Bag Net	Gill Net	Cast Net *	Bag Net	Basket Trap	Snare	Spear	Hands
kuapa'a	600		x			x							
kūmū						1,800	1,400	x	x	x		3,100	
kūpīpī	x		x				x						
kūpoupou	x		x			x							
lae-nihi	800		x			x	x						
lae	1,612		x			x	510						
lā'ī-pala	x		x			x	x			x		x	
lau-hau						x		3,251	x				
lehi	x		x	x									
leho													x
lelo	x												
limu													2,150
loli													x
mahukia	x		x	x									
mahimahi	9,390	x											
mālamalama						x							
mālolo						800	x		x				
mamamo						x				x			
manini	2,039		x			x	1,300			1,700			
manō	1,800					x					x		

*Introduced technique

TABLE V (continued) PRE-TWENTIETH CENTURY MARINE EXPLOITATION TECHNIQUES

	Hook and Line	Surface Trolling	Sub-surface	Long Hand Line	Octopus Lure	Seine/ Bag Net	Gill Net	Cast Net*	Bag Net	Basket Trap	Snare	Spear	Hands
maumau						x							
makiawa						x	x						
moano	148,160		x			1,400							
moi	x		x			x	2,000						
mūhe'e						x						x	
nehu						2,200							
nenue	x		x			x	x		x				
nohu	x		x										
nūnū						x			x				
'ō'io	63,109		x	x		x	1,400						
'ōkuhe						x							
'ōmaka						x							
'ōmilu	x		x										
ono	1,888		x					x			x		
'o'opu													x
'o'opu-hue								609				x	
'o'opu-kai	1,139		x										
'ōpaka	x		x	x									

*Introduced technique

TABLE V (continued) PRE-TWENTIETH CENTURY MARINE EXPLOITATION TECHNIQUES

	Hook and Line	Surface Trolling	Sub-surface	Long Hand Line	Octopus Lure	Seine/ Bag Net	Gill Net	Cast Net*	Bag Net	Basket Trap	Snare	Spear	Hands
'ōpae										818			x
'ōpakapaka	x		x	x		x	x						
'opelu	3,099		x			20,023	514		49,000				
'opihi													16,150
'ōpule	x		x			x	x		x	x			
pāki'i	x		x			1,745		10,849					
palani	2,600		x				1,400					500	
pāpa'i	x		x						x				800
pa'opa'o						x							
pā'ū'ū									x				
pīhā						945							
pili-ko'a							x						
pualu	3,295		x			800	1,200						
puauu	x												
pūhi	17,892		x							1,400	x	x	x
pūpū													x
uhu	x		x			x	809		x				
uku	13,372		x	x									
ula	3,025		x				7,825			x	600		3,745
'ula'ula	x		x	x			x						
'ulae	x		x										

*Introduced technique

TABLE V (continued) PRE-TWENTIETH CENTURY MARINE EXPLOITATION TECHNIQUES

	Hook and Line	Surface Trolling	Sub-surface	Long Hand Line	Octopus Lure	Seine/Bag Net	Gill Net	Cast Net*	Bag Net	Basket Trap	Snare	Spear	Hands
ulua	89,414		x	x		4,800	2,675						
ulua kihi-kihi						x							
umaumalei						x							
'upāpalu	1,524		x			x		x					
'ū'ū	26,161		x			x	7,900						
walu	x		x	x									
wana													1,514
weke	x		x			500	500		x				
wele'ā	x		x			x	600						
Total Weight	995,952					65,893	60,042	49,852	49,000	4,737	600	18,246	26,579
% of Total (Rounded)	78.3					5.1	4.7	3.9	3.8	.3	.04	1.4	2.0

GRAND TOTAL: 1,270,901 pounds

*Introduced technique

TABLE VI

MARINE REMAINS AND EXPLOITATION TECHNIQUES

HOOK AND LINE FISHING

'ahi (Scombridae _Thunnus albacares_); Pelagic; Benthic (?)
aku (Scombridae _Katsuwonus pelamis_); Pelagic
hananue (?)
hāpu'u (Serranidae _Epinephelus quernus_); Benthic
ilikiki (?)
kāhala (Carangidae _Seriola dumerilii_)
koa'e (Lutjanidae); Benthic
lehi (Lutjanidae _Aphareus rutilans_); Benthic
lelo (?)
mahukia (?)
mahimahi (Bramidae _Coryphaena hippurus_); Pelagic
nohu (Scorpaenidae _Scorpaenopsis cacapsis_; _S. gibbosa_);
Surge; Reef-protected, Sub-surge; Benthic
'ōmilu (Carangidae _Caranx melampygus_)
'o'opu-kai, po'o-pa'a (Cirrhitidae _Cirrhitus alternatus_);
'opaka (?)
palani (Acanthuridae _Acanthurus dussmieri_)
puauu (?)
uku (Lutjanidae _Aprion virescens_); Benthic
'ulae (Synodontidae _Synodus dermatogenys_)
walu (Gempylidae _Ruvettus pretiosus_); Benthic

Pelagic Surface Trolling

aku (Scombridae _Katsuwonus pelamis_)
mahimahi (Bramidae _Coryphaena hippurus_)

Hand Line Fishing

'ahi (Scombridae _Thunnus albacares_); Pelagic; Benthic
hananue (?)
hāpu'u (Serranidae _Epinephelus quernus_); Benthic
ilikiki (?)
kāhala (Carangidae _Seriola dumerilii_)
koa'e (Lutjanidae); Benthic
lehi (Lutjanidae _Aphareus rutilans_); Benthic
mahukia (?)
'ōpaka (?)
uku (Lutjanidae _Aprion virescens_); Benthic
walu (Gempylidae _Ruvettus pretiosus_); Benthic

TABLE VI (continued) MARINE REMAINS & EXPLOITATION TECHNIQUES

NETS

'aha (Belonidae Ablennes hians, Strongylura gigantea)
'ala'ihi (Holocentridae Holocentrus lacteoguttatus); Supra-surge; Surge; Reef-protected; Sub-surge
'ama'ama (Mugilidae Mugil cephalus); Brackish water ponds; Estuarine
'api (Acanthuridae Acanthurus guttatus); Surge
awa (Chanidae Chanos chanos); Brackish water ponds
'iao (Atherinidae Pranesus insularum)
kala (Acanthuridae Naso unicornis)
kalanoho (?)
kihikihi (Zanclidae Zanclus canescens); Reef-protected
kole (Acanthuridae Ctenochaetus strigosus); Sub-surge
kolepala (?)
lau-hau (Chaetodontidae Chaetodon quadrimaculatus)
mālamalama (?)
mālolo (Excoetidae Parexocoetus brachypterus, Oxyporhamphus micropterus); Pelagic
mamamo (Pomacentridae Abudefduf abdominalis); Surge, Reef-protected
maumau (?)
makiawa (Dussemieriidae Etrumeus micropus)
nehu (Engraulidae Stolephorus purpureus); Brackish water
nūnū (Aulostomidae Aulostomus chinensis); Reef-protected
'ōkuhe (Eleotridae Eleotris fusca)
'ōmaka (Carangidae Caranx mate, Labridae Stethojulis axillaris); Surge; Reef-protected; Sub-surge
pa'opa'o (Carangidae Gnathanodon speciosus)
pā'ū'ū (Holocentridae Myripristis chryseres)
pihā (Dussumieriidae Spratelloides delicatulus)
pili-ko'a (Cirrhitidae Paracirrhites forsteri; P. arcatus; P. cinctus); Surge; Sub-surge
ulua kihi-kihi (Carangidae Alectic ciliaris)
umaumalei (?)

Combination Seine/Bag Net

'aha (Belonidae Ablennes hians, Strongylura gigantea)
'api (Acanthuridae Acanthurus guttatus); Surge
'iao (Atherinidae Pranesus insularum)
kalanoho (?)
kihikihi (Zanclidae Zanclus canescens); Reef-protected
kole (Acanthuridae Ctenochaetus strigosus); Sub-surge
mālamalama (?)
maumau (?)

TABLE VI (continued) MARINE REMAINS & EXPLOITATION TECHNIQUES

nehu (Engraulidae *Stolephorus purpureus*); Brackish water
'ōkuhe (Eleotridae *Eleotris fusca*)
'ōmaka (Carangidae *Caranx mate*, Labridae *Stethojulis axillaris*)
pa'opa'o (Carangidae *Gnathanodon speciosus*)
pihi (Dussumieriidae *Spratelloides delicatulus*)
ulua kihi-kihi (Carangidae *Alectis ciliaris*)
umaumalei (?)

Gill Nets

pili-ko'a (Cirrhitidae *Paracirrhites forsteri*; *P. arcatus*; *P. cinctus*); Surge; Sub-surge

Bag Nets

kolepala (?)
mamamo (Pomacentridae *Abudefduf abdominalis*); Surge; Reef-protected
pā'ū'ū (Holocentridae *Myripristis chryseres*)

HAND COLLECTING

'ina (Echinodermata; *Echinometra mathaei*, *E. oblonga*); Surge
leho (Mollusca; Gastropoda; Cypraeaidae)
'o'opu (Gobiidae; Eleotridae); Freshwater; Marine
'opihi (Mollusca; Gastropoda; Patellidae); Supra-surge
pūpū (Freshwater limpet)
wana (Echinodermata; *Echinothrix diadema*, *E. calamaris*, *Diadema pauscispina*); Surge; Sub-surge

APPENDIX D

KOAIE DATA

TABLE VII

KOAIE ARTIFACT ANALYSIS BY FUNCTION*

Artifact Functional Class	Total	Percent of Site Total
Fishing Gear	286	7.31
Surface Gear	11	0.28
Lure	11	0.28
Bonito Lure	11	0.28
Point	9	0.23
Sub-surface Gear	243	6.21
Hook	182	4.65
Jabbing	35	0.89
Rotating	29	0.74
Lure	37	0.95
Octopus Lure	37	0.95
Point	5	0.13
Cowry Shell	25	0.64
Toggle	7	0.18
Sinker	21	0.54
Incomplete Manufacture	31	0.79
Incomplete Manufacture, Fishhook	24	0.61
Incomplete Manufacture, Toggle	1	0.03
Smoking Equipment	6	0.15
Pipe	6	0.15
Pipe, Tobacco	5	0.13
Pipe Stem, Tobacco	3	0.08
Pipe Bowl, Tobacco	1	0.03
Pipe, Opium	1	0.03
Cordage	3	0.08
Woven Fabric	3	0.08

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE VII (continued) KOAIE ARTIFACT ANALYSIS BY FUNCTION

Artifact Functional Class	Total	Percent of Site Total
Clothing	106	2.71
Footgear	18	0.46
Shoe	18	0.46
Uppers	1	0.03
Eyelet, Shoe	1	0.03
Clothing Hardware	85	2.17
Button	72	1.84
Buckle	10	0.26
Belt	5	0.13
Suspender/Vest	3	0.08
Hook and Eyes	3	0.08
Hook	2	0.05
Clothing Manufacture Implements	3	0.08
Pin	3	0.08
"Straight" Pin	3	0.08
Adornment	70	1.79
Ornament	67	1.71
Hat Pin	1	0.03
Necklace	33	0.84
Bead	33	0.84
Hair Comb, Decorative	22	0.56
Comb Teeth	10	0.26
Watch	2	0.05
Works/Stem	2	0.05
Jewelstone	1	0.03
Toilet Article	1	0.03
Mirror	1	0.03
Fragment of Finished Artifact	77	1.97
Fragment, Adze (?)	1	0.03
Partially Prepared Raw Material	121	3.09
Manufacture Detritus	237	6.06
Structure Material	7	0.18
Dwelling/House Part	7	0.18
Door Part	5	0.13
Fastener	4	0.10
Lock	3	0.08
Key	1	0.03
Tumbler	1	0.03
Plate	1	0.03
Latch	1	0.03
Hinge	1	0.03
Construction Material	2	0.05
Furniture	4	0.10
Bed Part	4	0.10
Bed Spring	4	0.10

TABLE VII (continued) KOAIE ARTIFACT ANALYSIS BY FUNCTION

Artifact Functional Class	Total	Percent of Site Total
Firemaking Equipment	1	0.03
Match	1	0.03
Woodblock	1	0.03
Lighting Equipment	7	0.18
Lamp	7	0.18
Kerosene	7	0.18
Chimney	7	0.18
Dyes	3	0.08
Alae/Red Ochre	3	0.08
Tools and Appliances	2895	73.98
Weapons	15	0.38
Firearm Equipment	15	0.38
Projectile/Shell	15	0.38
Cartridge	15	0.38
Shotgun Shell	7	0.18
Twelve-Gauge	7	0.18
Pistol Shell	4	0.10
.32 Caliber	4	0.10
Rifle Shell	4	0.10
30.06 Caliber	3	0.08
45.70 Caliber	1	0.03
General Tools	1251	31.97
Abrading Tools	1042	26.63
Sharpener/Whetstone	8	0.20
Scraper	642	16.41
Microscraper	608	15.54
Abrader	390	9.97
Handheld Tool	389	9.94
Intensive	333	8.51
Intensive/Extensive	14	0.36
Extensive	42	1.07
Stationary Tool	1	0.03
Flat Action	1	0.03
**Combo Abrader + V-Scarf	86	2.20
Combo Intensive + V-Scarf	58	1.48
Combo Extensive + Grooving	1	0.03
Combo Intensive + Extensive + V-Scarf	8	0.20
Combo Extensive + V-Scarf	14	0.36
Combo Extensive + Intensive + Grooving	2	0.05
Combo Whetstone + V-Scarf	1	0.03
Combo Intensive + Scraper	1	0.03

**Combo = combination

TABLE VII (continued) KOAIE ARTIFACT ANALYSIS BY FUNCTION

Artifact Functional Class	Total	Percent of Site Total
Cutting Tool	42	1.07
Adze	9	0.23
Fine Work	7	0.18
Axe/Hatchet	1	0.03
Knife/Slicing Implement	4	0.10
European	3	0.08
"Sheath" Type	2	0.05
Handle	2	0.05
Pocket Knife	1	0.03
Handle	1	0.03
Side	1	0.03
Parting or "Notching" Action	28	0.72
"V" Scarf/Notching	28	0.72
Triangular File (European)	1	0.03
Local "Saw"	25	0.64
Piercing Tool	52	1.33
Awl	6	0.15
Drill	1	0.03
Borer/Corer	1	0.03
Scooping Tool/Spatula	6	0.15
Striking Tool	16	0.41
Chopper	2	0.05
Hammerstone	10	0.26
Pounder	3	0.08
Poi	3	0.08
Multi-Function Tool	4	0.10
Hammerstone + Abrader	4	0.10
Base, Grinding	3	0.08
Special Tools	17	0.43
Writing Tools	16	0.41
Pencil	15	0.38
Slate	15	0.38
Digging Stick	1	0.03
Miscellaneous Hardware	895	22.87
Fastener	889	22.72
Nails	814	20.80
Land Use	382	9.76
Fine Work	17	0.43
Nail, Shoe	1	0.03
Heavy Work	364	9.30
Marine Use	404	10.33
Sheathing Nail	391	9.99
Planking Nail	13	0.33
Spike	23	0.59

TABLE VII (continued) KOAIE ARTIFACT ANALYSIS BY FUNCTION

Artifact Functional Class	Total	Percent of Site Total
Tacks	7	0.18
Screw	4	0.10
Rivet	4	0.10
Washer	4	0.10
Staple	3	0.08
Large Staple	2	0.05
Bar Metal	2	0.05
Bell	1	0.03
Horseshoe	2	0.05
Strap	1	0.03
Chain	4	0.10
Chain Link	3	0.08
Utensil	717	18.32
Container	444	11.35
Liquid	387	9.89
Liquor	58	1.48
Whiskey	21	0.54
Gin	13	0.33
Soda Pop	1	0.03
Medicine	6	0.15
Castor Oil	2	0.05
Bitters	1	0.03
Condiments (Sauces, Etc.)	1	0.03
Beer	13	0.33
Milk	1	0.03
Baby Bottle (Nurser)	1	0.03
Toilet Materials	1	0.03
Perfume	1	0.03
Semi-Solid	1	0.03
Food	1	0.03
Catsup	1	0.03
Solids/Powders	15	0.38
Condiments (Soda, Food, Spices)	3	0.08
Baking Soda	2	0.05
Barrel	12	0.31
Band, Barrel	12	0.31
Cooking	13	0.33
Boiling	4	0.10
Frying	1	0.03
Stove	1	0.03
Evaporation Device	4	0.10
Salt Pan	4	0.10
Closures	19	0.49
Bottle	17	0.43
External Insert	4	0.10

TABLE VII (continued) KOAIE ARTIFACT ANALYSIS BY FUNCTION

Artifact Functional Class	Total	Percent of Site Total
Cork	1	0.03
Shell	3	0.08
Screw	4	0.10
Mason Jar Cap	4	0.10
Mason Jar Cap Insert	4	0.10
Internal Insert	2	0.05
Codd	2	0.05
External Seal	1	0.03
Outer Covering	6	0.15
Foil	5	0.13
Eating Equipment	254	6.49
Dishes	247	6.31
Plate	12	0.31
Cup	16	0.41
Saucer	1	0.03
Bowl	140	3.58
Utensils	7	0.18
Shellfish Extractor (Pick)	7	0.18
Watercraft Equipment	3	0.08
Grommet	1	0.03
Oarlock Receptacle	2	0.05
Games and Sports Equipment	8	0.20
Die	1	0.03
Marble	4	0.10
'Ulu Maika Stone	2	0.05
Record, Phonograph	1	0.03
Musical Instrument	1	0.03
Harmonica	1	0.03

TOTAL = 3913

TABLE VIII

KOAIE ARTIFACT ANALYSIS BY MATERIAL*

Artifact Material	Count	Percent of Total Count
Organic	1255	32.07
Bone	579	14.80
Mammal	539	13.77
Bird	13	0.33
Skin	38	0.97
Marine Invertebrate	588	15.03
Mollusca	113	2.89
Gastropoda	35	0.89
Patellidae	1	0.03
Cellana	1	0.03
Neritidae	1	0.03
Nerita	1	0.03
Nerita Polita	1	0.03
Littorinidae	1	0.03
Cerithidae	1	0.03
Cerithium	1	0.03
Cypraeidae	29	0.74
Cypraea	29	0.74
Cypraea caputserpentis	1	0.03
Cypraea mauritiana	15	0.38
Cypraea maculifera	12	0.31
Cypraea sulcidentata	1	0.03
Mitra	2	0.05
Pelecypoda	78	1.99
Pearl Shell	77	1.97
Echinodermata	248	6.34
Echinometridae	248	6.34
Heterocentrotus mammilatus	248	6.34
Coral	226	5.78
Porites	226	5.78
Porites Lobata	223	5.70
Sponge	1	0.03
Vegetal	24	0.61
Wood	7	0.18
Pre-European Trees	1	0.03

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE VIII (continued) KOAIE ARTIFACT ANALYSIS BY MATERIAL

Artifact Material	Count	Percent of Total Count
Heavy Woods	1	0.03
Imported Trees	4	0.10
Softwoods	4	0.10
Cork	1	0.03
Fruit/Nut	4	0.10
Coconut (Nut)	2	0.05
Pandanus	2	0.05
Gourd	1	0.03
Fiber	10	0.26
Coconut Fiber	1	0.03
Synthetic Fiber	2	0.05
Synthetic	26	0.66
Hard Rubber	23	0.59
Inorganic	2652	67.77
Ceramics	906	23.15
Permeable	294	7.51
Earthenware, European	247	6.31
Terra Cotta, European	1	0.03
Ironstone, European	1	0.03
Glazed Earthenware, European	212	5.42
Kaolin, European	3	0.08
Earthenware, Oriental	43	1.10
Impermeable	603	15.41
Stoneware, European	42	1.07
Glass	561	14.34
Impermeable, Oriental	4	0.10
Stoneware, Oriental	4	0.10
Metal	1140	29.13
Ferrous	570	14.57
Iron	507	12.96
Zinc-coated Iron	54	1.38
Non-Ferrous	568	14.52
Yellow Metal	527	13.47
Bronze	1	0.03
Brass	13	0.33
Lead	31	0.79
Aluminum	4	0.10
White Metal	2	0.05
Stone	606	15.49
Native Stone	581	14.85
Basalt	71	1.81
Vesicular	10	0.26
Close Grain	1	0.03
Cinder	40	1.02

TABLE VIII (continued) KOAIE ARTIFACT ANALYSIS BY MATERIAL

Artifact Material	Count	Percent of Total Count
Obsidian/Trachyte	450	11.50
Coral/Stone Conglomerate	5	0.13
Hematite (Ochre)	4	0.10
Andesite	51	1.30
Dense	23	0.59
Felsitic	8	0.20
Imported Stone	25	0.64
Flint/Chert	4	0.10
Marble	1	0.03
Slate	18	0.46
Graphite	2	0.05

TOTAL ARTIFACTS: 3913

TABLE IX

KOAIE MIDDEN ANALYSIS: MICROANALYSIS LEVELS*

Component	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	Percent of Shell
Shell	43,426.6	95.5	60.7	85.4	
Gastropoda	42,095.4	92.6	58.8	82.8	96.9
Patellidae	895.8	2.0	1.3	1.8	2.1
Cellana	806.0	1.8	1.1	1.6	1.9
C. sandwichensis	133.0	0.3	0.2	0.3	0.3
C. exerata	62.8	0.1	0.09	0.1	0.1
Trochidae	266.7	0.6	0.4	0.5	0.6
Trochus	266.7	0.6	0.4	0.5	0.6
Neritidae	3,964.1	8.7	5.5	7.8	9.1
Nerita	3,963.6	8.7	5.5	7.8	9.1
N. picea	3,864.6	8.5	5.4	7.6	8.9
N. polita	77.2	0.2	0.1	0.2	0.2
Turbinidae	10.4	0.02	0.01	0.02	0.02
T. argyrostoma	10.4	0.02	0.01	0.02	0.02
Littorinidae	18.2	0.04	0.03	0.04	0.04
Littorina	15.4	0.03	0.02	0.03	0.04
Modulidae	23.7	0.05	0.03	0.05	0.05
Modulus	23.7	0.05	0.03	0.05	0.05
M. tectum	23.7	0.05	0.03	0.05	0.05
Strombidae	42.9	0.09	0.06	0.08	0.10
Strombus	42.9	0.09	0.06	0.08	0.10
S. maculatus	42.2	0.09	0.06	0.08	0.10

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE IX (continued) KOAIE MIDDEN ANALYSIS: MICROANALYSIS LEVELS

Component	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	Percent of Shell
Cerithiidae	3.2	0.007	0.004	0.006	0.007
Cerithium	3.2	0.007	0.004	0.006	0.007
C. sinese	3.2	0.007	0.004	0.006	0.007
Hipponicidae	271.3	0.6	0.4	0.5	0.6
Sabia	18.6	0.04	0.03	0.04	0.04
S. cornica	18.3	0.04	0.03	0.04	0.04
Hipponix	252.7	0.6	0.4	0.5	0.6
H. pilosis	252.3	0.6	0.4	0.5	0.6
Bursidae	29.8	0.07	0.04	0.06	0.07
Bursa	29.8	0.07	0.04	0.06	0.07
B. gemmatum	22.4	0.05	0.03	0.04	0.05
B. bufonia	7.4	0.02	0.01	0.01	0.02
Cypraeidae	21,406.9	47.1	29.9	42.1	49.3
Cypraea	21,406.9	47.1	29.9	42.1	49.3
C. caputserpentis	16,754.7	36.9	23.4	33.0	38.6
C. mauritiana	951.2	2.1	1.3	1.9	2.2
C. maculifera	2,711.5	6.0	3.8	5.3	6.2
C. sulcidentata	42.2	0.09	0.06	0.08	0.1
C. isabella	19.6	0.04	0.03	0.04	0.05
C. helvola	12.5	0.03	0.02	0.02	0.03
C. granulata	77.5	0.2	0.1	0.2	0.2
Cassidae	325.5	0.7	0.5	0.6	0.7
Cassis	325.0	0.7	0.5	0.6	0.7
C. cornuta	325.0	0.7	0.5	0.6	0.7
Casmaria	0.5	0.001	0.001	0.001	0.002
Cymatiidae	351.4	0.8	0.5	0.7	0.8
Cymatium	312.4	0.7	0.4	0.6	0.7
C. nicobaricum	28.6	0.06	0.04	0.06	0.07
C. pilare	13.0	0.03	0.02	0.03	0.03

TABLE IX (continued) KOAIE MIDDEN ANALYSIS: MICROANALYSIS LEVELS

Component	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	Percent of Shell
Charonia	39.0	0.09	0.05	0.08	0.09
C. tritonis	35.3	0.08	0.05	0.07	0.08
Thaisidae	4,034.4	8.9	5.6	7.9	9.3
Drupa	3,621.1	8.0	5.1	7.1	8.3
D. ricinus	2,967.0	6.5	4.1	5.8	6.8
D. morus	527.7	1.2	0.7	1.0	1.2
D. robusidaeus	10.2	0.02	0.01	0.02	0.02
Morula	182.8	0.4	0.3	0.4	0.4
M. uva	5.4	0.01	0.007	0.01	0.01
M. granulata	172.9	0.4	0.2	0.3	0.4
Thais	186.0	0.4	0.3	0.4	0.4
T. harpa	13.2	0.03	0.02	0.03	0.03
T. aperta	101.8	0.2	0.1	0.2	0.2
T. intermedia	3.5	0.007	0.004	0.006	0.008
Nassariidae	8.9	0.02	0.01	0.02	0.02
Nassarius	8.9	0.02	0.01	0.02	0.02
N. papillosus	1.1	0.002	0.001	0.002	0.002
N. serta	7.4	0.02	0.01	0.01	0.02
Fasciolariidae	62.3	0.14	0.09	0.1	0.1
Latirus	62.3	0.14	0.09	0.1	0.1
L. nodatus	54.7	0.1	0.8	0.1	0.1
Conidae	3,522.8	7.8	4.9	6.9	8.1
Conus	3,521.3	7.7	4.9	6.9	8.1
C. rattus	4.5	0.01	0.006	0.008	0.01
C. distans	632.4	1.4	0.9	1.2	1.5
C. ebraeus	13.8	0.03	0.02	0.03	0.03
C. imperialis	7.7	0.02	0.01	0.02	0.02
C. abbreviatus	2.3	0.005	0.003	0.004	0.005

TABLE IX (continued) KOAIE MIDDEN ANALYSIS: MICROANALYSIS LEVELS

Component	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	Percent of Shell
C. textile	17.8	0.04	0.02	0.04	0.04
C. catus	953.8	2.1	1.3	1.9	2.2
C. chaldaeus	75.3	0.2	0.1	0.1	0.2
C. striatus	86.2	0.2	0.1	0.2	0.2
C. pennaceus	0.9	0.002	0.001	0.001	0.002
C. vitulinus	11.4	0.03	0.02	0.02	0.03
Olividae	0.9	0.002	0.001	0.001	0.002
Oliva	0.9	0.002	0.001	0.001	0.002
O. sandwichensis	0.9	0.002	0.001	0.001	0.002
Opisthobranchia	2.6	0.006	0.003	0.006	0.005
Pulmonata	6.1	0.01	0.008	0.01	0.01
Siphonariidae	6.1	0.01	0.008	0.01	0.01
Siphonaria	6.1	0.01	0.008	0.01	0.01
S. normalis	6.1	0.01	0.008	0.01	0.01
Bivalvia	865.8	1.9	1.2	1.7	2.0
Anisomyaria	349.9	0.8	0.5	0.7	0.8
Isognomoniidae	349.9	0.8	0.5	0.7	0.8
Isognomon	335.9	0.7	0.5	0.7	0.8
Heterdonta	368.5	0.8	0.5	0.7	0.8
Tellinidae	7.1	0.02	0.009	0.01	0.02
Tellina	7.1	0.02	0.009	0.01	0.02
T. rugosa	1.1	0.002	0.001	0.003	0.002
Trachycardium	3.6	0.008	0.005	0.007	0.008
Periglypta	354.6	0.8	0.5	0.7	0.8
P. reticulata	8.2	0.02	0.01	0.02	0.02
P. edmondsoni	9.1	0.02	0.01	0.02	0.02

TABLE IX (continued) KOAIE MIDDEN ANALYSIS: MICROANALYSIS LEVELS

Component	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	Percent of Mammal
Mammal	1,409.9	3.1	2.0	2.8	
Pig	115.3	0.3	0.2	0.2	8.2
Dog	204.0	0.4	0.3	0.4	14.5
Foreign (sheep, cow, etc.)	373.8	0.8	0.5	0.7	26.5
Sea Urchin	4,099.5	9.0	5.7	8.1	
Kukui	883.5	1.9	1.2	1.7	
Fish	1,002.3	2.2	1.4	2.0	
					Percent of Bird
Bird	13.9	0.03	0.02	0.03	
Chicken	3.6	0.008	0.005	0.007	25.9
Turkey	5.6	0.01	0.007	0.01	40.3
Sea Bird	2.4	0.005	0.003	0.004	17.3
Turtle	12.0	0.03	0.02	0.02	
TOTAL FOOD	50,847.7	111.8	71.1		

TABLE IX (continued) KOAIE MIDDEN ANALYSIS: MICROANALYSIS LEVELS

Component	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	Percent of Non-Food
Metal	5,360.9	11.8	7.8		25.8
Glass	9,137.5	20.1	13.3		44.1
Pottery	4,984.5	11.0	7.2		24.0
Basalt Flakes	756.6	1.7	1.1		3.6
Obsidian Flakes	477.0	1.0	0.6		2.3
TOTAL NON-FOOD	20,716.5	45.6	28.9		100.0
SAMPLE TOTAL	71,564.2	157.4			

TABLE X

KOAIE ARTIFACT ANALYSIS:

USE FACETS OF SEA URCHIN SPINE FILES*

TAXON	NUMBER	PERCENT
Distal Use	44	13.9
One Flat Facet	19	6.0
Two Flat Facets	5	1.6
Three Flat Facets	4	1.3
Four Flat Facets	1	0.3
Concave	2	0.6
Grooved	2	0.6
Curved	5	1.6
Rounded	6	1.9
Proximal Use	23	7.3
One Flat Facet	8	2.5
Two Flat Facets	2	0.6
Three Flat Facets		
Four Flat Facets	1	0.3
Concave	4	1.3
Grooved	2	0.6
Curved	5	1.6
Rounded	1	0.3
Unknown/Middle Use	249	78.8
One Flat Facet	76	24.0
Two Flat Facets	10	3.2
Three Flat Facets	8	2.5
Four Flat Facets	2	0.6
Concave	36	11.4
Grooved	32	10.1
Notched	4	1.3
Curved	77	24.4
Rounded	4	1.3

TOTAL USE FACETS = 316

TOTAL SEA URCHIN SPINES = 248

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE XI

KOAIE FORMAL ARTIFACT ANALYSIS: SINKERS*

TAXON	NUMBER	PERCENT
Coffee Bean	3	16.7
Bottom + Top Grooving	3	16.7
Breadloaf	6	33.3
Lateral Grooving	1	5.6
Bottom Grooving	1	5.6
Lateral + Bottom Grooving	4	22.2
Plummet	2	11.1
Top Grooving	1	5.6
Oval	7	38.9
Lateral + Bottom Grooving	1	5.6
Lengthwise Grooving	6	33.3

TOTAL SINKERS = 18

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE XII

KOAIE FISHHOOK ANALYSIS BY MATERIAL*

ARTIFACT MATERIAL	COUNT	PERCENT OF TOTAL COUNT
Organic	192	88.5
Bone	174	80.2
Mammal	164	75.6
Marine invertebrate	17	7.8
Mollusca	17	7.8
Cypraea mauritiana	1	0.5
Pearlshell	16	7.4
Synthetic	1	0.5
Inorganic	25	11.5
Metal	25	11.5
Ferrous	22	10.1
Iron	20	9.2
Yellow metal	3	1.4

TOTAL FISHHOOKS = 217

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE XIII

KOAIE SINKER ANALYSIS BY MATERIAL*

ARTIFACT MATERIAL	COUNT	PERCENT OF TOTAL COUNT
Porites lobata (coral)	9	50.0
Basalt	3	16.7
Vesicular basalt	1	5.6
Coral/Stone conglomerate	4	22.2
Hematite (ochre)	1	5.6
Andesite	1	5.6

TOTAL SINKERS = 18

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE XIV

HAWAIIAN AND SCIENTIFIC NAMES FOR KOAIE FISH REMAINS

Monocanthidae (filefish)

Loulu, 'Ō'ili, 'Ō'ili-lepa, 'Ō'ili-uwī'uwī,* 'Ōhua

Labridae (wrasse)

'A'ala'ihi, Hīnālea lau-wili, 'A'awa, 'Aki-lolo, Hīnālea 'i'iwi, 'Awela, Hou, 'Ōlani, 'Ōlali, Palae'a, 'E'a, Hīnālea, Hilu, Hilu lau-wili, Hīnālea 'Aki-lolo, Kupoupou, Lae-nihi, Lā'ō, 'Ōhua, Pō'ou, Pa'awela, Mālamalama, 'Ōpule, Hilu, 'Ananalu, 'Ōmaka, Hīnālea luahine, Lolo

Carcharhinidae (shark)

Manō

Holocentridae (squirrelfish)

'Ala'ihi, 'Ū'ū, Uukanipo, Pā'ū'ū

Pomacentridae (damselfish)

'Ālo'ilo'i, Hā-nui, Kūpīpī, 'Ao'ao-nui, Mamamo, Mamo, Maomao

Acanthuridae (surgeonfish)

'Api, Kala, Pukulakala, Kole, La'ī-pala, Lau'ī-pala, Lau-kī-pala, Mā'i'i'i, 'I'i, Maiko, Māikoiko, Maneoneo, Marini, Na'ena'e, Pakalakala, Pakala, Pāku'iku'i, Palani, Pala, Pualu, Palapala, Puwalu, Kakaki

Muraenidae (eel)

Pūhi, Pūhi-lau-milo, Pūhi-wela

Balistidae (triggerfish)

Humuhumu

TABLE XIV (continued) HAWAIIAN AND SCIENTIFIC NAMES FOR KOAIE FISH REMAINS

Sphyraenidae (barracuda)

Kākū, Kawale'ā, Kawele'ā

Sparidae (snapper)

Mamamu, Mū*

Tetradontidae (puffer)

'O'opu-hue,* Makimaki, Keke'e

Diodontidae (spiny puffer)

'O'opu-kawa, 'O'opu-hue*

Scaridae (parrotfish)

Lauia, Pālukaluka, Pānuhunuhu, Uhu, Uhu'ula, 'Ōmalemale

Some of these native fish names are synonyms, local island names, or names of various growth stages and not necessarily types that would be placed into different genera or species below the common family level. An example of the problem in mating the Hawaiian and Linnean taxonomic schemes is seen with 'O'opu-hue which scientifically is split into two distinct families.

*definitely identified in the Koaie midden

APPENDIX E

APAAPAA 1 DATA

TABLE XV

APAAPAA 1

ARTIFACT ANALYSIS BY FUNCTION*

Artifact Functional Class	Total	Percent of Site Total
Fishing Gear	1	0.4
Inshore Gear	1	0.4
Lure	1	0.4
Octopus Lure	1	0.4
Cowry Shell	1	0.4
Smoking Equipment	5	1.8
Pipe	5	1.8
Pipe, Tobacco	5	1.8
Pipe Stem, Tobacco	3	1.1
Pipe Bowl, Tobacco	1	0.4
Clothing	34	12.5
Clothing Hardware	34	12.5
Button	33	12.1
Hook and Eyes	1	0.4
Hook	1	0.4
Adornment	58	21.3
Ornament	58	21.3
Bead	58	21.3
Fragment of Finished Artifact	34	12.5
Fragment, adze (?)	2	0.7
Partially Prepared Raw Material	1	0.4
Manufacture Detritus	7	2.6
Tools and Appliances	104	38.2
General Tools	34	12.5
Abrading Tools	22	8.1
Sharpener/Whetstone	2	0.7

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE XV (continued) APAAPAA 1 ARTIFACT ANALYSIS BY FUNCTION

Artifact Functional Class	Total	Percent of Site Total
Scraper	16	5.9
Microscraper	14	5.1
Abrader (Shaping/Smoothing)	2	0.7
Handheld Tool	1	0.4
Extensive	1	0.4
Stationary Tool	1	0.4
Rounding Action (Grooved)	1	0.4
**Combo Abrader + V-Scarf	1	0.4
**Combo Intensive + Extensive + V-Scarf	1	0.4
Striking Tool	7	2.6
Chopper	1	0.4
Hammerstone	3	1.1
Pounder	3	1.1
Poi	2	0.7
Multi-Function Tool	3	1.1
Hammerstone + Abrader	3	1.1
Base, Grinding	1	0.4
Special Tools	13	4.8
Writing	13	4.8
Slate	13	4.8
Miscellaneous Hardware	7	2.6
Fasteners	7	2.6
Nails	4	1.5
Land Use	3	1.1
Fine Work	1	0.4
Heavy Work	2	0.7
Marine Use	1	0.4
Sheathing Nail	1	0.4
Tacks	1	0.4
Screw	1	0.4
Utensil	50	18.4
Container	31	11.4
Liquid	30	11.0
Cooking	1	0.4
Boiling	1	0.4
Closures	1	0.4
Bottle	1	0.4
Outer Covering	1	0.4
Foil	1	0.4
Eating Equipment	18	6.6
Dishes	18	6.6
Plate	7	2.6
Bowl	10	3.7

**Combo = combination

TABLE XV (continued) APAAPAA 1 ARTIFACT ANALYSIS BY FUNCTION

Artifact Functional Class	Total	Percent of Site Total
Games and Sports Equipment	2	0.7
Marble	1	0.4
Papamū	1	0.4

TOTAL ARTIFACTS = 271

TABLE XVI

APAAPAA 1

ARTIFACT ANALYSIS BY MATERIAL*

Artifact Material	Count	Percent of Total Count
Organic	27	10.0
Bone	24	8.8
Mammal	24	8.8
Skin	1	0.4
Marine Invertebrate	2	0.7
Mollusca	2	0.7
Gastropoda	1	0.4
Cypraeidae	1	0.4
Cypraea	1	0.4
Cypraea mauritiana	1	0.4
Inorganic	242	90.0
Ceramics	125	46.0
Permeable	22	8.1
Earthenware, European	18	6.6
Glazed Earthenware, European	18	6.6
Kaolin, European	4	1.5
Impermeable, European	102	37.5
Glass	102	37.5
Metal	58	21.3
Ferrous	10	3.7
Iron	10	3.7
Non-Ferrous	48	17.6
Yellow Metal	46	16.9
Lead	1	0.4
White Metal	1	0.4
Stone	59	21.7
Native Stone	26	9.6
Basalt	5	1.8
Vesicular	1	0.4
Cinder	1	0.4
Obsidian/Trachyte	3	1.1

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE XVI (continued) APAAPAA 1 - ARTIFACT ANALYSIS BY MATERIAL

Artifact Material	Count	Percent of Total Count
Andesite	18	6.6
Dense	5	1.8
Felsitic	1	0.4
Imported Stone	33	12.1
Flint/Chert	18	6.6
Slate	15	5.5

TOTAL ARTIFACTS = 271

TABLE XVII

APAAPAA 1 MIDDEN ANALYSIS*

Components	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	% Shell
Shell	1,869.9	4.1	25.0	43.1	
Gastropoda	1,781.5	3.9	23.7	41.0	95.3
Patellidae	301.4	0.7	4.0	6.9	16.1
Cellana	301.4	0.7	4.0	6.9	16.1
Neritidae	83.0	0.2	1.1	1.9	4.4
Nerita	83.0	0.2	1.1	1.9	4.4
N. picea	82.9	0.2	1.1	1.9	4.4
Littorinidae	0.9	0.002	0.01	0.02	0.05
Littorina	0.9	0.002	0.01	0.02	0.05
Hipponicidae	1.4	0.003	0.02	0.03	0.07
Hipponix	1.4	0.003	0.02	0.03	0.07
H. pilosis	1.4	0.003	0.02	0.03	0.07
Cypraeidae	785.2	1.7	10.5	18.1	42.0
Cypraea	785.2	1.7	10.5	18.1	42.0
C. caputserpentis	476.5	1.0	6.3	11.0	25.5
C. mauritiana	48.8	0.1	0.7	1.1	2.6
C. maculifera	219.1	0.5	2.9	5.0	11.7
Cassidae	52.4	0.1	0.7	1.2	2.8
Cassis	52.4	0.1	0.7	1.2	2.8
C. cornuta	52.4	0.1	0.7	1.2	2.8
Thaisidae	266.5	0.6	3.6	6.1	14.3
Drupa	260.2	0.6	3.5	6.0	13.9
D. ricinus	173.0	0.4	2.3	4.0	9.3
D. morus	81.2	0.2	1.1	1.9	4.3

*Table entries are nested according to the indented hierarchy. Each hierarchy level entry is the total of its sub-levels, plus those entries not identifiable to a lower level.

TABLE XVII (continued) APAAPAA 1 MIDDEN ANALYSIS

Components	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	
					% Shell
Morula	0.6	0.001	0.008	0.01	0.03
M. granulata	0.6	0.001	0.008	0.01	0.03
Conidae	132.9	0.3	1.8	3.1	7.1
Conus	132.9	0.3	1.8	3.1	7.1
C. catus	10.9	0.02	0.1	0.3	0.6
Bivalvia (Pelecypoda)	39.0	0.09	0.5	0.9	2.1
Anisomyaria	1.4	0.003	0.02	0.03	0.07
Isognomoniidae	1.4	0.003	0.02	0.03	0.07
Isognomon	1.4	0.003	0.02	0.03	0.07
Heterdonta	15.4	0.03	0.2	0.4	0.8
Trachycardium	0.6	0.001	0.008	0.01	0.03
Periglypta	14.8	0.03	0.2	0.3	0.8
					% Mammal
Mammal	1,298.9	2.9	17.3	29.9	
Pig	64.0	0.1	0.9	1.5	4.9
Dog	4.7	0.01	0.06	0.1	0.4
Foreign (sheep, cow, etc.)	357.2	0.8	4.8	8.2	27.5
Sea Urchin	32.8	0.07	0.4	0.8	
Kukui	1,056.3	2.3	14.1	24.3	
Fish	55.6	0.1	0.7	1.3	
Bird	29.6	0.07	0.4	0.7	
Chicken	8.3	0.02	0.1	0.2	28.0
Turtle	0.0	0.0	0.0	0.0	
TOTAL FOOD	4,343.1	9.5	57.9		

TABLE XVII (continued) APAAPAA 1 MIDDEN ANALYSIS

Component	Weight (Grams)	Weight (Pounds)	Percent of Total	Percent of Food	Percent of Non-Food
Metal	706.4	1.6	9.4		22.3
Glass	762.0	1.7	10.2		24.1
Pottery	323.7	0.7	4.3		10.2
Basalt Flake	18.5	0.04	0.2		0.6
Obsidian Flake	39.4	0.09	0.5		1.2
Slate	58.6	0.1	0.8		1.9
Flint	57.6	0.1	0.8		1.8
Coral	1,195.5	2.6	16.0		37.8
TOTAL NON-FOOD	3,161.7	6.9	42.1		100.0

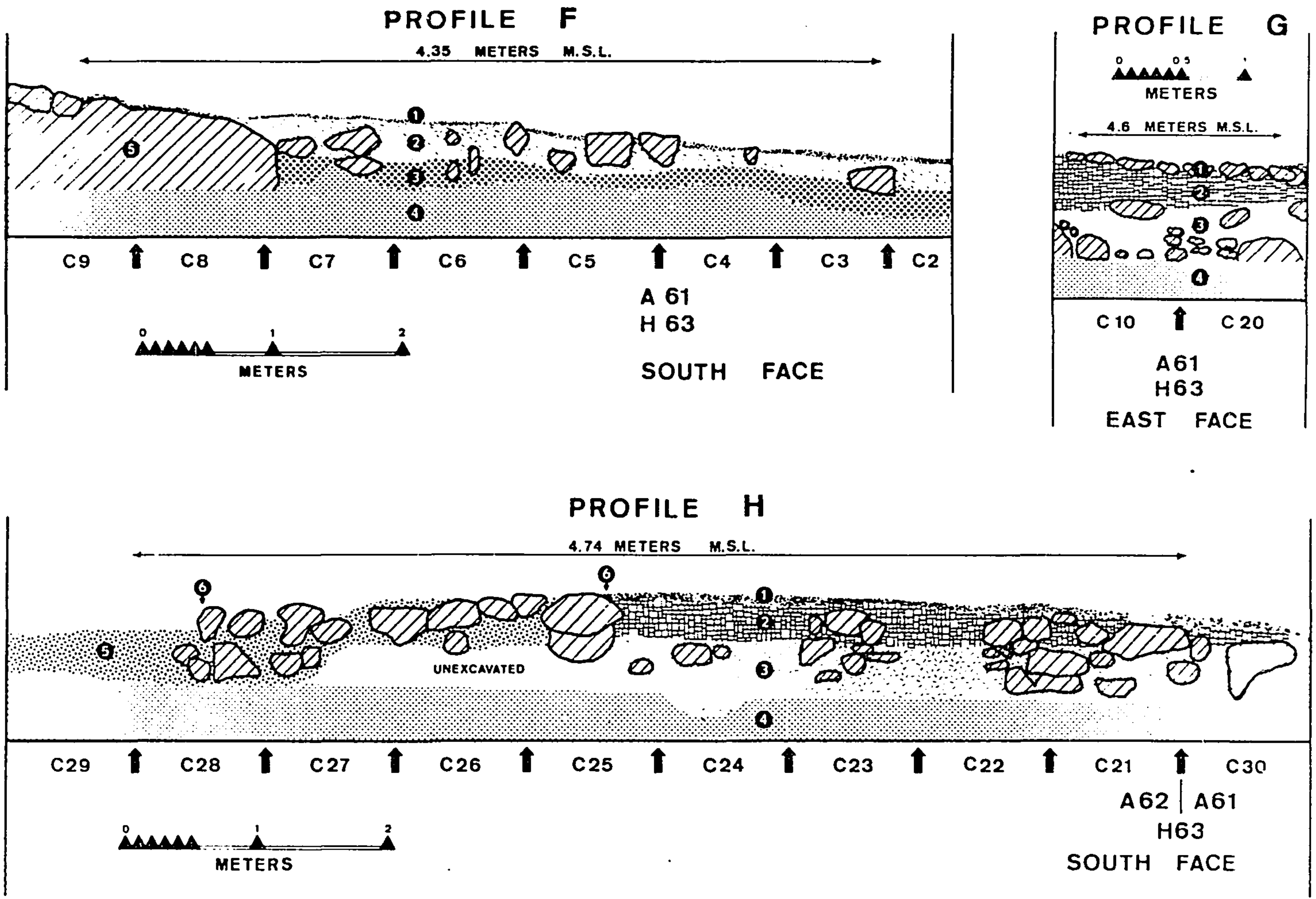
TOTAL FOOD & NON-FOOD	7,504.8	16.3

APPENDIX F

PROFILES

Figures 5 and 6 key to Map 9

by profile letter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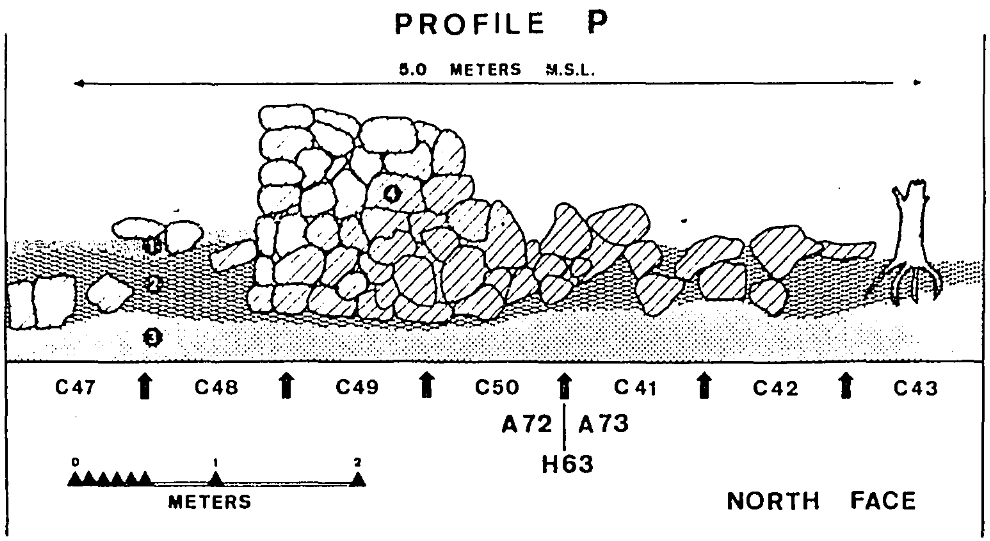
A 61
H 63
METERS
SOUTH FACE
PROFILE G
METERS
4.6 METERS M.S.L.
C10 C20
A61
H63
EAST FACE
PROFILE H
4.74 METERS M.S.L.
UNEXCAVATED
C29 C28 C27 C26 C25 C24 C23 C22 C21 C30
A62 A61
H63
METERS
SOUTH FACE

Fig. 5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C48
C49
C50
C41
C42
C43
A72 | A73
H63
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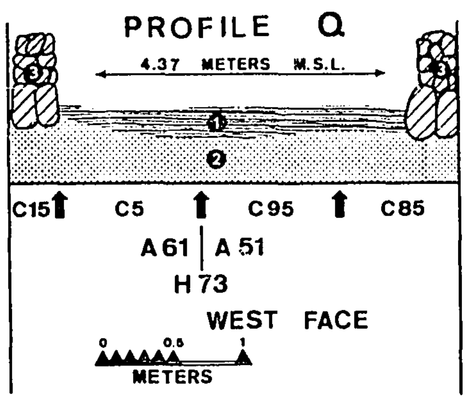
METERS
NORTH FACE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C5
C95
C85
A61 | A51
H73
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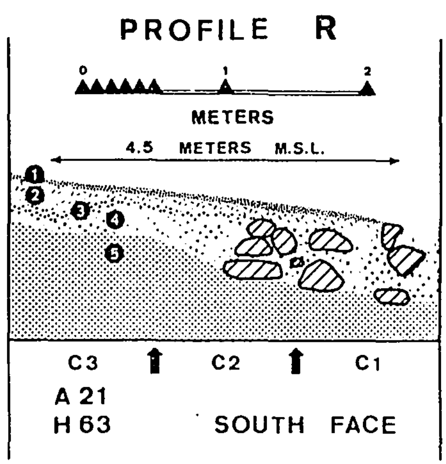
0.5
1
METERS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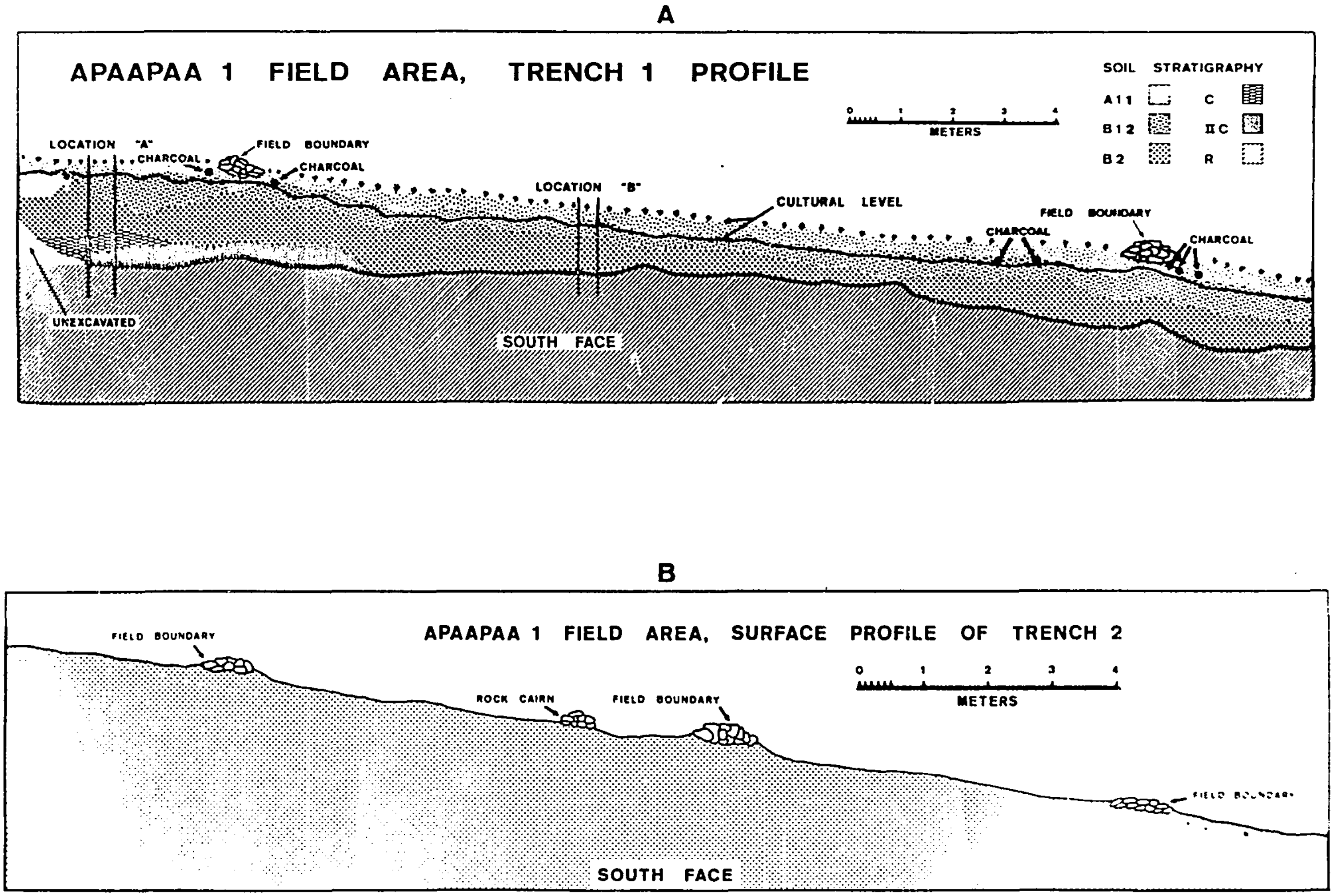
1
2
METERS
4.5 METERS M.S.L.
C3
C2
C1
A 21
H 63
SOUTH FACE

Fig. 6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APAAPAA 1 FIELD AREA, TRENCH 1 PROFILE
SOIL STRATIGRAPHY
A11
B12
B2
C
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R
0 1 2 3 4
METERS
LOCATION "A"
CHARCOAL
FIELD BOUNDARY
CHARCOAL
LOCATION "B"
CULTURAL LEVEL
FIELD BOUNDARY
CHARCOAL
CHARCOAL
UNEXCAVATED
SOUTH FACE
B
APAAPAA 1 FIELD AREA, SURFACE PROFILE OF TRENCH 2
FIELD BOUNDARY
ROCK CAIRN
FIELD BOUNDARY
0 1 2 3 4
METERS
SOUTH FACE

Fig. 7

APPENDIX G

ARTIFACT ILLUSTRATIONS

FIGURE 8

Artifacts: Fishhooks

Illus. #	Artifact Type	Number	Material
1	Fishhook, jabbing	3082	Bone
2	Fishhook fragment, jabbing	2027	Bone
3	Fishhook, jabbing	1642	Bone
4	Fishhook, jabbing	0675	Bone
5	Fishhook, jabbing	0098	Bone
6	Fishhook, jabbing	1271	Bone
7	Fishhook, jabbing	0715	Bone
8	Fishhook, jabbing	2805	Bone
9	Fishhook, jabbing	2776	Bone
10	Fishhook, rotating	2132	Bone
11	Fishhook, rotating	0467	Bone
12	Fishhook, rotating	0491	Bone
13	Fishhook, rotating	1533	Bone
14	Fishhook, rotating	2740	Bone
15	Fishhook, rotating	2143	Bone
16	Fishhook, rotating	0672	Bone
17	Fishhook fragment, rotating	2174	Bone
18	Fishhook fragment, rotating	2106	Bone
19	Fishhook fragment	2110	Bone
20	Incomplete manufacture, fishhook	0080	Bone
21	Incomplete manufacture, fishhook	1497	Bone
22	Incomplete manufacture, fishhook	0812	Bone
23	Incomplete manufacture, fishhook	2118	Bone
24	Incomplete manufacture, fishhook	2727	Bone
25	Bonito lure shank fragment (pa)	1473	Pearlshell
26	Bonito lure point	0494	Bone
27	Bonito lure point	0084	Pearlshell
28	Bonito lure point	1874	Bone
29	Bonito lure point	3077	Bone
30	Bonito lure point	2793	Pearlshell
31	Bonito lure point	2183	Pearlshell

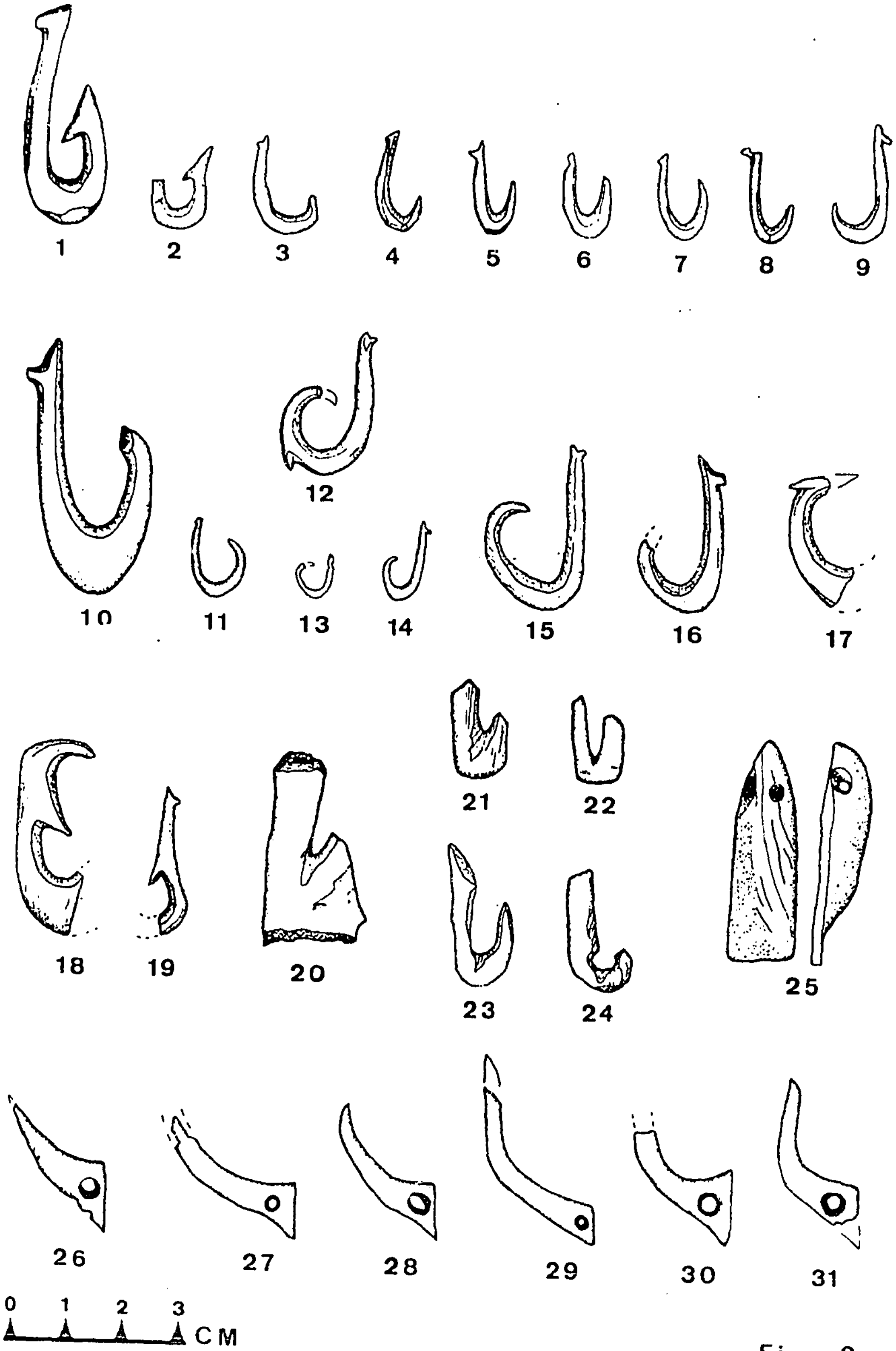
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Fig. 8

FIGURE 9

Artifacts: Fishhooks

Illus. #	Artifact Type	Number	Material
	Two-piece Fishhook Points, Jabbing, barbed		
1		1878	Shell (cowry)
2		2808	Bone
3		1539	Bone
4		1519	Bone
5		2737	Bone
6		1466	Bone
7	Two-piece fishhook point, rotating, unbarbed	1868	Bone
	Two-piece fishhook points, Jabbing, Unbarbed		
8		1813	Bone
9		1962	Bone
10		2886	Bone
11		1769	Bone
12		1477	Bone
13		1261	Bone
14		0816	Bone
15		2853	Bone
16		2831	Pearlshell
	Octopus lure points		
17		2561	Bone
18		2445	Bone
19	Fishhook fragment	0029	Synthetic
20	Fishhook, one piece, rotating	3460	Iron
21	Fishhook, two piece, shank	2756	Bone
22	Fishhook, two piece, shank	1975	Bone
23	Fishhook head	2021	Bone
24	Fishhook head	1845	Iron
25	Fishhook, one piece, jabbing	1255	Iron
26	Fishhook, one piece, jabbing	0340	Yellow Metal
27	Fishhook, one piece, rotating	0001	Iron

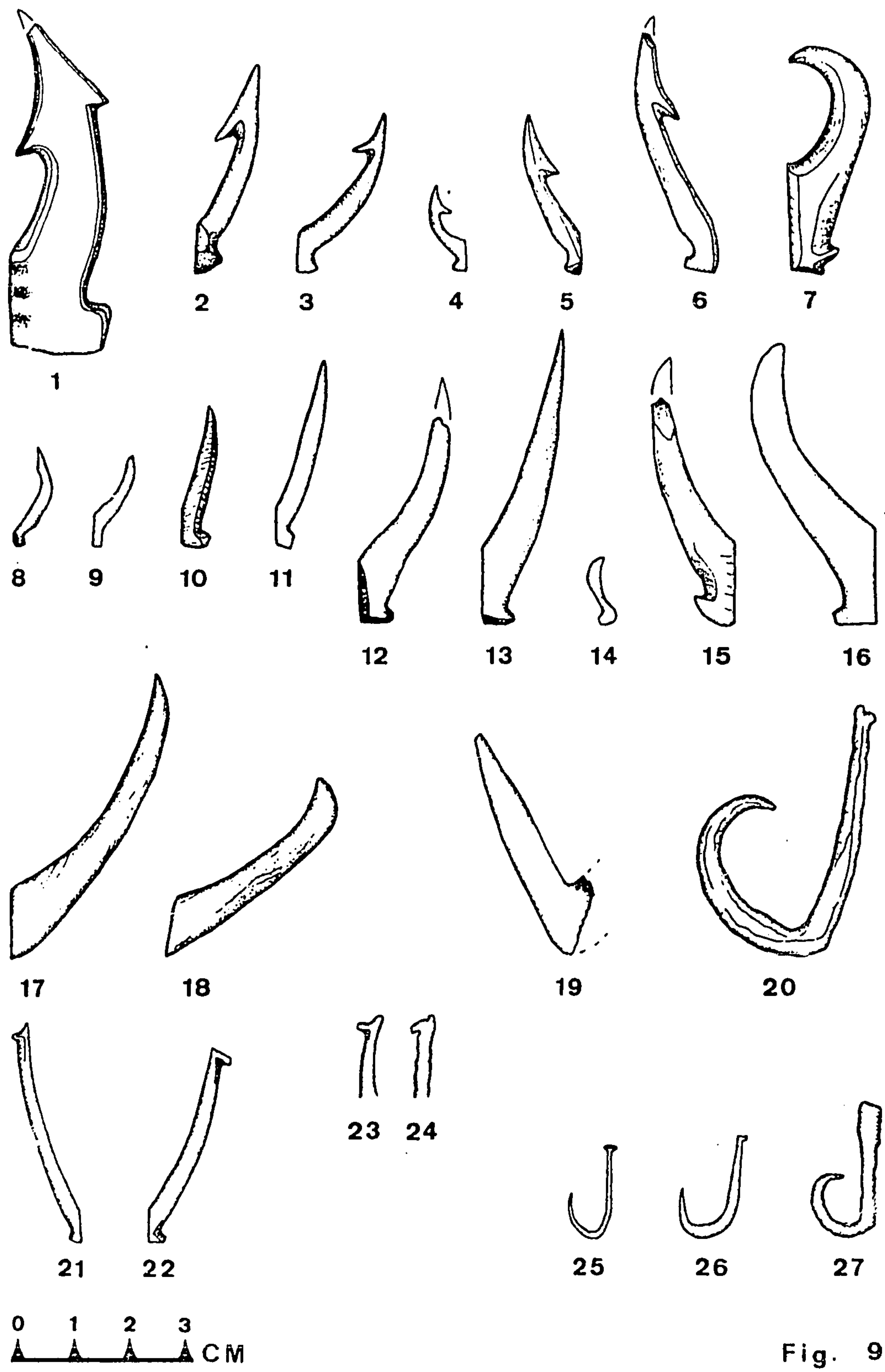
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Fig. 9

FIGURE 10

Artifact: Digging Stick

1 Probable digging stick of native heavy wood

(No. 1392)

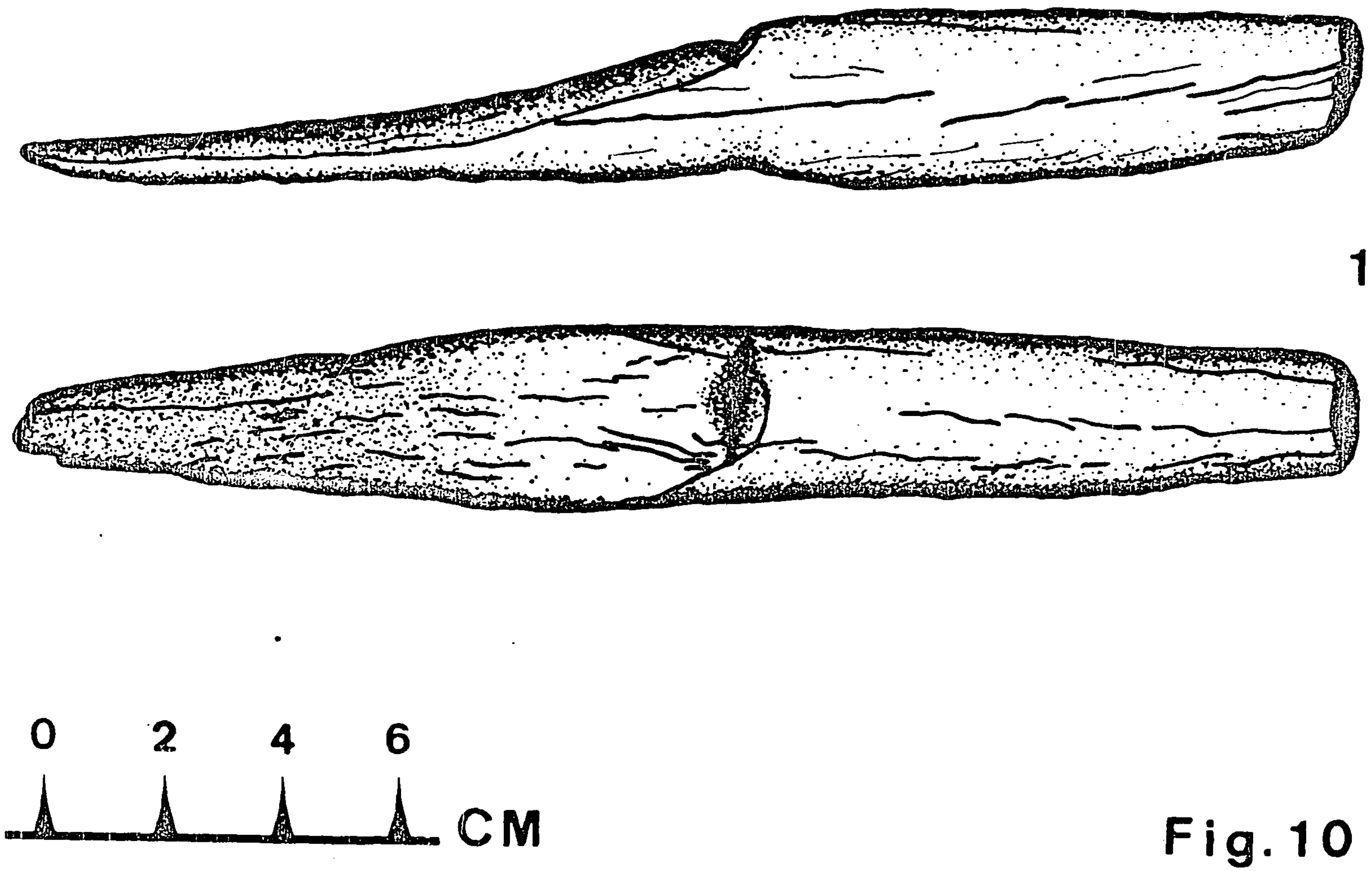

Fig. 10

APPENDIX H

EXTRACTS FROM THE JOURNAL OF WILLIAM ELLIS (1963)

NOTE: The orthography of Ellis has been retained in the text while the modern place names have been substituted in the headings.

KAILUA (1)

Kairua, though healthy and populous, is destitute of fresh water, except what is found in pools, or small streams, in the mountains, four or five miles from the shore. (p. 29)

The houses, which are neat, are generally built on the sea-shore, shaded with cocoa-nut and kou trees, which greatly enliven the scene.

The environs were cultivated to a considerable extent; small gardens were seen among the barren rocks on which the houses are built, wherever soil could be found sufficient to nourish the sweet potato, the watermelon, or even a few plants of tobacco, and in many places these seemed to be growing literally in the fragments of lava, collected in small heaps around their roots.

The next morning, Messrs. Thurston, Goodrich, and Harwood, walked towards the mountains, to visit the high and cultivated parts of the district. After travelling over the lava for about a mile, the hollows in the rocks began to be filled with a light brown soil; and about half a mile further, the surface was entirely covered with a rich mould, formed by decayed vegetable matter and decomposed lava.

Here they enjoyed the agreeable shade of bread-fruit and 'ōhi'a trees. . . . (p. 31)

The path now lay through a beautiful part of the country, quite a garden compared with that through which they had passed on first leaving the town. It was generally divided into small fields, about fifteen rods square, fenced with low stone walls, built with fragments of lava gathered from the surface of the enclosures. These fields were planted with bananas, sweet potatoes, mountain taro, paper mulberry plants, melons, and sugar-cane, which flourished luxuriantly in every direction.

Having travelled about three or four miles through this delightful region, and passed several valuable pools of fresh water, they arrived at the thick woods, which extend several miles up the sides of the lofty mountain that rises immediately behind Kairua.

Among the various plants and trees that now presented themselves, they were much pleased with a species of tree ferns, whose stipes were about five feet long, and the stem about fourteen feet high, and one foot in diameter. (p. 32)

Numbering the houses for one mile along the coast, they found them to be 529; and allowing an average of five persons to each house, the inhabitants in Kairua will amount to 2645 persons. This certainly does not exceed the actual population, as few of the houses are small, and many of them large, containing two or three families each. (p. 36)

Leaving Kairua, we passed through the villages thickly scattered along the shore to the southward.

The sides of the hills, laid out for a considerable extent in gardens and fields, and generally cultivated with potatoes, and other vegetables, were beautiful.

KAILUA (1) TO KEAUHOU (2)

During our walk from Kairua to this place we counted six hundred and ten houses, and allowed one hundred more for those who live among the plantations on the sides of the hills.

Reckoning five persons to each house, which we think not far from a correct calculation, the population of the tract through which we have travelled today will be about 3550 souls. (p. 76)

KEAUHOU (2) TO KAAWALOA (3)

During our journey today, we have numbered 443 houses . . . (p. 109)

HONAUNAU (4)

After breakfast, Mssrs. Thurston and Goodrich examined the inland part of the district, and found, after proceeding about two miles from the sea, that the ground was generally cultivated.

They passed through considerable groves of bread-fruit trees, saw many cocoa-nuts, and numbers of the prickly pear (cactus ficus indicus), growing very large, and loaded with fruit. They also found many people residing at the distance of from two to four miles from the beach, in the midst of their plantations, who seemed to enjoy an abundance of provisions, seldom possessed by those on the sea shore. (p. 109)

The town contains 147 houses. . . . (p. 109)

KAILUA (1) TO HONAUNAU (4)

The coast for twenty miles to the northward, includes not less perhaps than forty villages, either on the shore or a short distance inland, and contains probably a population of 20,000 souls, among whom a missionary might labour with facility. (p. 116)

KEOKEA (5) TO KALAHIKI (6)

They passed through two villages, containing between three and four hundred inhabitants, and reached Kalahiti about four in the afternoon. (p. 118)

KAPUA (7)

. . . about five in the afternoon landed at Kapua, a small and desolate-looking village, on the southwest point of Hawaii, and about twenty miles distant from Kalahiti. (p. 124)

At this place we hired a man to go about seven miles into the mountains for fresh water; but he returned with only one calabash full; a very inadequate supply as our whole company had suffered much from thirst, and the effects of the brackish water we had frequently drank since leaving Honaunau.

Nothing can exceed the barren and solitary appearance of this part of the island, not only from the want of fresh water, but from the rugged and broken tracts of lava of which it appears to be entirely composed.

. . . we knew of no village before us containing more than five or six houses for nearly thirty miles' distance. (p. 125)

GENERAL DESCRIPTION OF THE KONA DISTRICT (1 to 8 plus more to the north)

Kona is the most populous of the six great divisions of Hawaii, and being situated on the leeward side, would probably have been the most fertile and beautiful part of the island, had it not been overflowed by floods of lava.

The northern part, including Kairua, Kearake'kua, and Honaunau, contains a dense population; and the sides of the mountains are cultivated to a considerable extent; but the south part presents a most inhospitable aspect. The population is thin, consisting principally of fishermen, who cultivate but little land, and that at the distance of from five to seven miles from the shore. (p. 126)

KA'U DISTRICT

On entering it, the same gloomy and cheerless desert of rugged lava spread itself in every direction from the shore to the mountains. Here and there at distant intervals they passed a lonely house, or a few wandering fishermen's huts, with a solitary shrub, or species of thistle, struggling for existence among the crevices in the blocks of scoriae and lava. All besides was "one vast desert, dreary, bleak, and wild". (p. 126)

KAILIKII (9)

At 10 A.M. Mr. Thurston preached to the people of Tairitii, and the neighbouring village of Patini, all of whom are fishermen. (p. 128)

KAHUKU BLUFF (Above the pali to the northeast of Kailikii)

A beautiful country now appeared before us, and we seemed all at once transported to some happier island. . . .

The rough and desolate tract of lava, with all its distorted forms, was exchanged for the verdant plain, diversified with gently rising hills, and sloping dales, ornamented with shrubs, and gay with blooming flowers. We saw, however, no stream of water during the whole of the day; but, from the luxuriance of the herbage in every direction, the rains must be frequent or the dews heavy.

About noon we reached Kalehu, a small village, upwards of four miles from Tairitii. (not located; p. 130)

We . . . resumed our journey over the same beautiful country, which was partially cultivated, and contained a numerous, though scattered population. (p. 131)

The path led us through several fields of mountain taro (a variety of the arum), a root which appears to be extensively cultivated in many parts of Hawaii. It was growing in dry sandy soil, into which our feet sank two or three inches every step we took.

It is, however, very palatable, and forms a prime article of food in those parts of the island, where there is a light soil, and but little water. (p. 131)

KAULU (Not found but between Kailikii and Waiohinu)

. . . we reached Kauru, a small village environed with plantations. . . .

During the evening, a baked pig, with some potatoes, and taro, was brought for our supper, of which we made a hearty repast. (p. 131)

KAULU TO WAIOHINU (10)

. . . we left Kauru, and, taking an inland direction, travelled over a fertile plain, covered with a thin yet luxuriant soil. Sometimes the surface was strewed with small stones, or fragments of lava, but in general it was covered with brushwood.

The population in this part did not appear concentrated in towns and villages, as it had been along the sea-shore, but scattered over the whole face of the country which appeared divided into farms of varied extent, and upon these houses generally stood singly, or in small clusters, seldom exceeding four or five in number. (p. 132)

WAIOHINU (10)

Our path running in a northerly direction, seemed leading us towards a ridge of high mountains, but it suddenly turned to the east, and presented to our view a most enchanting valley, clothed with verdure, and ornamented with clumps of kukui and kou trees. On the southeast it was open towards the sea, and on both sides adorned with gardens, and interspersed with cottages, even to the summits of the hills.

A fine stream of fresh water, the first we had seen on the island, ran along the centre of the valley, while several smaller ones issued from the rocks on the opposite side, and watered the plantations below. (p. 133)

Between three and four o'clock we took leave of them, and pursued our journey towards the sea-shore. Our road, for a considerable distance, lay through the cultivated parts of this beautiful valley: the mountain taro, bordered by sugar-cane and bananas, was planted in fields six or eight acres in extent, on the sides of the hills, and seemed to thrive luxuriantly. (pp. 133-134)

WAIOHINU (10) TO HONUAPO (11)

The country appeared more thickly inhabited than that over which we had travelled in the morning. The villages, along the sea shore, were near together, and some of them extensive.

. . . we found tall rows of sugar-cane lining the path on either side. . . . (p. 136)

HONUAPO (11)

. . . Honuapo, an extensive and populous village, standing on a level bed of lava which runs out a considerable distance into the sea. (p. 137)

HILEA (12)

The head man then asked us to stop till he could prepare some refreshment; saying he had hogs, fish, taro, potatoes, and bananas in abundance. (p. 143)

PUNALUU (13) TO KAPAPALA (14)

We now left the road by the sea-side, and directed our course towards the mountains. Our path lay over a rich yellow-looking soil of decomposed lava, or over a fine black vegetable mould, in which we occasionally saw a few masses of lava partially decomposed. . . . There was but little cultivation, though the ground appeared well adapted to the growth of all the most valuable produce of the islands. (p. 146)

We . . . then resumed our journey over the same verdant country, frequently crossing small valleys and water-courses, which, however, were all dry.

The surface of the country was covered with a light yellow soil, and clothed with tall grass, but the sides and bed of every watercourse we passed were composed of volcanic rock. . . .

The land, though very good, was but partially cultivated, till we came to Kaaraara (Kaalaala), where we passed through large fields of taro and potatoes, with sugar-cane and plantains growing very luxuriantly.

. . . we passed on through a continued succession of plantations, in a high state of cultivation. (p. 148)

KAPAPALA (14)

In the neighbourhood of Kapapala we noticed a variety of the paper-mulberry, somewhat different from that generally cultivated, which grew spontaneously, and appeared indigenous. (p. 149)

PONAHOAHOA (Not found but about five miles from Kapapala)

After travelling about five miles, over a country fertile and generally cultivated, we came to Ponahohoa. It was a bed of ancient lava, the surface of which was decomposed; and in many places shrubs and trees had grown to a considerable height. (p. 150)

The lava is decomposed, frequently a foot in depth, and is mingled with a prolific soil, fertile in vegetation, and profitable to its proprietors. . . . (p. 153)

The road by which we returned lay through a number of fields of mountain taro, which appears to be cultivated here more extensively than the sweet potato. (p. 153)

KAPAPALA (14) TO KILAUEA VOLCANO (15)

The path for several miles lay through a most fertile tract of country, covered with bushes, or tall grass and fern, frequently from three to five feet high, and . . . heavily laden with dew. . . . (p. 157)

Leaving the wood, we entered a waste of dry sand, about four miles across. (p. 158)

KILAUEA VOLCANO (15) TO KEALAKOMO (16)

As we approached the sea, the soil became more generally spread over the surface, and vegetation more luxuriant.

The natives ran to a spot in the neighbourhood, which had formerly been a plantation, and brought a number of pieces of sugar-cane, with which we quenched our thirst, and then walked on through several plantations of sweet potato, belonging to the inhabitants of the coast. . . . (pp. 182-183)

Down this [the cliff] we descended, by following the course of a rugged current of ancient lava, for about 600 feet perpendicular depth, when we arrived at the plain below, which was one extended sheet of lava, without shrub or bush, stretching to the north and south as far as the eye could reach, and from four to six miles across, from the foot of the mountain to the sea. (p. 183)

[NOTE: Ellis' direction must be wrong because the coastline runs east-west here, or at most, northeast-southwest.]

The population of this part of Puna though somewhat numerous, did not appear to possess the means of subsistence in any great variety or abundance; and we have often been surprised to find the desolate coasts more thickly inhabited than some of the fertile tracts in the interior; a circumstance we can only account for, by supposing that the facilities which the former afford for fishing, induce the natives to prefer them as places of abode; for they find that where the coast is low, the adjacent water is generally shallow.

We saw several fowls and a few hogs here, but a tolerable number of dogs, and quantities of dried salt fish, principally albacores and bonitos. This latter article, with their poe and sweet potatoes, constitutes nearly the entire support of the inhabitants, not only in this vicinity, but on the seacoasts of the north and south parts of the island. (p. 190)

[NOTE: This reference to north and south sea coasts was not very helpful because it is not known which coasts were under consideration.]

KALAPANA (17) VICINITY

When we had passed Punau, Leapuki, and Kamomoa, the country began to wear a more agreeable aspect. Groves of cocoa-nuts ornamented the projecting points of land, clumps of kou-trees appeared in various directions, and the habitations of the natives were also thickly scattered over the coast. (p. 190)

Shortly after, we reached Kupahua, a pleasant village, situated on rising ground, in the midst of groves of shady trees, and surrounded by a well-cultivated country. (p. 191)

KAIMU (18)

We next traced its course [a volcanic fissure] through the fields of potatoes. (p. 196)

Kaimu is pleasantly situated near the sea shore, on the S. E. side of the island, standing on a bed of lava considerably decomposed, and covered with a light and fertile soil. It is adorned with plantations, groves of cocoa-nuts, and clumps of kou-trees. It has a fine sandy beach, where canoes may land with safety; and, according to the houses numbered today, contains about 725 inhabitants.

Including the villages in its immediate vicinity, along the coast, the population would probably amount to 2000; and, if water could be procured near at hand, it would form an eligible missionary station.

There are several wells in the village, containing brackish water, which has passed from the sea, through the cells of the lava, undergoing a kind of filtration, and is collected in hollows scooped out to receive it.

The natives told us, that, at the distance of about a mile there was plenty of fresh water.

The extent of cultivation in the neighbourhood, together with the decent and orderly appearance of the people, induced us to think they are more sober and industrious than those of many villages through which we have passes. (p. 197)

KAMAILI (19)

Leaving Kehena, we walked on to Kamaili, a pleasant village, standing in a gently sloping valley, cultivated and shaded by some large cocoa-nut trees.

The hospitable inhabitants, at the request of our guide, soon brought us some fresh fish, a nice pig, with potatoes and taro, and a calabash of good water.

The people who were not employed on their plantations, or in fishing, afterwards assembled. . . . (pp. 199-200)

KAIMU (18) TO KEAHIALAKA (20)

The country had been much more populous than any we had passed since leaving Kona. . . . (pp. 201-202)

KEAHIALAKA (20) TO KAPOHO (21)

A most beautiful and romantic landscape presented itself on our left, as we travelled out of Pualaa. The lava was covered with a tolerably thick layer of soil, and the verdant plain, extending several miles towards the foot of the mountains, was agreeably diversified by groups of picturesque hills, originally craters, but now clothed with grass, and ornamented with clumps of trees.

We soon left this cheerful scenery, and entered a rugged tract of lava, over which we continued our way till about two p.m., when we reached Kapoho. (p. 205)

KAPOHO (21)

A cluster, apparently of hills three or four miles round, and as many hundred feet high, with deep indented sides, overhung with trees, and clothed with herbage, standing in the midst of the barren plain of lava, attracted our attention.

We walked through the gardens that encircled its base, till we reached the S.E. side, where it was much lower than on the northern parts. Here we ascended what appeared to us to be one of the hills, and, on reaching the summit, were agreeably surprised to behold a charming valley opening before us. It was circular, and open towards the sea.

The outer boundary of this natural amphitheatre was formed by an uneven ridge of rocks, covered with soil and vegetation. Within these there was a smaller circle of hills, equally verdant, and ornamented with trees. The sides of the valley, which gradually sloped from the foot of the hills, were almost entirely laid out in plantations, and enlivened by the cottages of their proprietors.

In the centre was an oval hollow, about half a mile cross, and probably two hundred feet deep, at the bottom of which was a beautiful lake of brackish water, whose margin was in a high state of cultivation, planted with taro, bananas, and sugar-cane.

The steep perpendicular rocks, forming the sides of the hollow, were adorned with tufts of grass, or blooming pendulous plants, while, along the narrow and verdant border of the lake at the bottom, the bread-fruit, the kukui, and the 'ōhi'a trees, appeared, with now and then a lowly native hut standing beneath their shade. (pp. 205-206)

KAPOHO (21) TO KAHUWAI (22)

Our way now lay over a very rugged tract of country. Sometimes for a mile or two we were obliged to walk along on the top of a wall four feet high and about three feet wide, formed of fragments of lava that had been collected from the surface of the enclosures which these walls surrounded. (p. 210)

The shore, which was about a mile to the eastward of us, was occasionally lined with the spiral pandanus, the waving cocoa-nut grove, or the clustering huts of the natives. (p. 211)

HONOLULU (23) TO KEAAU (24)

The country was populous, but the houses stood singly, or in small clusters, generally on the plantations, which were scattered over the whole country. Grass and herbage were abundant, vegetation in many places luxuriant, and the soil, though shallow, was light and fertile. (p. 212)

KEAAU (24) TO WAIAKEA (25: present city of Hilo)

At half-past ten we resumed our walk, and passing about two miles through a wood of pretty large timber, came to the open country in the vicinity of Waiakea.

WAIAKEA (25: Hilo)

The light and fertile soil is formed by decomposed lava, with a considerable portion of vegetable mould. The whole is covered with luxuriant vegetation, and the greater part of it formed into plantations, where plantains, bananas, sugar-cane, taro, potatoes, and melons, grow to the greatest perfection. (p. 239)

Groves of cocoa-nut and breadfruit are seen in every direction loaded with fruit, or clothed with umbrageous foliage. The houses are mostly larger and better built than those of many districts through which we had passed. We thought the people generally industrious; for in several of the less fertile parts of the district we saw small pieces of lava thrown up in heaps, and potato vines growing very well in the midst of them, though we could scarcely perceive a particle of soil. (p. 239)

There are 400 houses in the bay, and probably not less than 2000 inhabitants. . . . (p. 240)

HILO COAST UP SLOPES OF MAUNA KEA

"There appear to be three or four different regions in passing from the sea-shore to the summit. The first occupies five or six miles, where cultivation is carried on in a degree, and might be to almost any extent; but, as yet, not one-twentieth part is cultivated."

"The next is a sandy region, that is impassable, except in a few footpaths. Brakes, a species of tall fern, here grow to the size of trees; the bodies of some of them are eighteen inches in diameter." (Dr. Blatchely and Mr. Ruggles' publication on a trip from Hilo up the slopes of Mauna Kea, quoted by Ellis; p. 291)

WAIAKEA (25) TO LAUPAHOEHOE (26) BY CANOE

The country, by which we sailed, was fertile, beautiful, and apparently populous. The numerous plantations on the eminences and sides of the deep ravines or valleys, by which it was intersected, with the streams meandering through them into the sea, presented altogether a most agreeable prospect. (p. 244)

HUMUULA (27) TO KAULA (28)

The high land over which we passed was generally woody, though the trees were not large. The places that were free from wood, were covered with long grass and luxuriant ferns. The houses mostly stood singly, and were scattered over the face of the country.

A rich field of potatoes or taro, five or six acres sometimes in extent, or large plantations of sugar-cane and bananas, occasionally bordered our path. But though the soil was excellent, it was only partially cultivated. The population also appeared less than what we had seen inhabiting some of the most desolate parts of the island. (pp. 249-250)

KAULA (28)

When a drawing had been taken of this beautiful valley, where kukui trees, plantains, bananas, and ti plants were growing spontaneously with unusual richness of foliage and flower, we took leave of the people, and, continuing our journey, entered Hamakua. (p. 251)

HILO DISTRICT (25 to 28)

Hiro, which we had now left, though not so extensive and populous as Kona, is the most fertile and interesting division on the island.

The habitations of the natives generally appear in clusters at the opening of the valleys, or scattered over the face of the high land. The soil is fertile, and herbage abundant. (p. 251)

HILO AND HAMAKUA DISTRICTS

. . . the inhabitants, excepting at Waiakea, did not appear better supplied with the necessaries of life than those of Kona, or the more barren parts of Hawaii. They had better houses, plenty of vegetables, some dogs, and few hogs, but hardly any fish, a principal article of food with the natives in general. (p. 252)

MANIENIE (29) TO KAPULENA (30)

. . . we left Manienie, and travelled over a well-cultivated tract of country, till we reached Toumoarii. . . . (p. 252)

KAPULENA (30) TO WAIMEA (39) BY BISHOP AND GOODRICH

. . . taking an inland direction passed over a pleasant country, gently undulated with hill and dale. The soil was fertile, the vegetation flourishing, and there was considerable cultivation, though but few inhabitants.

About noon they reached the valley of Waimea, lying at the foot of Mouna-Kea, on the northwest side. Here a number of villages appeared on each side of the path, surrounded with plantations in which plantains, sugar-cane, and taro were seen growing unusually large. (p. 253)

WAIPIO (31)

Viewed from the great elevation at which we stood, the charming valley, spread out beneath us like a map, with its numerous inhabitants, cottages, plantations, fishponds, and meandering streams. . . . (p. 254)

The bottom of this valley was one continued garden, cultivated with taro, bananas, sugar-cane, and other productions of the islands, all growing luxuriantly.

A number of small villages, containing from twenty to fifty houses each, stood along the foot of the mountains, at unequal distances on each side, and extended up the valley till projecting cliffs obstructed the view. (p. 256)

According to the number of houses which we have seen, in all 265, there are at least 1325 inhabitants in this sequestered valley, besides populous villages on each side along the coast, which might be easily visited. This circumstance, together with the fertility of the soil, the abundance of water. . . . (p. 261)

WAIMANU (32)

The valley, though not so spacious or cultivated as Waipio, was equally verdant and picturesque. . . . (p. 264)

THE "HAMAKUA COAST" (25-31)

The coast is bold and steep, and the cliffs, from three to five hundred feet high, partially covered with shrubs and herbage, intersected by numerous deep ravines and valleys, frequently in a high state of cultivation. . . . (p. 273)

HONOKANE (33)

The valley contained fifty houses. (p. 273)

POLOLU (34)

Pololu is a pleasant village, situated in a small cultivated valley, having a fine stream of water flowing down its centre. . . .

The houses stand principally on the beach. . . . (p. 273)

POLOLU (34) TO HALAWA (35)

The country was fertile, and seemed populous, though the houses were scattered, and more than three or four seldom appeared together. The streams of water were frequent, and a large quantity of ground was cultivated on their banks, and in the vicinity. (p. 274)

[NOTE: This was from the top of Pololu bluff to Halawa; it does not describe the valley itself.]

HALAWA (35) AND VICINITY

A wide tract of country in the neighbourhood was divided into fields of considerable size, containing several acres each, which he used to keep in good order, and well stocked with potatoes and other vegetables. (p. 277)

The soil was fertile and vegetation abundant. (p. 283)

The tract we passed over today seemed more populous than that through which we had travelled yesterday. . . . (p. 283)

AWALUA (36; near Pahoa)

About three p.m. we reached Owawarua, a considerable village on the north-west coast, inhabited mostly by fishermen. (p. 285)

HALAWA (35) TO MAHUKONA (37)

Though we had numbered, in our journey today, 600 houses, we had not seen any thing like four hundred people, almost the whole population being employed in the mountains cutting sandal wood. (p. 286)

BY CANOE AT NIGHT TO KAWAIHAE (38)

KAWAIHAE BACK NORTH TOWARD MAHUKONA BY THURSTON

The coast was barren; the rocks volcanic; the men were all employed in fishing; and Mr. Thurston was informed that the inhabitants of the plantations, about seven miles in the interior, were far more numerous than on the shore. (p. 288)

[NOTE: This distance is erroneous for that would place them on the other side of the Kohala Mountains--probably more like 2-3 miles.]

KAWAIHAE TO SOUTHWEST OF WAIMEA AND RETURN BY THURSTON

The soil over which he had travelled was fertile, well watered, and capable of sustaining many thousand inhabitants. In his walks he had numbered 220 houses, and the present population is probably between eleven and twelve hundred.

KIHOLO (40)

. . . I landed at Kihoro, a straggling village, inhabited principally by fishermen. (p. 294)

ON TO KAILUA BY CANOE

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