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Prehistoric Agriculture in Kohala, Hawaii

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The general context of the present paper on Hawaiian archaeology is the nature of cultural adaptation in island environments and the expansion of agricultural systems into unoccupied territory. The control of agricultural production was one of the sources of power for the leaders of Hawaiian societies, societies which were among the most highly stratified in Polynesia at the time of European exploration.[1] *Population growth and expansion, elaboration of the agricultural system, and the development of socio-political complexity provide a series of problems of recent concern in Hawaiian archaeology.*[2] *Within this framework archaeological research focusing on prehistoric agricultural change was conducted for three seasons*[3] *in windward valleys of the* NW *section of the Island of Hawai'i.*[4] *A summary of the evidence regarding agricultural change in two of these valleys is presented in this paper.*

Background

Hawaiian Environment and Culture

The Hawaiian chain (FIG. 1) is composed of a series of differentially eroded volcanoes lying across the subtropics, a belt characterized by moderate temperatures and moisture-laden trade winds. A great variety of landforms and soils can be found across the islands as a result of weathering differences related to age and rainfall patterns. At the time of European contact in 1778, Hawaiian subsistence was based on horticulture,[5] animal husbandry, and the collection of ocean resources. Hawaiians had dramatically modified the landscape by the construction of extensive irrigation and dry-field complexes extending from the coast inland. Additionally, fishponds had been built in many areas at the coastal outlet of irrigation fields, thus creating a complex, artificial ecosystem for food production.[6] Hawaiian habitation was primarily along the coast, with population size and density related to productivity of the adjacent agricultural zone. Occupying eight major islands, the contact-period population numbered about 250,000 people, divided into four politically independent, stratified, redistributional societies.[7]

1. M.D. Sahlins, *Social Stratification in Polynesia* (Seattle 1968); T. Earle, "Economic and Social Organization of a Complex Chiefdom: the Halelea District, Kaua'i, Hawaii," *Anthropological Papers*, No. 63 (Ann Arbor 1978).

2. Earle, ibid.; R. Cordy, "A Study of Prehistoric Social Change: The Development of Complex Societies in the Hawaiian Islands," unpublished Ph.D. dissertation, University of Hawaii (1978); R. Hommon, "The Formation of the Primitive State in Pre-Contact Hawaii," unpublished Ph.D. dissertation, University of Arizona (1976).

3. The primary funding for the research came from a National Science Foundation Grant (GS-38069); student support and related research funding were obtained from two National Science Foundation Undergraduate Research Participation grants and from an award from the Hawaii Foundation for History and the Humanities. Portions of the research were conducted as part of the University of Hawaii summer field-training program and additional funds were derived from the University of Hawaii.

4. Glottalized "Hawai'i," used for the individual island of that name, is a closer representation of the original pronunciation than is the unglottalized "Hawaii," which is used here to refer to the entire island group.

5. It is recognized that there are many distinctions in the literature involving the term "agriculture" and related concepts: agriculture and cultivation; agriculture and horticulture; farming and gardening. The distinctions, however, are often conflicting or not made with consistency. For present purposes "agriculture" is used as the generic and "horticulture" is used to refer to agricultural practices that did not employ draft animals.

6. W.K. Kikuchi, "Prehistoric Hawaiian Fishponds," *Science* 193 (1976) 295–299.

7. R.S. Kuykendall, *The Hawaiian Kingdom*, Vol. I: 1778–1854

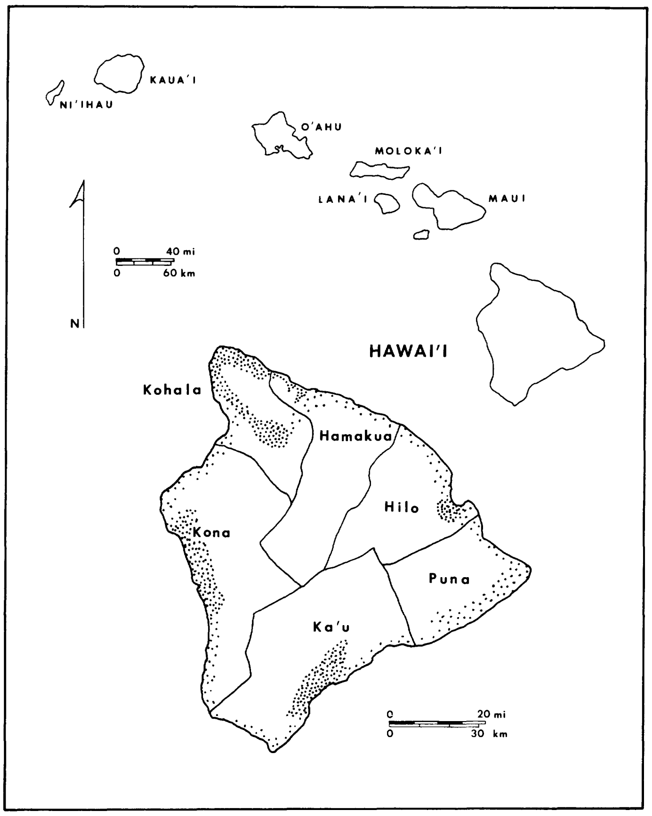

Figure 1. Main Islands of the Hawaiian chain with an enlargement of the Island of Hawai'i. On the enlargement the traditional district names and boundaries are shown; stippling represents relative concentration of prehistoric agriculture and associated population density.

The Island of Hawai'i (FIG. 1), largest and youngest of the chain, had a population of nearly 100,000 and was under the control of one political organization. Formed of five volcanoes, Hawai'i has large expanses of unproductive land because of rain shadows and unweathered lava flows. Permanent streams, used for irrigation, are primarily on the windward side of the island but rainfall is adequate in other areas to have allowed non-irrigated cultivation. The primary areas of occupation are illustrated in Figure 2.

The Nature of Hawaiian Archaeological Remains

From the coast to the inland reaches of the prehistoric agricultural complexes, Hawai'i has a visible archaeological landscape as a result of the extensive use of stone by the early inhabitants. Stone was involved in nearly every phase of Hawaiian life. Stone, usually unmodified, was used to form agricultural terraces and field borders, house platforms, low-walled house enclosures, compound enclosures, and the massive platforms and walls of temples. Unmodified stones were used in a variety of household activities, and stone modified by chipping, pecking, and grinding was used for extractive and maintenance tools. In habitation sites the most common portable artifacts are flakes of basalt and volcanic glass. Finished stone tools are not found in large numbers. Fishhooks and other tools of bone and shell occur in quantities varying with site function. Shell constitutes the most common food remnant. Cultural deposits are often shallow with poorly developed stratification, although on occasion well-stratified sites are found in coastal dunes, valley alluvium, and cave deposits.

Until 1950 the study of pre-European Hawaiian history centered on Hawaiian oral traditions that were recorded during the 19th century. Archaeology was generally limited to the recording of the monumental structures, primarily temples and fishponds, and to broad survey. In the 1950s the combination of modern excavation and radiocarbon dating provided the means to establish a material-based history of Hawaii. Recent archaeology has had two primary research interests. The first was the problem of Hawaiian origins, with much of the work of the 1950s directed toward location and excavation of early sites. In the 1960s regional prehistory began to be emphasized, based on themes of settlement pattern and local adaptation. In this context the agricultural sites so prevalent in Hawaii became a center of research attention.[8] The research reported in the present article developed within this framework.

Chronometric dating in Hawaii began with radiocarbon but within the last 10 years has been dominated by "basaltic glass" age determination, a regional application of the obsidian hydration method.[9] Although often used to derive "absolute" dates, the method is best considered as a means of relative dating.[10]

(Honolulu 1938) 44–45; Sahlins, op. cit. (in note 1) 13–22; R.C. Schmitt, "New Estimates of the Pre-censal Population of Hawaii," *Journal of the Polynesian Society* 80 (1971) 273–343.

8. R. Green's concern with settlement pattern was instrumental in organizing this work, see, e.g. R. Green, "Settlement Pattern Archaeology in Polynesia," in R.C. Green and M. Kelly (eds.) "Studies in Oceanic Culture History, Vol. 1," *Pacific Anthropological Records* 11 (1970) 13–32.

9. M. Morgenstein and T. Riley, "Hydration-rind Dating of Basaltic Glass: A New Method for Archaeological Chronologies," *Asian Perspectives* 17 (1974) 145–159.

10. H.D. Tuggle, R. Cordy, and M. Child, "Volcanic Glass Hydration-rind Age Determinations for Bellows Dune, Hawaii," *New Zealand Archaeological Association Newsletter* 21 (1978) 57–72.

Figure 2. Aerial photo of the Kohala area of Hawai'i. View to the south.

Prehistory

Polynesian settlement of Hawaii occurred sometime in the centuries after Christ. The number of people involved, the number of voyages, and the occurrence of two-way voyaging between Hawaii and the origin area of central Polynesia remain matters of debate, with little relevant substantial evidence available.[11] Whatever the specific history may have been, the cumulative result was colonization by a society which brought primary cultigens, domesticated animals, and a fundamental knowledge of horticultural technology. It is easy to assume on ethnological grounds that this society was organized according to the principles of Polynesian ranking, a genealogically based authoritarian system, adapted to the demands of long distance voyaging which characterized the history of the Polynesians. Hawaiian archaeology thus has the opportunity to explore questions about human expansion in an unoccupied environment, including the nature of population growth, evolution of social stratification and political control, and patterns of agricultural growth. Answers to these questions are taking shape as research defines the history of settlement and material changes occurring in the islands.[12] The research in the Kohala valleys has focused on the evidence for the events of agricultural change as one component in the overall history of Hawaiian adaptation.

Background Research on the Island of Hawai'i

The earliest dates, around 750 A.C., from the Island of Hawai'i are from specialized fishing sites.[13] The probable locales of early substantial settlement have not been explored. Dates from other islands indicate that occupation should have occurred at least by about 500 A.C.[14] There was extensive coastal settlement by 1300 A.C. and agriculture in many areas of the islands had been pushed well inland by 1300 A.C. It has been argued that the pattern of household and community structure present at the time of European contact had developed by at least 1000–1200 A.C., and that the level of organizational complexity encountered by Europeans had evolved by 1600 A.C.[15]

Traditional Land Divisions of Hawai'i

The largest traditional land division in Hawaii was a political and administrative unit referred to as a "district" (FIG. 2). The most important of the subdivisions of the district was the unit known as the *ahupua'a*. Communities within the *ahupua'a* tended toward subsistence autonomy, but they were tied into a larger economic network in the supply of material goods and labor, supporting the elite section of the society. From an economic standpoint, the control of the areas of production was the driving force of the political system in which warfare between elite was often across district boundaries. Hawai'i was divided into six districts (FIG. 1), each of which centered on a rich resource area, including land with high agricultural productivity. District boundaries fell in marginal areas or areas with natural obstacles. At the time of European contact the districts were approximately equal in size and in population. These areas were probably centers of early settlement which developed as independent political entities, eventually coming into competition with one another. If archaeological research bears this out, this provides an example of spacing which results from a balanced com-

11. P.V. Kirch, "The Chronology of Early Hawaiian Settlement," *Archaeology and Physical Anthropology in Oceania* 9 (1974) 110–119; B. Finney, "Voyaging Canoes and the Settlement of Polynesia," *Science* 196 (1977) 1277–1285.

12. Hommon, op. cit. (in note 2); R. Cordy, "Complex-rank Cultural Systems in the Hawaiian Islands," *Archaeology and Physical Anthropology in Oceania* 9 (1974) 89–109; H. D. Tuggle, "The Archaeology of Hawaii," in J. Jennings (ed.), *The Prehistory of Polynesia* (Cambridge, in press).

13. K.P. Emory and Y.H. Sinoto, "Age of the Sites in the South Point Area, Ka'u, Hawaii," *Pacific Anthropological Records* No. 9 (1969); R.C. Green, "The Chronology and Age of Sites at South Point, Hawaii," *Archaeology and Physical Anthropology in Oceania* 6 (1971) 170–176.

14. Kirch, op. cit. (in note 11) 115–118.

15. Hommon, op. cit. (in note 2) 229–296; Cordy, op. cit. (in note 2) 165–250.

petition for resources associated with population growth and increase in social complexity.[16]

Hawaiian Agriculture and Agricultural Change

Historical information indicates that traditional Hawaiian agriculture entailed a number of elements in the cultivation of the staples, taro *(Colocasia esculenta)* and sweet potato *(Ipomoea batatas)*, including constructing agricultural fields, using the digging stick, green fertilizing, mulching, and burning.[17] Archaeological research has identified a variety of features for moisture and soil control in dry environments and a number of ways of capturing and distributing water in irrigation environments. The excavation record includes evidence for burning, soil disturbance, ponding, and terrace rebuilding; the data are sufficient to contend that agricultural practices in some areas underwent prehistoric change.[18]

Agricultural change may entail either growth or decline. For archaeological purposes, growth may occur in three forms: colonization, expansion, and intensification. Agricultural colonization is the introduction of agriculture into a previously uncultivated region; the establishment of new settlements, seasonal or permanent, would be a corollary association. Expansion is an increase in the absolute amount of area covered by an established agricultural complex. Intensification is a change in a given locale from one mode of agricultural technology to a more productive mode. Broadly, it can be argued that agricultural systems of increasing productivity per unit of land are swidden, permanent dry-field cultivation, and irrigation.[19] These forms may also operate contemporaneously within the same system but in different locales. Agricultural decline may be expressed as the reversal of any of these forms. The criteria for archaeological identification of these forms are evident and will not be discussed here except for those related to intensification.

The immediate archaeological problem is establishing the identification criteria for the remains of these agricultural systems. For the purposes of Hawaiian archaeology, the following identifications prevail. Irrigation features include stone-faced, terraced depressions with level floors and some structural means of gravity-based water distribution; soils are characterized by an upper level with a heavy clay content and a lower level which is hard-packed and iron-stained.[20] Dry-field intensification may take a number of forms with varying archaeo-

16. M.J. Harner, "Population Pressure and the Social Evolution of Agriculturalists," *SWJA* 26 (1970) 67–86.

17. Early European explorers were impressed by the state of Hawaiian agriculture and often described it in some detail; e.g., A. Menzies, *Hawaii Nei 128 Years Ago: Journal of Archibald Menzies* (Honolulu 1920); 19th century Hawaiian scholars described traditional agriculture; e.g., S.M. Kamakau, "The Works of the People of Old: Na Hana a ka Po'e Kahiko," *Bishop Museum Special Publication* 61 (Honolulu 1976) 24–25, 31–34; a broad summary based on a variety of sources is found in E.S.C. Handy and E.G. Handy, "Native Planters in Old Hawaii: Their Life, Lore, and Environment," *Bishop Museum Bulletin* 233 (Honolulu 1972) 89–94, 129; and a summary of irrigation practices is in Earle, op. cit. (in note 1) 109–141.

18. Examples of relevant evidence include the following: W.S. Ayres, "Archaeological Survey and Excavations, Kamana Nui Valley, Moanalua Ahupua'a," *Bishop Museum Department of Anthropology Report* 70-8 (Honolulu 1971) 15–36; D.E. Yen, P. Kirch, P. Rosendahl, and T. J. Riley, "Prehistoric Agriculture in the Upper Valley of Makaha, Oahu," in E.J. Ladd and D. Yen (eds.), "Makaha Valley Historical Project, Interim Report 3," *Pacific Anthropological Records* 18 (1972) 69–85; T.J. Riley, "Survey and Excavations of the Aboriginal Agricultural System," in P.V. Kirch and M. Kelly (eds.), "Prehistory and Ecology in a Windward Hawaiian Valley: Halawa Valley, Molokai," *Pacific Anthropological Records* 24 (1975) 91–115.

19. It is beyond the scope of this paper as an interpretive field report to explore the problems of agricultural intensification. The concept has been approached in the literature by labor input, by productivity, by a ratio between the two, by length of fallow, and by energy flow. Generally, the evidence suggests that intensification leads to greater productivity, at least in the short run, per land unit: cf. R. Netting, *Hill Farmers of Nigeria* (Seattle 1968) 55–107; R. Netting, "Agrarian Ecology," *Annual Review of Anthropology* 3 (1974) 21–56; E. Waddell, *The Mound Builders: Agricultural Practices, Environment, and Society in the Central Highlands of New Guinea* (Seattle 1972) 202–214; H.C. Brookfield and D. Hart, *Melanesia: A Geographical Interpretation of an Island World* (London 1971) 94–124. While intensification is considered in terms of productivity, the argument that labor efficiency decreases with intensification is a major point of contention: cf. E. Boserup, *The Condition of Agricultural Growth: The Economics of Agrarian Change under Economic Pressure* (Chicago 1965); H.C. Brookfield, "Intensification and Disintensification in Pacific Agriculture: A Theoretic Approach," *Pacific Viewpoint* 13 (1972) 30–48; C. Geertz, *Agricultural Involution: The Processes of Ecological Change in Indonesia* (Berkeley 1963) 12–37; H.W. Basehart, "Cultivation Intensity, Settlement Patterns, and Homestead Forms among the Matengo of Tanzania," *Ethnology* 12 (1973) 57–73. The body of literature on intensification, of which the above is only a small sample, generally supports the position that there is a continuum of practices of increasing intensification (measured along one or more of the dimensions mentioned above) from broad swidden to irrigation. The division of the continuum into swidden, permanent dry-field cultivation, and irrigation is an archaeological simplification.

20. A technical description of these soils is in M.C. Cline, "Soil Survey of the Territory of Hawaii," *Soil Survey Series 1939,* No. 25 (Washington, D.C. 1955) 570. Archaeological identifications of ponded soils are in Riley, op. cit. (in note 18) 91–115 and M. Morgenstein and W.C. Burnett, "Geological Observations at an Agricultural Area in the Upper Makaha Valley," in Ladd and Yen, op. cit. (in note 18) 95–113.

logical visibility.[21] In Hawaii the most visible expression of "permanent dry-fields" is through the construction of stone features, ranging from field borders to dry terraces.[22] The associated soils do not have a clear structure and have a high occurrence of charcoal fragments.

Swidden soils are difficult to deal with but for the present purposes they are defined by the same criteria as permanent field soils except that they are not associated with field alignments.[23] But there are some difficulties with this identification. As Earle has pointed out,[24] the features used to identify swidden soils could be produced by natural conditions of weathering and fire, or fire could have been used by humans for non-cultivation purposes. However, although forest fire does occur in Hawaii, it is infrequent (away from active volcanoes) because bolt lightning is rare.[25] In the case of the Kohala soils, those postulated as "swidden" have a clear association with the features and portable artifacts, so at least the human presence is established. Like the soils associated with the field boundaries, these deposits contain charcoal fragments throughout and these fragments have a dispersion pattern which suggests mechanical disturbance.

The Windward Kohala Research Project

Research in windward Hawai'i began during the summer of 1972 with a general survey of the valleys of Pololu and Honokane in the district of Kohala and Honopue in the district of Hamakua (FIGS. 2, 3). Research continued the following two summers with detailed survey and excavations in Pololu and Honokane, with more effort expended on the former valley as the sites and deposits proved to be of great complexity. Excavation centered on agricultural features, with supporting work on habitation sites directed toward collection of datable material and of information relating to agricultural association.[26]

21. Dry fields lined with stone borders and dry terraces of a variety of types, found in many areas of the world, are generally regarded as a form of intensive or intensified cultivation; e.g. Netting op. cit. (1968 in note 19) 56–64, 85–87; Brookfield and Hart op. cit. (in note 19) 114; H.C. Brookfield, "Land Study and Comparative Method: an Example from Central New Guinea," *AAAG* 52 (1962) 248; R. Bradley, "Prehistoric Field Systems in Britain and North-west Europe — A Review of Some Recent Work," *WA* 9 (1978) 265–281. The term "permanent dry-fields" should not be misconstrued. The phrase tends to refer more to their condition as distinctly bounded or permanently modified fields, while cultivation itself may have ranged from an intensified swidden to annual cultivation; cf. D. Yen, "The Origins of Oceanic Agriculture," *Archaeology and Physical Anthropology in Oceania* 8 (1973) 78; H.C. Brookfield, "New Directions in the Study of Agricultural Systems in Tropical Areas," in E.T. Drake (ed.), *Evolution and Environment* (New Haven 1968) 413–439.

22. The dry-field complexes of Hawaii contain different types of features from field borders to terraces and served variously for boundary delineation, erosion prevention, soil accumulation, water control, and wind diversion. Some of the "dry features" thus involve water and could be graded into irrigation complexes. Some classifications of agricultural features emphasize water control and define a scale of types which often includes true irrigation; c.f. R.G. Vivian, "Conservation and Diversion: Water Control Systems in the Anasazi Southwest," in T.E. Downing and McG. Gibson (eds.), "Irrigation's Impact on Society," *Anthropological Papers of the University of Arizona* No. 25 (Tucson 1974) 95–112; J.E. Spencer and G.A. Hale, "The Origin, Nature, and Distribution of Agricultural Terracing," *Pacific Viewpoint* 2 (1961) 1–40; R.A. Donkin, "Agricultural Terracing in the Aboriginal New World," *Viking Fund Publications in Anthropology* 56 (Tucson 1979). For purposes of analysis of Hawaiian agriculture, however, it is fruitful to separate irrigation from less intensified forms of water control. Irrigation involved tapping a more or less permanent water source and controlling flow through ponded fields. Features to control runoff or conserve moisture are here considered "dry-field" features. There are numerous examples of Hawaiian dry-field complexes reported in the literature, including P. Rosendahl, "Aboriginal Agriculture and Residence Pattern in Upland Lapakahi, Island of Hawaii," unpublished Ph.D. dissertation, University of Hawaii (1972); C. Sugiyama, "Analysis of Agricultural Features in Upland Lapakahi," in H.D. Tuggle and P.B. Griffin (eds.), "Lapakahi, Hawaii: Archaeological Studies," *Asian and Pacific Archaeology Series* No. 5 (1973) 259–293; T.S. Newman, "Two Early Hawaiian Field Systems on Hawaii Island," *Journal of the Polynesian Society* 81 (1972) 87–89; R. Hommon, "An Interim Report on Archaeological Zone 1," in R.C. Green (ed.), "Makaha Valley Historical Project, Interim Report No. 1," *Pacific Anthropological Records* No. 4 (1969) 45–53.

23. Evidence for swidden soils is proposed in Kirch and Kelly, op. cit. (in note 18) 91–115 and Ayres, op. cit. (in note 18) 15–36.

24. T. Earle, "Review of Kirch and Kelly (eds.), *Prehistory and Ecology in a Windward Hawaiian Valley*," in *Asian Perspectives* 19 (1976) 306.

25. R.J. Vogt, "The Role of Fire in the Evolution of Hawaiian Flora," *Proceedings, Tall Timbers Fire Ecology Conferences* (1969).

26. As an outgrowth of previous extensive research in the ahupua'a of Lapakahi in leeward Kohala, the research discussed here focused on the development and change of agricultural systems within the framework of Hawaiian adaptation to windward valley environments. Under the direction of H.D. Tuggle, three summers of field work from 1972 to 1974 were carried out in the valleys of Honokane and Pololu in the district of Kohala and in the valley of Honopue in the district of Hamakua. The initial summer work was a general survey of the three valleys by a University of Hawaii summer field school directed by the principal investigator and a graduate student, D. Callan. Field work in the following summer concentrated on intensive mapping and test excavations of agricultural systems in the Kohala valleys. Senior staff included N. Ewart, P. Luscomb, K. Moore, C. Nielsen (in central Pololu Valley), B. Davis (in upper Pololu Valley), and R. Hughes (in upper Honokane Valley). D. Callan carried out excavations on the dune at the mouth of Pololu Valley, investigating possible early habitation sites. T.J. Riley was assistant director in charge of undergraduate independent researchers. Field work in the summer of 1974 concentrated on excavations in selected agricultural complexes and possible habitation areas in central Pololu and lower Honokane Valleys. The work was carried out by a small, experienced research

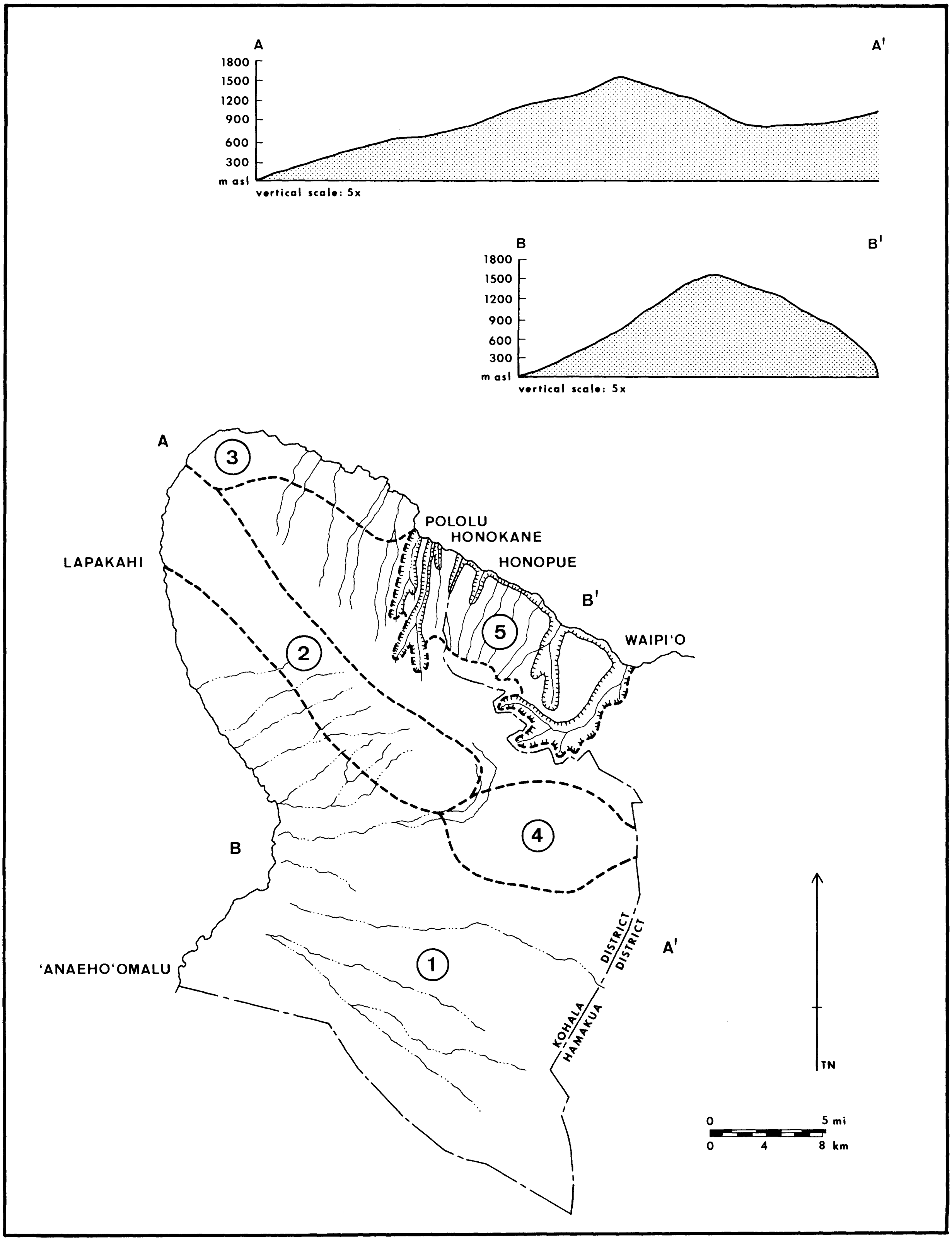

Figure 3. The traditional district of Kohala, Hawai'i and adjoining section of Hamakua (see FIG. 1); permanent streams and the primary ephemeral streams are shown along with a schematic presentation of the cliff and valley topography of the NE coast; the numbered areas of occupation are described in the text.

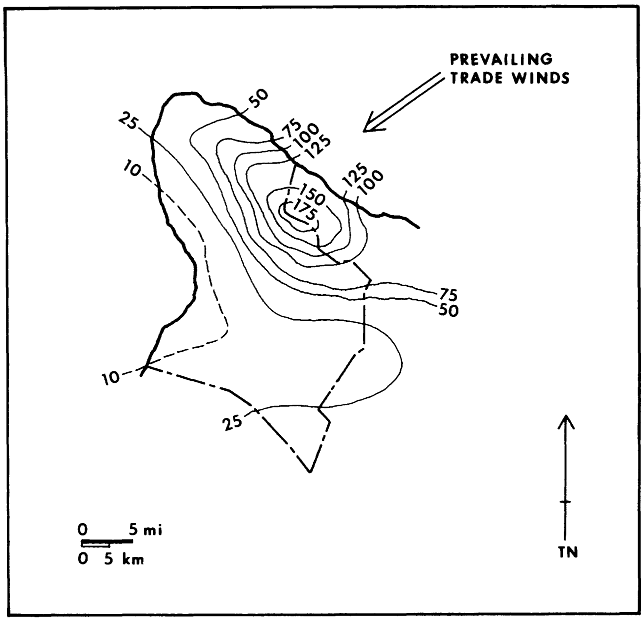

Figure 4. Estimated annual rainfall, in inches, of Kohala.

Kohala: Environment and Prehistory

The district of Kohala spans the NW tip of Hawai'i encompassing windward and leeward zones, and is thus characterized by great environmental variety (FIGS. 3, 4). It is divided by the Kohala Mountains, the remnant of the oldest volcano of the island, which reach an elevation of about 1700 meters. Kohala district is about 1020 sq. km. in area and has some 50 km. of coastline, most of which is rocky and cliffed. Approximately 250 sq. km. of the district were under cultivation in prehistoric times.

Kohala can be divided into five major environmental zones relevant to human occupation (FIG. 3). On the south leeward coast is a low rainfall area of barren lava fields. Ocean resources and fishpond productivity supported a moderate to low population in this area with occupation occurring perhaps as early as 1000 A.C.[27] Another environmental zone is the leeward slope of the Kohala Mountains, an area with good soils and rainfall above 25 inches annually in areas inland. The rainfall belt was characterized by the construction of extensive field-border complexes for dry-land cultivation that emphasized the sweet potato. Current evidence indicates that coastal habitation and inland agriculture may have been well underway by the mid-14th century A.C.[28]

The third environmental zone extends from the northern tip of Kohala to the beginning of the Kohala-Hamakua valleys. It is dissected slope with rainfall from 30 to 75 inches. A number of permanent streamlets supported small-scale irrigation, while the slopes were under intensive non-irrigated cultivation of taro. This area was the population center and the locus of political power for the Kohala district. No archaeological work has been done in this zone nor in the fourth zone, Waimea, an inland saddle area with good rainfall, which supported a productive agricultural system.

The final environmental zone is a cliff-and-valley region which extends from Windward Kohala into the adjoining district of Hamakua. This area has rainfall from 75 to 150 inches a year. It is geologically the oldest surface region of Hawai'i Island and is dominated by narrow, deep valleys with permanent streams. It extends from the research valleys, Pololu and Honokane, to the grand valley of Waipi'o, which contained a massive system of irrigated fields of taro and served as a political center for the district of Hamakua and, at times, the entire island of Hawai'i.

The Kohala Valleys

The valley terrain of Kohala (FIGS. 2, 5) is one of sharp relief. Wave action has cut away the original coastline to produce a series of high cliffs, which are intersected by narrow, steep-walled valleys. The valleys have little talus accumulation and have a low gradient from their mouths to the amphitheatre heads. There is no reef, and cove protection is minimal. Beaches are basalt boulder, cobble, and sand. The area is a zone of high hazard from landslide, rockfall, flashflood, and tsunami.[29] There is no permanent habitation today, a result not so much of hazard as of the lack of roads, but livestock is maintained in the valleys by people who live outside. Each of these valleys was one of the traditional land units *(ahupua'a)* of the district of Kohala.

crew under the direction of H.D. Tuggle. Supplementary research was provided by a summer field school supervised by P. Beggerly and S. Nakama. Detailed information will be available in H.D. Tuggle and M.J. Tomonari-Tuggle, *Archaeological Research in the Windward Valleys of Kohala and Hamakua, Island of Hawai'i* (in preparation).

27. W. Barrera, "Anaehoomalu: A Hawaiian Oasis," *Pacific Anthropological Records* 15 (1971) 105.

28. Rosendahl, op. cit. (in note 22) 369–371; Tuggle and Griffin (eds.), op. cit. (in note 22) 21–23.

29. P. Hubbard, "An Environmental Survey of Pololu Valley," in R.W. Armstrong and H.T. Lewis (eds.), *Preliminary Research in Human Ecology, North Kohala Studies* (Honolulu 1970) 1–14.

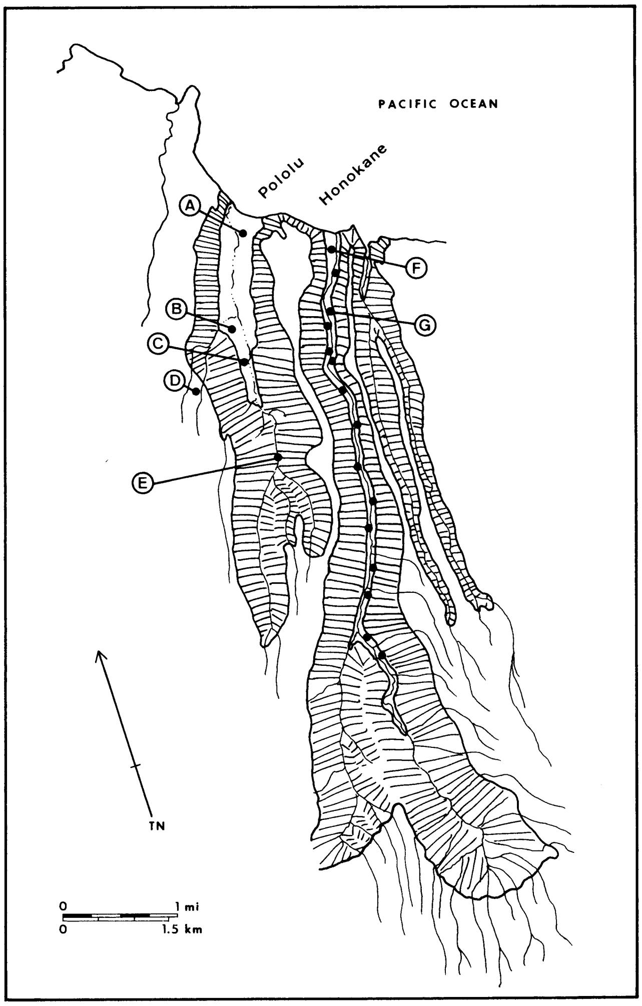

Figure 5. Schematic relief of the research area, showing principal irrigation complexes.

Pololu: Environment, Settlement Patterns, and Agricultural History

Dominated by a sand dune 40 m. high, the mouth of Pololu extends some 500 m. wide, with the stream outlet to the NW side (FIG. 5). The valley floor extends inland for about 2500 m. at a 1 to 2 degree slope from a swampy area behind the dune to a small waterfall with plungepool, which separates the lower alluvial floor from an upper gulch. The lower valley has an area of some 100 ha.

Based on evidence summarized below, the following is a model of the hydrological environment of Pololu. During human occupation waterflow within Pololu has been predominantly ephemeral. The ephemeral flow has varied in intensity, creating a complex erosional and depositional pattern, with an undetermined periodicity. Under normal conditions the limited water availability was the major constraint on the development of irrigation. Under extreme conditions, flooding at times posed a threat to the agricultural fields and drought at other times interrupted irrigation and created problems for dry cultivation.

There is at present no permanent stream on the floor of the lower valley. The four small waterfalls that enter the valley seep underground at their bases. There is at least one spring near the mouth of the valley but no stream flow is created. Evidence indicates that the absence of a permanent stream is not a recent phenomenon. The one dike exposure in Pololu is part of a system whose water has been largely intercepted by the adjoining valley of Honokane. There has been no significant erosion or growth of Pololu since an andesite flow entered the rear of the valley about 150,000 years ago.[30] The valley floor has elaborate evidence of ephemeral water flow: braiding, head-cutting, scour holes, and discontinuous channels choked with debris from rapid flood dissipation. Stream channels have up to 3 m. of alluvial deposits exposed in erosion channels. The sedimentary structures indicate a complex history of variable water flow creating erosion and deposition, with lateral and vertical accretion indicating environments of flashflood, overbank flooding, and tranquil flow.

The archaeological features of Pololu demonstrate that the Hawaiian agricultural system was established to

30. H.T. Stearns and G.A. MacDonald, "Geology and Ground-Water Resources of the Island of Hawaii," *Hawaii Division of Hydrology, Bulletin* 9 (1946) 176–178.

Figure 6. Field alignments forming part of the dry-field agricultural complex on the floor of Pololu; a portion of this complex is illustrated in Figure 7. View to the south.

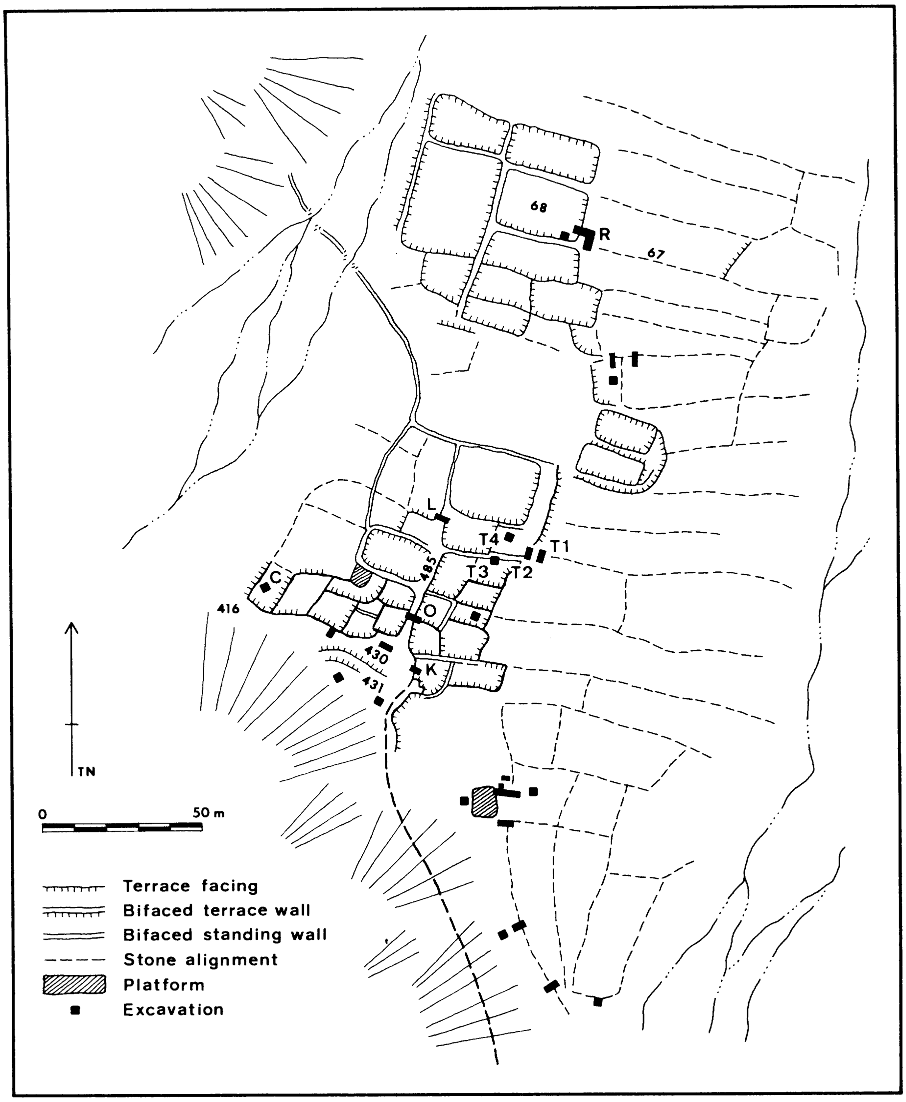

Figure 7. Irrigation system (Complex B) and associated dry-field boundaries found on the floor of Pololu (see FIG. 5); historic features have not been included in drawing.

contend with these hydrological conditions.[31] These aspects of the Hawaiian adaptation are discussed below.

1. Intensive dry-field cultivation was carried out on Pololu's alluvial floor. This circumstance contrasts sharply with the evidence for irrigation commonly found on the alluvium of valleys with good stream flow.

The survey of Pololu has located agricultural features over much of the valley floor, while excavation and stream exposures indicate that occupational deposits, primarily agricultural, exist throughout the valley. The majority of the agricultural evidence is identifiable as the result of dry cultivation and not irrigation. The surface features are dry-field areas formed by stone alignments or low embankments of stone and soil (FIGS. 6, 7), creating a rectilinear pattern similar to the field systems of the leeward Kohala slopes and reminiscent of features of the dry areas of Makaha Valley, O'ahu.[32] The Pololu features are superficial, extending only a few centimeters beneath the soil, with some 20 cm. of soil accumulated behind them. These field borders aided in moisture retention, retarded soil creep, and served to spread sheet wash. This dry-field system on the floor of Pololu represents the last Hawaiian effort to cultivate the inland valley. Throughout the valley beneath this field complex are buried agricultural soils, some possibly swidden modified, others from permanent field cultivation. The number of buried agricultural horizons numbers from one to three, but the overall impression is that time and again the agricultural soils were either eroded away or buried by heavy alluvial deposition under the erratic

31. Cf. Earle, op. cit. (in note 1) 101–108.

32. Hommon, op. cit. (in note 22) 45–53.

hydrological conditions of the valley. Habitation debris and features have also been found in association with the buried fields.

2. In Pololu irrigation was limited by water supply, not by alluvium. Irrigation complexes were developed with meager water sources and under conditions of environmental hazard.

Four irrigation complexes were constructed in lower Pololu (FIG. 5). The largest, located in the front of the valley, was supplied by a spring. It was historically expanded for rice cultivation, so its size is unknown but can be estimated at about five ha., based on archival data.[33] The three other complexes, watered from springs or spring-fed waterfalls, are quite small by Hawaiian standards, ranging from 0.07 to 0.60 ha. Additional irrigation terraces are found in upper gulches but there is alluvial terrain for development, and the terraces are small and marginal.

The water sources for these irrigation complexes have a very small flow today, and there is no evidence to suggest that the supply was greater when they were in use. Not only are the terrace complexes small, but the pond soils are poorly developed, and there is evidence from one complex (B) that it was abandoned for a period of time, probably during drought.

In being located to take advantage of the available water, the complexes were subject to other environmental problems: Complexes A and C to flood damage and Complex E to landslide. Complex E was located where there is no alluvium, and Complex D was placed at the rim of the valley, far above the valley floor, in a setting uncharacteristic of Hawaiian settlement pattern.

The irrigation features themselves are constructed in standard Hawaiian fashion: stone embankments formed pondfields, floors were packed, and silt accumulated. Water was brought in from canals (stone lined or earthen packed) or by placement of fields adjacent to spring flow. The smaller complexes distributed water internally by spill-over.

While the dry-field complexes and irrigation systems were established to take advantage of the limited water supply, additional modifications were made to contend with the periodic problem of flood.

Long, poorly faced walls were built in the dry-field complex to retard stream braiding, but the dry-field systems simply had to be periodically rebuilt after damaging floods occurred. Some effort was made to protect the irrigation complexes from flood damage. Complex B was erected on an old, natural terrace placing it above the general flood level of the valley but necessitating that water be transported much further than otherwise necessary. Complex C has a large protective stone wall and facing which would serve to divert flood water away from the irrigation fields.

33. Unfortunately we were unable to make direct investigations of this complex; we did not have equipment to work in the swampy conditions, and we did not want to disturb the domesticated animals kept in the area.

Agricultural Change in Pololu

Agricultural colonization of Pololu has not been dated directly, but if it was associated with the earliest habitation, it occurred by the late 16th century A.C. based on four radiocarbon dates and a series of volcanic glass alteration measurements (TABLE 1). The evidence is not solid but it points to colonization involving all three forms of cultivation previously defined: swidden, permanent field cultivation, and irrigation. Initial dates from several areas of the valley are comparable, pointing either to large-scale colonization or rapid expansion of the systems, particularly the swidden and permanent fields.

Following colonization, some intensification did occur. There is clear evidence (summarized below) for a shift from permanent field cultivation to irrigation at Complex B. The evidence regarding a swidden-to-permanent field succession is poor because exposure of the buried agricultural deposits is too limited to allow a clear distinction between the two. If swidden, however, was a significant factor in early agriculture, it had clearly been replaced by the final prehistoric agricultural occupation in which field borders covered the greater portion of the valley floor.

There were periods of decline of undetermined duration in the agricultural history of the valley. These occurred during the two terms of intensive flooding when dry-fields were destroyed and one term of drought when Complex B was temporarily abandoned. The final decline of the traditional agricultural system took place in the early historical period. The inland field areas were abandoned, probably in association with depopulation, a phenomenon that characterized much of Hawaii in the early 19th century. The conditions of field preservation and volcanic glass measurements indicate that abandonment of the interior areas was "recent" but archival records and the small number of European artifacts indicates that this occurred by at least 1850. By the turn of the century the Hawaiian population was small, other cultural groups were living in the valley, and the only active agricultural system was Complex A, which had been converted from taro to rice production.

Table 1. Chronometric dates from Pololu.

Radiocarbon dates (from Rikagaku Kenkyusho, Japan), 1975

Sample No.	Site	Feature	BP (½5730)	BP (½5568)	AC (½5568)	Tree Ring Calibration (Clark 1975)*	(Ralh et al. 1973)**
N-2180	4981		450 ± 80	435 ± 80	1515 ± 80	1400 ± 105	1430 ± 90
N-2181	4893	F	270 ± 95	260 ± 90	1690 ± 90	1610 ± 140	1630–1530 ± 90
N-2182	4893	1	260 ± 80	255 ± 75	1695 ± 75	1615 ± 105	1630 ± 90
N-2179	4870		260 ± 80	255 ± 80	1695 ± 80		

Volcanic glass hydration rind dates (Marcus Child, Hawaii Marine Research)***

Site No.	Location	Stratum	Sample Quality	Average Date BP	Average Date AC	Range Date AC
4893	3	IX	Good	351	1623	1583–1660
4893	3	IX	Fair	322	1652	1626–1669
4893	3	IX	Fair	336	1638	1600–1669
4893	3	IX	Fair	343	1631	1600–1651
4893	3	IX	Fair	337	1637	1600–1677
4893	3	IX	Fair	327	1647	1626–1660
4893	3	IX	Good	356	1618	1532–1660
4893	3	IX	F-G	353	1621	1583–1660
4893	3	IX	Fair	355	1619	1583–1660
4893	8	VI	F-G	345	1630	1600–1660
4893	8	VI	Fair	316	1659	1626–1686
4893	8	VI	Good	320	1655	1608–1686
4838	Pit O	IV	Good	367	1608	1575–1634
4838	Pit F	II	F-G	306	1668	1643–1685
4838	Pit F	II	Good	313	1661	1643–1685
4838	Pit T-2	I-A	Good	268	1706	1651–1753

*R.M. Clark, "A Calibration Curve for Radiocarbon Dates," *Antiquity* 49 (1975) 251–266.
**E. K. Ralph, H.N. Michael, and M.C. Han, "Radiocarbon Dates and Reality," *MASCA Newsletter* 9 (1973) 1–20.
***Morgenstein and Riley, op. cit. (in note 9) 152 use the equation $r_h = 11.7668\ \mu/10^3$ years, where r_h equals the rate of hydration.

Excavations of Complex B (Pololu Site 4838)

Details of Complex B (FIG. 7) are presented as an example of the type of research and the kinds of data upon which the above models are based.

Complex B, which covers an area of about 1 ha. (about 0.6 ha. irrigated), is formed by 33 pondfields and associated dry agricultural terraces constructed at the base of a ridge. Dry-cultivation field borders are found in the vicinity of the site. When the site was mapped, it became clear that the field boundaries ran to the edge of the pondfields on each side of the complex. In some cases the pondfield walls continued the line of the dry-field border. It appeared that the field borders were constructed first, followed by the building of the irrigation complex over a segment of them, employing the field lines as a guide. Excavation was carried out (1) to identify the function of features of the complex; (2) to determine the construction relationship between field boundaries and irrigation terraces; and (3) to establish a sequence of construction phases and/or stratigraphic changes, if any.

Excavations provided evidence regarding feature function and thus the overall operation of the irrigation complex. The complex was constructed by cut and fill on an alluvial terrace remnant at the base of a sharp ridge and it rises in a series of steps at about three degrees. Features which were tentatively identified as irrigation terraces on the basis of surface structure, proved when excavated, to have deposits with pondsoil characteristics. Water was brought by canal along the base and side of the ridge from a waterfall about 500 m. distant. From the head of the complex the water was dis-

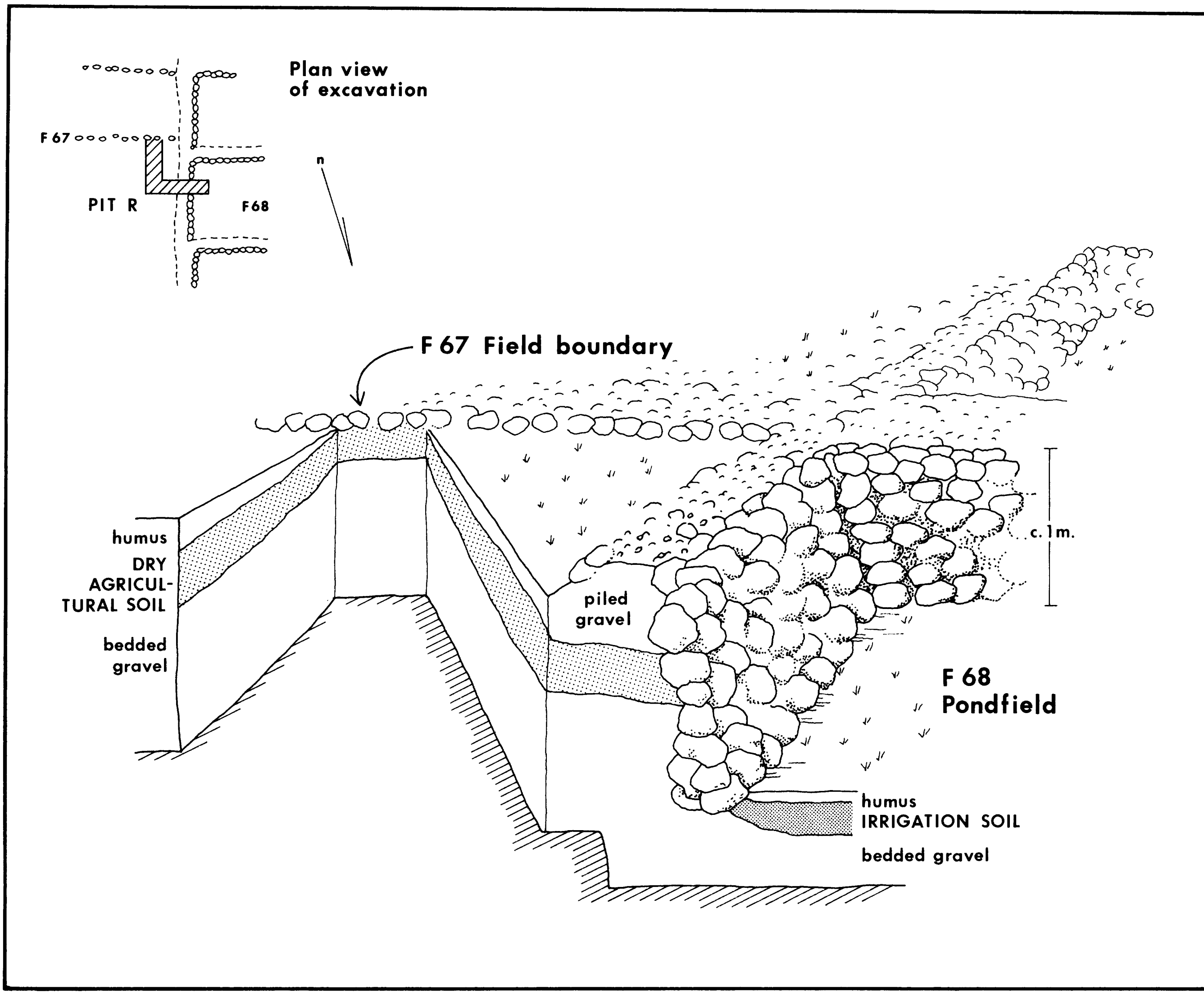

Figure 8. A schematic view of excavation of a portion of Complex B (Pit R: see FIG. 7), illustrating the relationship between dry-field irrigation and pondfield construction; soils are identified by criteria described in text.

tributed to terraces at either side and carried to the interior of the complex by a distribution canal (Feature 435). Excavation of the canal showed at least two building periods, the earlier of which included a side channel into the adjacent pondfield. Water was taken to the lower part of the complex by terrace spillways. There was habitation in association with the complex as indicated by features located on the ridge face above the site and at the edge of the dry-field system (Features 431, 429). Habitation features were also found in the stratified deposits of the complex, indicative of change in the operation of the system, as discussed below.

The relationship between dry-field boundaries and pondfields was clarified by excavations. Soils identified as non-irrigated agricultural deposits were succeeded by pondsoils in three excavations (Pits T, L, and R). Pit R (FIG. 8) demonstrates the conversion of a dry-field border into a terrace wall. Feature 67 was an original dry-field boundary with associated cultivation soil. The pondfield was created by digging out the north side of the dry-field, thus cutting through the original agricultural soil and into the alluvial gravels beneath. This material was thrown to the side to make the embankment perpendicular to Feature 67, and the dug-out area was then faced with cobbles to form the pondfield faces (Feature 68). Similar evidence was found in the Pit T series. Finally, an excavation pit in the intake canal (Feature 430) indicated that it was built over what had been a habitation structure occupied in association with the dry-fields. The proposition, based on mapping data, that the area had been intensified by conversion of a dry-field area to irrigation was thus supported by the excavation data.

The limited success of the irrigation venture is suggested by at least one period of abandonment and rebuilding. The intake canal was abandoned after some period of use, the area reconverted to habitation, followed by the construction of another canal. Other evidence also suggests two periods of irrigation activity. The distribution canal (Feature 435, Pit O) was abandoned and rebuilt, and pondsoils in several of the upper terraces show two levels of development. Additionally, agricultural use of one of the pondfields was supplanted by habitation (Feature 416, Pit C). These changes could have occurred at any time during occupation, perhaps at the end of the first period of irrigation without a reconversion when irrigation was attempted a second time. The actual number of terraces constructed or used at any one time cannot be determined, but the pondsoil characteristics of the lower set of terraces are much more poorly developed than those of the upper. This fact, associated with structural evidence not given here, indicates that the lower terrace fields were constructed well after the upper set. Whether or not this occurred as a part of the reuse phase of the upper terraces is unknown. In summary the evidence is substantial that Complex B was constructed and maintained under conditions of limited water availability.

Honokane Valley

Honokane Valley (FIGS. 3, 5) contrasts sharply with Pololu in configuration, water availability, and settlement system. Research in Honokane was on a smaller scale than that in Pololu and is only briefly summarized here.

Honokane (or Honokane Nui) is a canyon-like valley; steep-sided and narrow, it winds from the coast inland for some 9 km. to end at a grand amphitheatre head. The valley sides range from 300 m. high at the coast to nearly 700 m. high inland. The valley mouth, faced by a high boulder beach, is about 250 m. wide. Within 2 km. the valley bottom narrows to less than 100 m., then generally varies from 50 to 100 m. wide for the remainder of its length. A permanent stream, fed by a number of dikes,[34] meanders from side to side leaving a series of isolated benches, a total of about 30, set against the valley walls. The benches have a stream parallel grade of 2 to 3 degrees but are level across. There is virtually no talus development; the contact between a bench and the valley wall is kept sharp by back-channel erosion. The two largest benches, one nearly 5 ha., the other 3 ha., are in the lower segment of the valley. Others are generally under 1 ha. and as small as 0.1 ha. Almost all of these benches have sites on them and the majority of the sites are irrigation complexes.

Settlement and Agricultural History

Irrigation complexes are constructed on benches that have any reasonable amount of level land (FIGS. 5, 9). The largest complex has nearly 150 pondfields covering 4.7 ha. and is 960 m. long. Water sources vary; some complexes depended on canals that tapped the main stream; others obtained water from springs adjacent to the site or by run-off canals from perched springs. The larger complexes have one or more internal distribution canals.

The benches are composed of massive alluvial debris of cobbles and boulders with gravel-filled interstices. The only fine sediments are those found in the pondsoils, which appear to have been artificially deposited as part of the irrigation process (FIG. 10). There is no evidence for problems with flooding, nor is there any indication of rebuilding, except in the lower portion of the largest irrigation complex where pondfields silted in, requiring a build-up of terrace facings.

The limited dates from habitation deposits in the front and rear areas of the valley indicate that like Pololu, Honokane was either colonized on a large scale or its agricultural complexes were expanded rapidly. The colonization was roughly contemporaneous with that occurring in Pololu, that is, the 1600s A.C. There is no indication from the excavations or from the numerous stream exposures that any cultivation was carried out before the construction of the irrigation fields that are at present visible on the surface. Thus, unlike Pololu, Honokane did not experience any efforts of intensification. The overall impression is that, with the availability of abundant water, agriculture was introduced into the valley at its highest level of intensification; that complexes were built on a large scale, and that expansion was rapid.

Discussion and Conclusions

Research in the windward Kohala and Hamakua valleys supports five propositions regarding agricultural change within this region.

1. At one level of labor expenditure (or one level of intensification) agricultural colonization of the valleys had reached its limit.

34. The water has been diverted into the Kohala Ditch, an irrigation system of historical times which takes the water out of the valleys, leaving the streambed dry except after heavy rain.

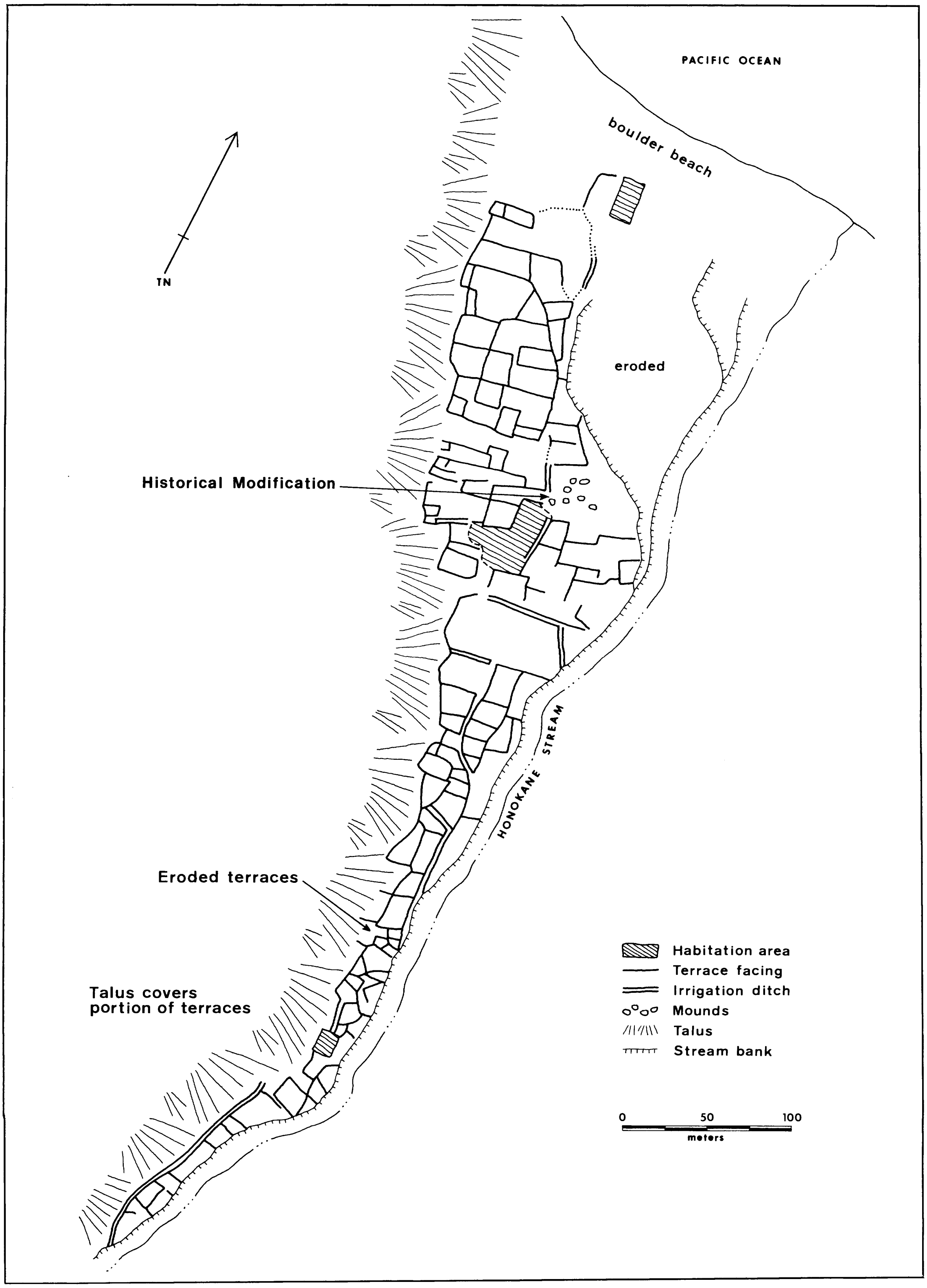

Figure 9. An irrigation system (Complex F, see FIG. 5) in Honokane. Terraces, canals, and associated habitation areas are illustrated; the streamside terraces have been damaged by erosion and talus has covered sections of the terraces below the cliff. The stream, originally permanent, is currently intercepted above this point for modern irrigation outside the valley.

Figure 10. Eroded bank of an irrigation system (Complex G; see FIG. 5) exposing the thin mantle of irrigation soil deposited above the natural valley fill.

2. Agricultural complexes had been intensified to the highest level possible within the framework of Hawaiian technology.

3. Agricultural intensification did occur in some areas, but not in a simple progression of swidden, permanent dry-field, irrigation.

4. In some areas no intensification took place; irrigation was introduced as the first and only form of cultivation.

5. The agricultural colonization of the Kohala valleys was late in the prehistory of Hawai'i, but it occurred in several places at more or less the same time, and it was followed by rapid expansion.

Yen has suggested a division of irrigation complexes into simple systems "where the valley floors are modified in their topography," and complex systems "where valleys and ridges are incorporated into unified systems."[35] Most of the irrigation in Oceania, including that in Hawaii, falls into the simple category. Earle[36] has noted that the amount of cut-and-fill involved in terrace construction is another means of measuring irrigation labor intensity. If a constant labor expenditure per terrace is maintained, the fields must decrease in size as slope increases; if a constant field size is maintained, the labor per field must increase because of the extra volume of earthmoving required. In Earle's study of irrigation on the island of Kaua'i it is indicated that irrigation systems were of low intensity: steeper areas were not irrigated, and there is generally a positive correlation between slope and terrace size. The surveys within the Kohala-Hamakua region indicated that irrigation was developed at a low level of intensity, one comparable to that of Kaua'i. Further, in the Kohala region, all of the areas which could be irrigated at this level were developed. In addition, intensive dry cultivation was found in Pololu and adjoining ridges on all of the areas of limited slope (up to about 20 degrees). The steeper slopes, however, were not dry terraced. In Pololu, the limits of the technological system are demonstrated: irrigation was attempted where there was suitable land even though water was inadequate. In other areas of Kohala-Hamakua, however, there was adequate water but irrigation was restrained by the amount of land that could be terraced with a low level of labor output. More complex, labor-intensive irrigation was certainly possible.

The extent and intensity of the complexes in Kohala lead to the conclusion that agricultural growth had reached its limits in the Kohala-Hamakua region, under the constraints of a simple irrigation technology and probably a comparable level of dry-field technology. This does not appear to have been the case on the other large islands, where more eroded landscapes provided much more room for irrigation (and perhaps dry cultivation) than was available on the island of Hawai'i. It has been noted that despite the extensive fields on such islands as Kaua'i and O'ahu there was still room for expansion.[37] If all this is translated into simple terms of food production and population, it suggests that population growth on Hawai'i had reached a plateau while on other islands it was still increasing. There is some evidence that Hawai'i was politically unified at an earlier date than the other islands and that it may have had a somewhat more complex political hierarchy.[38] If so, it can be argued that demand for agricultural land, particularly irrigation land, increased competition among polities, thus acting as a variable in the process of political elaboration.

The last proposition is the least secure of the five because of problems with sampling and with the methods of age determination. Viewed together, however, they indicate that agricultural growth was not a result of simple population increase. If this alone were operating causally, it would be expected to have produced an earlier colonization and a more gradual ex-

35. Yen, op. cit. (in note 21) 79.

36. Earle, op. cit. (in note 1) 106; T. Earle, "Control Hierarchies in the Traditional Irrigation Economy of Halelea District, Kauai, Hawaii," unpublished Ph.D. dissertation, University of Michigan (Ann Arbor 1973) 68–70.

37. Handy and Handy, op. cit. (in note 17) 269–272; Earle, ibid. (1973) 139–140.

38. Personal communication from R. Cordy; R. Cordy, "Traditional History of Oahu Political Units" (in preparation).

pansion and/or intensification. If population growth were to be argued as the primary factor in the agricultural growth, the pattern of development would have to be explained by environmental constraints such as limited water in Pololu, and a Honokane stream whose heavy flow would be difficult to control. A limited environmental model, however, appears to be less useful than models that combine population and production with an element of political behavior. Two are suggested here. The first is that settlement expansion was tightly regulated by ruling chiefs for purposes of political control. Settlement and agricultural colonization would be allowed to take place when population of adjacent areas reached a certain level and the bureaucracy was well enough developed to be able to maintain control of expanded boundaries.

A second model rests on the postulation that the traditional districts served as centers of competing political power. Boundaries between these units would be areas of contention and would have sparse development until a unification of competing districts took place. There is some additional evidence that adds to the strength of this model. There is archaeological and ethnohistorical evidence that conflict did take place in this border region. At least two of the ridges were fortified, or made sanctuaries, by the common Polynesian method of isolating an area by cutting trenches across narrow access routes. Oral traditions also refer to several critical battles that took place on the ridges within this region.[39] Oral traditions also indicate that, by genealogical count, the unification of the Island of Hawai'i occurred about the same time as the postulated colonization of the Kohala valleys based on archaeological dating. A similar model has been presented by Cordy[40] for possible boundary areas in leeward Hawai'i.[41]

As a closing comment, we would like to point out one of the advantages of working with the archaeology of agriculture. Agricultural sites tend to be extensive and relatively homogeneous. Excavation generally removes only a small percentage of a given site. This means that unlike excavation in habitation deposits or burials, the chance is very small that unique information will be destroyed by the excavation process. Agricultural sites may be returned to again and again to test field hypotheses with essentially the same data set. Thus the possibility of replication of observations reaches as high a level as is perhaps possible in field archaeology. As has become evident in recent years, replication is one of the most serious methodological problems facing this discipline.

39. S.M. Kamakau, *Ruling Chiefs of Hawaii* (Honolulu 1961) 82.

40. Cordy, op. cit. (in note 2) 251–266.

41. Hommon, op. cit. (in note 2) 173–296 has also discussed the issues of boundaries and political unification; further, he has dealt with the overall pattern of agricultural expansion in the Hawaiian Islands and explored a number of models not considered here, such as environmental change and introduction of new food crops.

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