

*Pre-Contact Arboriculture and Vegetation
in the Marquesas Islands, French Polynesia:
Charcoal Identification and Radiocarbon Dates
from Hatiheu Valley, Nuku Hiva*



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INTRODUCTION

STUDIES INVESTIGATING HUMAN-INDUCED ENVIRONMENTAL IMPACTS on tropical islands have a long scientific history, with significant early momentum created by publication of Raymond Fosberg's (1965) conference volume entitled *Man's Place in the Island Ecosystem*. The islands of the Pacific, known for their great cultural and environmental variability (Kirch 1984; Thomas 1965), have formed the setting for the majority of global research on the subject. In the Pacific Island region, debates that first emerged four decades ago continue today, and increasingly data-driven models have by now begun to replace more speculative and at times overreaching early assessments.

Previous research has securely demonstrated that individual islands and archipelagoes can have highly variable long-term ecological histories, which can be productively compared and contrasted (Florence and Lorence 1997; Kirch 1997; Kirch and Hunt 1997; Rolett and Diamond 2004). Several authors have also described, classified, and interpreted the diversity of agricultural production systems in the Pacific Islands (e.g., Kirch 1994; Leach 1999; Yen and Mummery 1990), but studies of irrigated taro systems and dryland "tuber"-growing landscapes have far exceeded, in number and intensity, studies of arboriculture. Because Marquesan islands like Nuku Hiva were among Polynesia's most breadfruit-reliant at the time of European contact, the Hatiheu Valley study area discussed here is an ideal setting to investigate long-term patterns in the development of Pacific Island arboricultural economies.

Intensive irrigated or dryland crop-growing systems often leave visible and distinctive remains on the landscape, whether in the form of "landesque capital" (Kirch 1994) or more indirect evidence such as that indicative of burning or erosion. Arboriculture, on the other hand, often involves significant modification of

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native vegetation but little modification of the abiotic landscape. Because of this, alternative means of studying the diachronic development of arboriculture must be developed and employed. Taxonomic identification of macroscopic wood charcoal (“anthracology”) is one means by which to recover cultural and environmental information during the course of archaeological investigations, and this approach has been fruitfully applied in many Pacific Island studies as a means by which to recover information regarding the identity and distributions of specific trees and shrubs, or of broader vegetation zones or communities, in a study area of interest (e.g., Allen and Murakami 1999; Athens et al. 1996; Coil 2004; Murakami 1983; Orliac 1997; Orliac and Orliac 1999). Like other forms of paleoecological data, wood charcoal identification results must be interpreted in accordance with a set of caveats involving potential biases and translocations. Approaches based upon the holistic incorporation of multiple lines of archaeobotanical, palynological, faunal, geoarchaeological, and ethnohistoric evidence, have therefore proven to be the most effective strategies to help untangle complex questions related to the role of humans in diachronic patterns of island environmental change.

In some locales, however, such as the Marquesas Islands, paleoenvironmental data remain essentially uncollected, and initial foundations have yet to be laid to help direct more expansive paleoecological studies. Though ethnographic and ethnohistoric studies have greatly expanded our knowledge of the developmental endpoints of Pacific Island agricultural systems and practices, these types of evidence are simply unable to provide any information on long-term patterns of economic development and change (Addison 2001). Proxy evidence for pre-contact vegetation change is found in Marquesan archaeofaunal studies (Kirch 1973; Rolett 1992; Steadman and Rolett 1996). Such studies have suggested that “habitat loss” was a significant cause of faunal shifts, but the nature and extent of the implied vegetation change remain indeterminate with only faunal data.

The present study analyzes some of the archipelago’s first direct and diachronic evidence of pre-contact vegetation patterns. The focus here is on taxonomic identification of 15 excavated wood charcoal assemblages from archaeological sites in the Hatiheu Valley on the Marquesan island of Nuku Hiva (Fig. 1), and on radiocarbon dates associated with a subsample of these assemblages. Ways in which this data help elucidate the deeper history of breadfruit-centered arboricultural production systems in parts of Eastern Polynesia are also considered, as are relations between these results and contrasting models of arboricultural development that have emerged in the Pacific Island region.

The authors recognize that the results are preliminary due to the restricted sample size. However, we hope that this study will encourage others to pursue research on arboriculture development and ecological transformation in the Marquesas Islands.¹

THE STUDY AREA: HATIHEU VALLEY²

Located on the north coast of Nuku Hiva Island, Hatiheu is a wide amphitheater-headed valley ringed by irregular ridges and peaks, which rise to a maximum elevation of about 800 m above sea level (masl). Small sub-valleys have been formed by long-term erosion and usually contain intermittent streams. These smaller

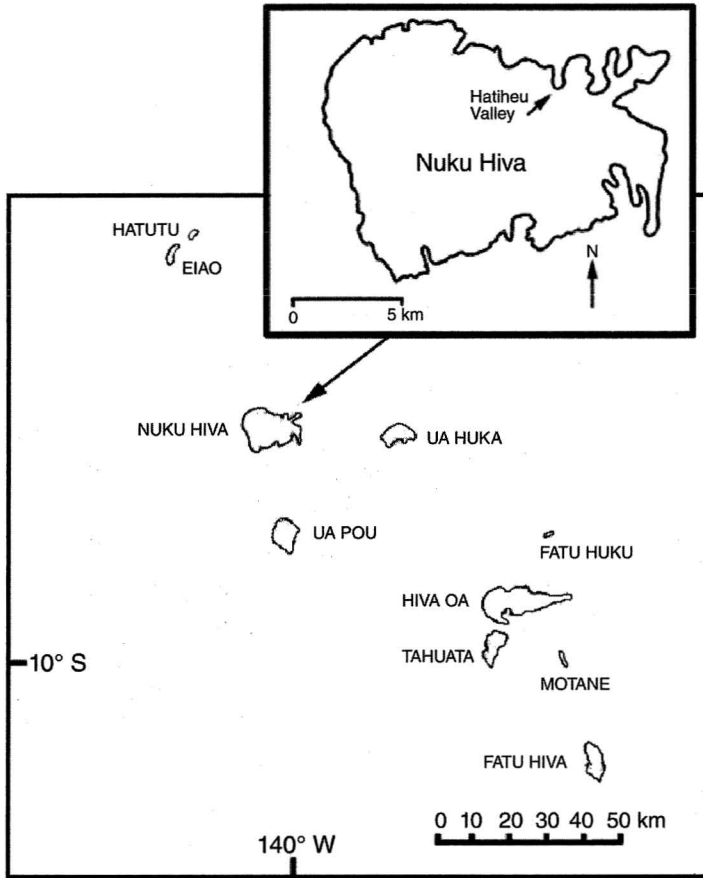


Fig. 1. Map of the Marquesas Islands with locations of Nuku Hiva and Hatiheu Valley indicated.

streams feed four large perennial streams/ivers (*Ahupa'a*, *Puaiki*, *Vaiu'ua*, and *Puhi'oho*), which flow across the wide floor of the main valley and empty into the ocean at Hatiheu Bay. The beachfront is about 1000 m in breadth, while the valley floor, formed by alluvial and colluvial deposition of upland sediments, is approximately 1 to 1.5 km deep (Fig. 2). Elevations in the valley floor range from sea level to about 160 masl.

In the Marquesas as a whole, rainfall is highly variable while temperature is highly stable (Adamson 1936). Modern pluviometric data collected from six of the main islands reveal that Hatiheu Valley is one of the wettest in the archipelago (Cauchard and Inchauspe 1978:77). Being less subject to the prolonged droughts that often occur in the Marquesas (Rolett 1998:47), the northeastern part of Nuku Hiva Island was probably among the archipelago's most well-suited islands for permanent habitation. Regarding nearby Taipi Valley, a 1797 observer on the missionary ship *Duff* noted that, "All the valleys about this bay appeared fertile, many of the hills were covered with trees, and the interior parts seemed more habitable than any other of the Marquesas" (Wilson 1997 [1797]:130).

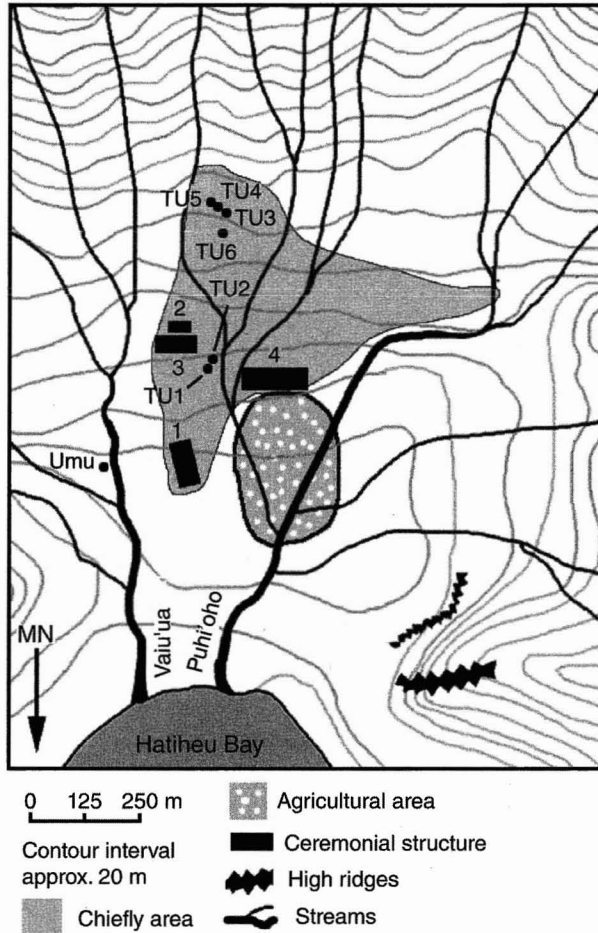


Fig. 2. Hatihehu Valley with locations of sites and test units discussed.

This study area would thus seem to represent a setting where agricultural adaptations would not have been constrained by marginal environmental conditions.

METHODS

Archaeological survey in Hatihehu Valley, focused on investigating the spatial and temporal relationships between rock art and archaeological sites, was conducted between *Vaiu'ua* and *Puhi'oho* streams, and all visible stone remains from the beach to the inland extent of the valley were recorded and mapped (Millerstrom 2001). The largest concentration of architecturally elaborated sites was found on the valley floor, but with sites also occurring on the colluvial slopes that develop toward the back of the valley (see shaded area on Fig. 2). An extensive agricultural complex with abandoned stone-walled taro pondfields of unknown age, is located to

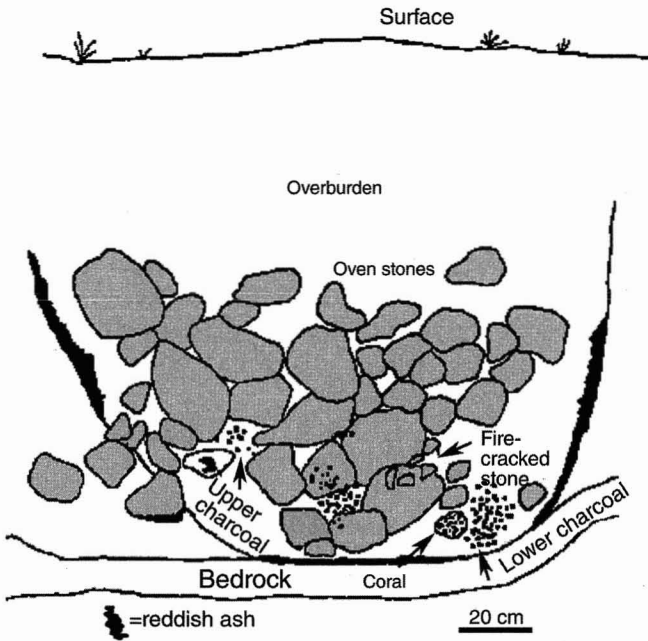


Fig. 3. Profile drawing of earth oven located in road-cut.

the north of this area (stippled area in Fig. 2). Neither detailed survey nor excavations have yet taken place in this area.

During test pit excavation, charcoal was collected from sites in five discrete locations within the valley, which were distributed in the lower, middle, and upper “zones” of the western part of Hatiheu. Excavations took place in a variety of archaeological contexts including a large earth oven exposed in a road cut near the beach (*umu* in Fig. 2), two residential terraces surrounded by four large ceremonial complexes in the lower valley, a house pit (*pakaho*) in a large residential structure toward the back of the valley, and in a residential complex very close to the upper limits of the valley’s habitable area (Figs. 3–7). Table 1 summarizes the more specific archaeological contexts from which the identified and radiocarbon-dated samples derived. Because of this spatial separation of these sample contexts, the taxonomic charcoal data discussed below should reflect, to some degree, the pre-contact vegetation of various microenvironmental zones within the valley.

Five charcoal samples were used for radiocarbon dating and these dates, presented and discussed below along with taxonomic charcoal data, represent the first reported absolute dates from Hatiheu Valley. As Rolett (1998) has reviewed, establishment of a well-delimited sequence of cultural development in the Marquesas has been fettered by a radiocarbon chronology that is based on too few dates, many of which are from a limited range of environmental and archaeological contexts such as coastal dune sites and megalithic stone structures. The new dates reported here and discussed below thus provide novel information in the form of AMS radiocarbon dates from a broad range of site types that span the preserved archaeological settlement pattern found in Hatiheu Valley.

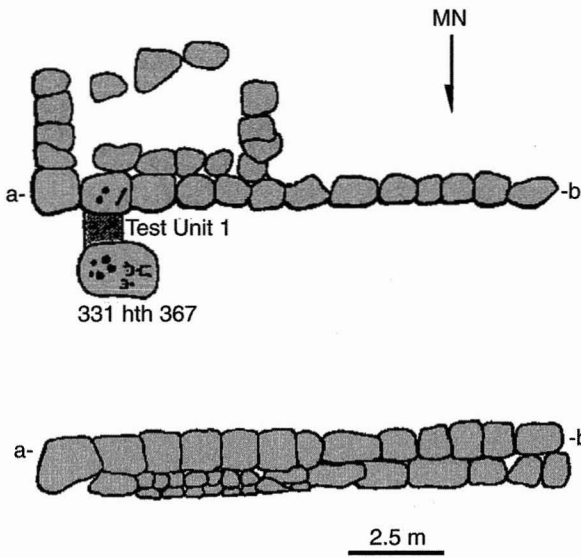


Fig. 4. Drawing of structure 200 with location of Test Unit 1.

During site excavation, visible charcoal fragments and small deposits embedded in sticky clay matrices were hand-collected. Although this method successfully produced the charcoal samples analyzed here, more intensive methods such as wet-sieving or flotation may have allowed expanded macrobotanical recovery. Before the identifications reported here took place, a single fragment was removed from five of the samples for AMS radiocarbon dating. Further efforts were made in the laboratory to separate smaller charcoal fragments from the clay soil with which they were collected, by immersing soil clumps containing charcoal in a beaker of water containing a small amount of sodium hexametaphosphate, and wet-sieving through 2 mm mesh. After this process, the 15 samples examined

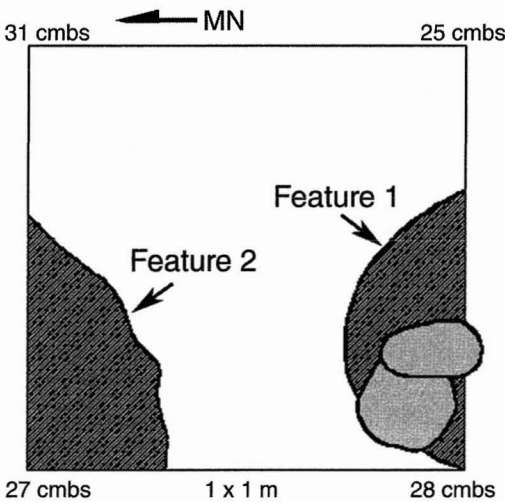


Fig. 5. Test Unit 1 plan view showing Features 1 and 2.

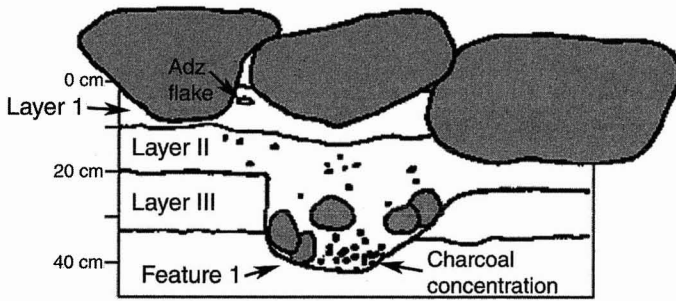


Fig. 6. Profile drawing of Test Unit 1.

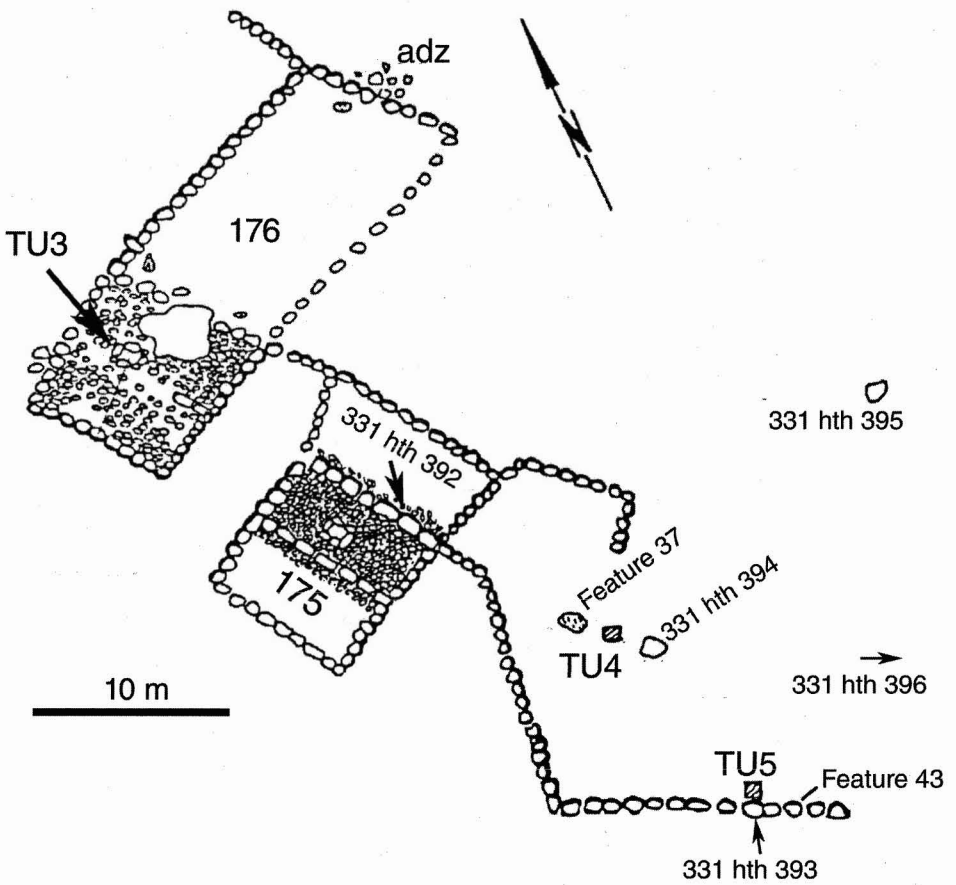


Fig. 7. Sites 175 and 176 showing locations of Test Units 3, 4, and 5. "331" labels are petroglyph locations.

TABLE 1. SUMMARY OF CHARCOAL SAMPLE LOCATIONS AND CONTEXTS

TEST UNIT NO.	SITE TYPE	APPROXIMATE ELEVATION	CHARCOAL SAMPLE CONTEXT(S)	RELATED FIGURES
Umu	Large earth oven exposed in roadcut	~50 masl	Three samples: upper, lower, scattered	3
Test Unit 1 and 2	In two stone-faced terraces near area of four large ceremonial complexes	~100 masl	Seven samples total: 4 from Test Unit 1 and 3 from Test Unit 2	4, 5, and 6
Test Unit 6	Stone-lined house pit (<i>pakaho</i>)	~150 masl	One very small sample from X context	none
Test Units 3, 4, and 5	Residential complex	~175 masl	Four stratified samples from Test Unit 4; Test Units 3 and 5 had no charcoal recovered	7

contained between 3 and 35 charcoal fragments of a size sufficient to allow an attempt at identification.

Taxonomic identification was attempted for as many fragments as possible, using a methodology adapted from that initially described by Leney and Casteel (1975). Individual charcoal fragments were hand-fractured to reveal each of the three planes used to fully view the anatomical structure preserved in the carbonized wood: transverse, tangential longitudinal, and radial longitudinal. Two reflected light microscopes—one stereoscopic for lower magnifications and one metallurgical for higher—were used to examine the exposed surfaces.

Taxonomic assignments were made by comparison of the anatomical details preserved in the archaeological charcoal with thin-sectioned and experimentally carbonized wood samples from the vouchered Pacific Island wood collection curated at the University of California at Berkeley Archaeological Research Facility. Published photos and descriptions of Pacific wood anatomy also helped control for possible variability in some taxa (Brown 1922; Detienne and Jacquet 1999; Lamberton 1955).

RESULTS

Though every effort was made to ensure accuracy in these taxonomic identifications, the fact that the utilized reference materials did not comprehensively represent the full range of possible taxa from the study area means that species-level identifications were not always possible, and that some minor inaccuracies may also exist. Six taxa of Polynesian-introduced trees and shrubs were identified in these samples, as well as at least eight taxa representing native tree and shrub vegetation. Three distinctive but unknown dicotyledonous wood types were encountered, as well as one unidentifiable monocotyledonous type and several unidentifiable bark and seed endocarp fragments. Most samples also had some fragments that have been classified as “unidentifiable” because of their fragility, unusual grain, insufficient size, or deteriorated state.

Table 2 presents the taxonomic data for the fifteen wood samples examined,

TABLE 3. CHARCOAL TAXA UBIQUITIES, WITH BOTANICAL, ENGLISH, AND MARQUESAN NAMES, AND ECONOMIC USES

LATIN	AUTHORITY	MARQUESAN (ENGLISH)	KNOWN USES	UBIQUITY (%)
<i>Hibiscus tiliaceus</i>	L.	fau/hau	fiber, timber	73%
<i>Artocarpus altilis</i>	(S. Parkinson ex Z.) Fosb.	mei (breadfruit)	food, timber, etc.	53%
<i>Thespesia populnea</i>	(L.) Sol. Ex Corrêa	mi'o	carving wood	47%
<i>Sapindis saponaria</i>	L.	koku'u	fuelwood for ovens	27%
cf. <i>Bauhinia</i>	—	—	—	13%
cf. <i>Cocos nucifera</i>	L.	ehi (coconut)	food, fiber, etc.	13%
<i>Inocarpus fagifer</i>	Fosb.	i'i, mape (Tahitian chestnut)	food	13%
cf. <i>Alstonia</i>	—	—	—	7%
cf. <i>Claoxylon</i>	—	—	—	7%
<i>Cordia subcordata</i>	Lam.	tou	carving wood, food (seeds)	7%
<i>Crossostylis</i> sp.	—	—	—	7%
cf. <i>Metrosideros</i> sp.	Banks ex Gaertn.	heua	—	7%
cf. <i>Weinmannia</i> sp.	—	—	—	7%
cf. <i>Wikstroemia</i> sp.	Endl., 1841, orth. et nom. cons.	ka'apihi	—	7%

clustered in three “zones”: lower valley, middle valley, and upper valley. Table 2 also gives provenience information and radiocarbon dates where available. Taxa preceded by “cf.” indicate less secure identifications—these are attached mainly to native trees and shrubs. Taxonomic data is presented quantitatively as percentages by both weight and by fragment count for each sample, with economic trees and shrubs grouped to the left and native trees and shrubs to the right. In quantifying these results, however, some interpretive caveats must be mentioned. The pitfalls of attempting to directly correlate quantitative proportions of charcoal with estimates of ecological dominance have been widely debated (e.g., Boyd 1988; Godwin and Tansley 1941; Keepax 1988; Smart and Hoffman 1988), and the small size of many of our samples in the present study may further distort this relationship. Small sample sizes also precluded statistical analyses. Table 3 lists the taxa present in order of ubiquity, or the total number of samples in which each occurred in any quantity. It also provides Marquesan and English names for the identified taxa where available.

Figure 8 uses OxCal (version 3.8; Stuvier et al. 1998) calibration software to plot the calibrated age ranges of the five radiocarbon determinations obtained for this project. Because AMS dating sub-sample fragments were removed from these charcoal assemblages before identification took place, the specific taxa dated remain unknown. Because of this, it is possible that some of the samples may be biased by “inbuilt age” that can exist in older wood before it is burned (Bowman 1990; Schiffer 1986), and may have yielded dates somewhat older than the burning events being dated. These issues are discussed further below.

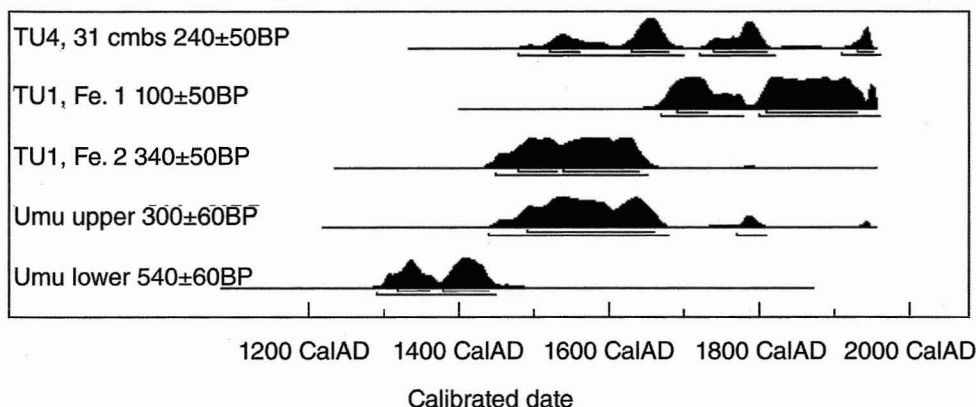


Fig. 8. OxCal (version 3.8) plot of radiocarbon dates for five AMS radiocarbon dates obtained from earth oven and test unit excavations. Atmospheric data from Stuiver et al. (1998).

DISCUSSION

The analyzed charcoal samples displayed marked variability in the presence and proportions of the 14 tree and shrub taxa identified in this study, and this variability is found both between sites and within samples from the same site. This variability may be attributed to several possible factors, including spatial and temporal variation in sample origins, excavation from different types of archaeological contexts (e.g., ovens or hearths versus burn lenses or pits), or statistically random variability caused by small sample sizes. We discuss our results in view of these first two factors, although because of the third we base our interpretations more on presence/absence of particular taxa in particular samples, while considering more quantitative proportions only broadly or as averaged for multiple samples.

Lower Valley Samples

The three lowest elevation samples derived from sampling of the profile of a large earth oven exposed in a modern roadcut. One sample came from the upper part of the oven profile, one from near the base, and another was scattered throughout the feature. The deepest sample was found to contain only *Hibiscus tiliaceus* charcoal. Though it is possible that this low-density wood was used for fire starting and thus was logically recovered from the bottom of the umu, the radiocarbon date associated with this assemblage suggests that it may also have been associated with early use of this oven, whereas the uppermost sample may reflect later episodes of the oven's use. In this upper sample, a more diverse set of taxa was found, with *Hibiscus* occurring only in small quantities and with *Thespesia populnea*, *Crossostylis* sp., and *Sapindus saponaria* also present. These are all denser woods that would have burned longer and hotter than *Hibiscus*. *Sapindus*, in particular, was recorded by Decker (1970) as a preferred wood for modern Marquesan bakers, who during his study would sometimes exchange loaves of bread with those who could supply this wood. The presence of *Sapindus* in this earth oven

feature suggests a similar cultural preference as an oven wood in the pre-contact past. The third charcoal sample, dispersed more broadly, contained more *Sapindus* wood, as well as a small quantity of breadfruit (*Artocarpus altilis*) wood.

Middle Valley Samples

Seven samples derived from two test pit excavations in the lower valley area, in an area dominated by the remains of large ceremonial complexes. Test Unit 1 was excavated in a residential terrace that contained two identified combustion features, both of which yielded charcoal samples and were radiocarbon dated. Charcoal from two general stratigraphic levels from this test unit were also analyzed. Test Unit 2, located in another residential terrace nearby, had charcoal samples recovered and analyzed from three stratigraphic levels.

All of the seven charcoal samples from this area contained a marked predominance of economic taxa, although small quantities of native woods did also occur. The favored Polynesian carving wood *Thespesia populnea* was found to be especially abundant in these test units, and another Polynesian carving wood, *Cordia subcordata*, was also present. This latter tree grows primarily on coastlines, so the presence of *Cordia* charcoal in this mid-valley location may represent intentional inland transport of the wood, and perhaps along with *Thespesia* wood suggests the burning of the remains of carving projects at these sites. Also present at this site are *Artocarpus*, *Hibiscus*, and *Inocarpus fagifer*. These assemblages suggest a dominance of introduced, economically utilized trees and shrubs in the middle valley during the time periods these samples represent.

Upper Valley Samples

Test Unit 6, excavated in a high-status residential site on a steepening section of the valley's back slope, produced only a single charcoal sample. This sample provided little information as it contained only two identifiable charcoal fragments, both *Hibiscus tiliaceus*. However, excavation of three more test units (#3, #4, and #5) in sites from further back in the upper valley, past which the slope becomes too steep for habitation, have provided more substantial information on this zone's pre-contact vegetation. Two of these test units (#3 and #5) produced no visible evidence of macroscopic charcoal. The third, Test Unit 4, produced four stratified samples.

Charcoal samples from all four stratigraphic levels at this upper valley site were dominated by *Hibiscus tiliaceus* charcoal, and although this charcoal type is common in all of the sites analyzed in this study, *Hibiscus* may have tended to grow most profusely in the wettest climates near the back of the valley. *Artocarpus* is also fairly ubiquitous, suggesting that breadfruit trees were planted far back in the valley interior during the pre-contact period, not just on the valley floor. In contrast, and despite its highly ubiquitous presence in middle valley samples, *Thespesia* charcoal is completely absent in these back valley assemblages. Interestingly, while showing less diversity of economic wood taxa than the middle valley samples, identified charcoal in the four upper valley samples consisted of almost 100 percent economic woods. The exception here is found in the form of about 25 percent native wood charcoals by weight in the third stratified sample. Here,

TABLE 4. SUMMARY OF PROPORTIONS OF ECONOMIC WOODS IN LOWER, MIDDLE, AND UPPER VALLEY ZONES

ARTOCARPUS ALUTILIS	COCOS NUCIFERA	CORDIA SUBCORDATA	HIBISCUS TILIACEUS	INOCARPUS FAGIFER	THESPESIA POPULNEA	PERCENTAGE OF ECONOMIC WOODS
Upper valley 40	20		100			95.4
Middle valley 71	14	14	57	29	86	88.1
Lower valley 33			66		33	55.0

Blank box = did not occur; white box = 1–25% economic woods; light gray = 25–50%; medium gray = 51–75%; and dark gray = 76–100%.

three non-economic, native taxa were found in a basal context that appeared to be an in situ burn layer, suggesting some burning of native vegetation during site construction, or perhaps the local presence of shifting cultivation before the site was situated. However, such burning may also have been spatially and/or temporally limited, as no charcoal was recovered from similar contexts in Test Units 3 or 5 nearby.

Summary of Wood Distribution Patterns

Table 4 summarizes the proportions of individual economic tree and shrub taxa present in all samples from the lower, middle, and upper valley zones. Taxa that occur in 1–25 percent of the samples from a given zone are unshaded, 26–50 percent shaded light gray, 51–75 percent medium gray, and 75–100 percent dark gray. This is meant to schematize the pre-contact distributions of these economic taxa across Hatiheu and provides a rough index of their possible pre-contact abundances in each zone. The rightmost column in Table 4 uses the proportions by weight found in Table 2 to create average figures for the proportion of economic woods in each zone's charcoal samples. In other words, what is the average proportion by weight of economic tree and shrub charcoal versus native woods in each zone?

Interestingly, the highest average proportion of economic woods is found in the upper valley samples, where economic taxa account for 95.4 percent of all identified fragments by weight. In the middle valley samples, economic taxa show a slightly lower average weight of 88.1 percent, while the three oven samples from the lower valley contain only 55.0 percent economic woods. The lower number here may reflect use of a preferred native wood (*Sapindus*) for oven fuel, rather than a less modified vegetation landscape in more coastal areas. It is also possible that this lower proportion reflects use of the oven at a time period earlier than the middle and upper valley sites, and hence perhaps at a point when local native vegetation remained more intact and available for fuel wood collection. With the exception of the *Sapindus* wood that may have been selectively col-

lected for oven use, other native woods revealed in these charcoal samples show indistinct patterning. A wider range of larger samples would appear to be necessary to further elucidate patterning in relict or pre-human native vegetation. Vagaries in the existing radiocarbon chronology (discussed below) prevent secure diachronic analysis of these distributions, so Table 4 represents a somewhat essentialized, synchronic reconstruction of Hatiheu's pre-contact arboricultural landscape.

Though it is possible that some of the woods in this study were transported to the sites from which they were excavated—such as through stream flooding or human movement of preferred carving woods or fuel woods, it is also likely that these assemblages reflect the general patterns of localized vegetation from which wood was collected. Charcoal from *Hibiscus tiliaceus* was the most ubiquitous in this study, occurring abundantly in all valley zones where excavations occurred. Though valued economically for its fiber and construction uses (Petard 1986 [1957]:215), this large and aggressive shrubby plant probably spread and reproduced naturally in the valley and was in little danger of being overexploited. *Hibiscus tiliaceus* can quickly colonize disturbed landscapes (Lepofsky et al. 1996), and acts as a common pioneer in fallowed garden areas (Decker 1970). Orliac (1997:209), based on experimental burning, notes that this wood tends to burn to ash and therefore is unlikely to be well represented in charcoal assemblages. The fact then that *Hibiscus* charcoal was in this study the most abundant, may serve as further evidence of its probable ecological abundance in all valley areas.

Decker (1970) notes that *Thespesia populnea*, the tree that produces the most popular Polynesian carving wood, is generally a shoreline tree, and that the fact that it is found in Marquesan valley interiors in modern studies reflects intentional upland planting. He also notes that the popularity of the wood for carving makes *Thespesia* rare in many populated valleys today. Data from this study indicate that in the pre-contact past, this wood seems to have been available throughout the range of time periods reflected in the reported radiocarbon dates, although it was apparently not as commonly planted or used in the upper valley zone, where its charcoal did not occur. The common presence of this charcoal in the middle valley test units, however, along with the presence of *Cordia subcordata*, could indicate a relation between woodcarving activities and the ceremonial *tohua* structures that surround the middle valley's excavated sites.

Breadfruit (*Artocarpus altilis*) was historically a staple arboricultural crop in the Marquesas (see ethnohistoric reviews in Addison 2008 and Rolett 1998), and the wood of this tree was found to be quite ubiquitous in these sites and samples, second only to *Hibiscus*. Orliac has characterized the fuel value of *Artocarpus* wood as poor (210), so like *Hibiscus*, the common presence of *Artocarpus* wood in our samples probably reflects its abundance in the pre-contact Hatiheu landscape, where the proximity of trees and ease of firewood collection may have outweighed considerations of the wood's less-than-ideal burning qualities. Charcoal from other economic trees and shrubs, such as *Inocarpus*, *Cocos*, and *Cordia*, occurs with more limited and sporadic distributions. The relatively low quantities of these woods, in tandem with the absence of charcoal from other Polynesian economic trees such as those from the genera *Morinda*, *Syzygium*, *Aleurites*, *Pandanus*, *Barringtonia*, and *Calophyllum*, indicate the pre-contact existence of a heavily breadfruit-centered arboricultural system. This is an alternative interpretation of subsistence to that

of a more biodiverse "agroforest" such as those described by Athens et al. (1996), Lepofsky (1999), or Kirch and Yen (1982).

Other types of food plant macroremains, such as carbonized tuber fragments or other parenchymatous tissues, were absent from these samples. Though this may reflect sampling error or lack of preservation, it may also reflect a relatively insignificant reliance upon annual crop cultivation in pre-Contact Hatiheu. When considered in tandem with the relatively low proportions of native woods in basal site charcoal deposits and the fact that upper valley test pits lacked visible charcoal deposits in two of three cases, these data support Rolett's earlier conclusion that "there is no [Marquesan ethnohistoric or ethnographic] evidence to suggest any degree of intensified shifting cultivation comparable to systems known elsewhere in Polynesia" (1998:36).

Radiocarbon Dates

Taken as a whole, the five radiocarbon dates from this project span, when calibrated, a calendar age range of approximately A.D. 1300 to the present, at the 2-sigma level. The age determination for the stratigraphically deepest sample from the lower valley earth oven is the earliest of the five, and suggests that first construction and use of this feature dates to between A.D. 1300 and A.D. 1450. Though the taxonomic identity of the dated charcoal fragment remains unknown, all of the remaining fragments in this assemblage were identified as the relatively short-lived taxon *Hibiscus tiliaceus*, and it thus seems likely that this date accurately reflects a relatively early period of the valley's occupation, although not necessarily the earliest. The date from the more shallow charcoal sample from the earth oven calibrates significantly later than the first date (although also with some overlap), suggesting that this oven was used repeatedly over a substantial period of time, perhaps hundreds of years, or was re-used later after initial construction. As indicated by the road cut exposure of the buried earth oven, it is likely that many of the sites reflecting early occupation and use of the Hatiheu Valley floor have been similarly buried by eroded sediments, and more concerted efforts to locate and excavate such buried sites may be required to recover better evidence of early valley settlement and economy.

The two age determinations from Features 1 and 2 in Test Unit 1, situated in the middle valley, suggest that sites in this area were settled as early as the late 1400s. Again here, two contrasting radiocarbon dates suggest this site was occupied for a considerable length of time, from about A.D. 1450 to the point of European contact and beyond. It is likely, however, that the earlier date was run on a subsample of *Thespesia* charcoal (the dominant taxon later identified in the assemblage), which may have contained some inbuilt age bias, without which the dates from these two Test Unit 1 samples may have been more similar. This consideration would still permit a very conservative assignment of initial construction in and use of middle-valley sites to around A.D. 1600–1700. The final dated sample, from Test Unit 4 in the extreme back of the valley, returned a wide calibrated spread of possible dates, indicating use or occupation of the upper valley by as early as about A.D. 1500 or as late as A.D. 1800. However, since none of the excavated sites contained historic materials, it is likely that portions of the date ranges that would indicate post-contact or modern occupation of these sites can

be de-emphasized, and these charcoal samples can thus be reasonably considered to derive from burning events that took place in the pre-contact period.

Clearly more dates are required to advance a more definite regional chronology for settlement and use of various areas in Hatiheu Valley, or to allow this valley's prehistory to shape broader models of Marquesan settlement and cultural change. However, these results are broadly in accord with previous chronological models of Marquesan prehistory, which propose that subsequent to the 1300s–1400s (Rolett 1998; Sinoto 1979), inter- and intra-island exchange and cooperation largely collapsed, as increasing warfare and raiding mandated greater economic self-reliance among dispersed populations. The results from this project should reflect the conditions of these "Expansion Period" transformational processes (Rolett 1998), as populations increased, residential settlement and arboricultural production spread to the upper limits of Hatiheu Valley, ceremonial architecture was increasingly enlarged and became more complex and, in Addison's (2001) model, irrigated taro cultivation was increasingly relied upon as an alternative means of survival during times of drought, supplanting less viable earlier strategies based upon interregional exchange, relocation, or redistribution.²

While the new radiocarbon dates from this study can by no means eliminate the existing vagaries of the Marquesas' expansion period chronology, the dense distribution of similar archaeological structures and rock art images (Millerstrom 2001) throughout the valley makes it seem quite likely that the entirety of Hatiheu Valley was densely settled and economically utilized by the late prehistoric period. Importantly, however, given the abundant presence of economic woods in all of the sampled valley zones—even in the deepest stratigraphic levels—it also appears that vegetation conversion in inner valley areas took place significantly before many of the pre-contact sites that comprise the valley's visible surface settlement had been constructed.

CONCLUSION

Within the bounds of interpretive caution mandated by small sample sizes, few radiocarbon dates, and biases inherent to wood charcoal data, the results of this study have helped delineate the spatial and temporal dynamics of the Hatiheu Valley's pre-contact economy and settlement pattern. These dates appear to push the antiquity of breadfruit-centered arboriculture back several centuries before contact. Addison has argued:

Basing an understanding of traditional Marquesan agriculture on historic and ethnographic accounts alone is problematic. . . . Temporally, only the endpoint in a developmental sequence is represented. Change through time that led to the system described for the ethnographic present is not represented in these accounts. Spatially, variation between different environmental contexts becomes blurred as fragments of information from various localities are blended. (2001:268–269)

In this study's samples, *Artocarpus* wood occurs across the spatial range of our archaeological contexts, as well as in dated contexts suggesting breadfruit cultivation as early as the 1300s if the somewhat loose association of breadfruit wood with the lower valley's earlier earth oven date is considered. Other arboricultural taxa, including *Cordia*, *Inocarpus*, *Thespesia*, and *Cocos*, also occur in these samples,

but in limited quantities and with a pattern of occurring most heavily in the middle valley samples.

The new data presented thus help to confront the issues raised by Addison, by establishing some basic temporal and spatial parameters for vegetation change and the development of arboriculture in Hatiheu, as a case study relevant to understanding of the archipelago as a whole. This study presents an intermediate temporal view of Marquesan valley vegetation change and its relation to pre-contact Marquesan settlement patterns and the development of arboricultural food production strategies. This view seems to lie chronologically between the shift to more extensive agricultural food production hypothesized in existing models to have taken place around A.D. 1300, based upon faunal studies and dating of elaborated site architecture, and the ethnohistoric or ethnographic viewpoints recorded in the post-contact period after breadfruit production had clearly come to play the dominant role in Marquesan food production.

This study also addresses wider issues of economic development and change in the Pacific islands as a whole. As discussed by authors including Kirch and Yen (1982), Kirch (1994), Athens et al. (1996), and Latinis (2000), arboricultural economic strategies formed the backbone of many Pacific Island economies by the point of European contact. However, the spatial and temporal parameters associated with these pre-contact developments remain poorly evidenced, and contrasting models have emerged as based upon specific island case studies. In Kirch and Yen's (1982) model of long-term economic development in the Polynesian outlier island of Tikopia, for example, the reliance on arboriculture documented in ethnographic studies and modern observations was thought to be a slow, gradual process that did not substantially replace earlier reliance on annual crop cultivation for more than 2000 years. Based on their studies of the Micronesian island of Kosrae, however, Athens et al. (1996) believe that conversion of native vegetation to arboriculture-dominated landscapes was a very immediate result of initial colonization, with long-term Boserupian (Boserup 1965) intensification patterns not supported by their various lines of paleoecological evidence. The present study seems to reflect the latter model, with development of a broad spatial landscape dominated by economic trees evidenced even prior to residential settlement of upper valley areas, and with little clear evidence for earlier economic systems based on shifting cultivation.

Further research work in Hatiheu Valley could continue to contribute to economic model-building for pre-Contact Polynesia. Excavation and dating of the valley's large pondfield complex would help determine the chronology of irrigated taro development and its relation to the timing of arboricultural expansion. Addison (2001) has argued that irrigated taro formed a previously underrecognized aspect of subsistence and survival in the pre-contact Marquesas, and that its incorporation in breadfruit-oriented production systems may have helped safeguard against periods of extended drought, which can decimate breadfruit crops for several years in a row. If further research determines that pondfield development commenced later than construction of sites containing assemblages of arboricultural woods in charcoal assemblages, it may indicate that other drought survival strategies, such as population mobility, exchange, or range expansion, had become less easily utilized over time, and new, more locally self-sufficient economic adaptations instead took place.

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NOTES

1. The focus of the original research was to place rock art within a cultural context. The research was limited to the area between two major river systems on the western side of Hatiheu village. Archaeologically this topic and this area had not been studied previously. No excavation was conducted in the coastal section, in part, because this section is disturbed due to early historic and contemporary settlement. In addition no rock art was found in the coastal area. Because of the scope of the research no specific attention was paid to the collection of macrobotanical material in order to understand the issues of arboriculture development and ecological transformation. Presently there are no future plans to follow up on this type of research.
2. Pioneering stratigraphic excavation was first done by Robert C. Suggs, a member of the American Museum of Natural History Expedition to the archipelago in 1956. Based on artifacts and radiocarbon dates from several excavated sites on Nuku Hiva, Suggs (1961) developed a unilineal, evolutionary cultural sequence of four periods: The Settlement Period (150 B.C.–A.D. 100); the Development Period (A.D. 100–1100); the Expansion Period (A.D. 1100–1400); and the Classic Period (A.D. 1400–1790). An initial settlement date of approximately 150 B.C., the earliest evidence of human colonization in East Polynesia, was based in part on excavation at the Ha'atuatua (Nhaa1) sand dune site (Suggs 1961). Sinoto (1979, 1983), who excavated both at Ha'atuatua and Ho'oumi, Nuku Hiva, proposed that the islands were settled approximately A.D. 300. Inconsistency in the results of both Suggs' and Sinoto's carbon analysis have since troubled archaeologists and led to spirited debates (Kirch 1986; Kirch and Ellison 1994; Spriggs and Anderson 1993). The process of Marquesan initial colonization remains largely unresolved (but see; Rolett 1998; Rolett and Conte 1995:223–226; Sinoto 1996:131–152). In the future, archaeologists will have to grapple with problems such as small and scattered early human traces, as well as sites destroyed by human settlement, erosion, or buried through alluvation and natural shoreline progradation (Kirch 1986).

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ABSTRACT

In order to address long-standing questions in the field of Pacific Island archaeology regarding the extent, timing, and causes of human-induced environmental change, as well as the deep history of the development of distinct regional agricultural and arboricultural adaptations, this study presents and discusses taxonomic identification data for 15 wood charcoal samples recovered from archaeological excavations in the Hatiheu Valley, Nuku Hiva, Marquesas Islands. This is some of the first archaeobotanical data collected and analyzed from this archipelago, and the only direct evidence of past distributions of economic and indigenous tree and shrub taxa in specific temporal and spatial contexts. The 14 native and Polynesian-introduced tree and shrub taxa identified are analyzed in view of their archaeobotanical and more modern distributions, as well as in consideration of radiocarbon dates obtained from five of the charcoal samples. Finally, these results are evaluated in regard to the degree to which they can provide useful cultural and environmental information relating to existing models of prehistoric Marquesan and broader Pacific Island settlement, economy, and environmental change over time. **KEYWORDS:** archaeology, archaeobotany, anthracology, charcoal, Marquesas Islands.