# Approaches to Dating Wetland Agricultural Features : An Example from Wailau Valley, Moloka ‘i Island, Hawai ‘i



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*Irrigated Taro* (Colocasia esculenta) *in the Indo-Pacific*
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# Approaches to Dating Wetland Agricultural Features: An Example from Wailau Valley, Moloka‘i Island, Hawai‘i

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The dynamic environment of wetland agricultural systems presents unique challenges for dating. As water and sediment move through the system, charred plant material is transported as well, thus scattered charcoal collected from pondfield deposits may have originated from anywhere upslope. My paper considers several alternative approaches for assessing the age of wetland agricultural features, including wall superposition and abutment analyses, re-use of wetland terraces for non-agricultural purposes, the presence of historical material and introduced plant taxa, and radiocarbon dating charcoal from beneath wall foundation stones as *termini post quem*. These techniques were used to estimate the age of 19 wetland systems in Wailau Valley, Hawai‘i, and the utility of each approach will be assessed here.

## 1. Introduction

Radiocarbon dating has a long history in Hawai‘i, with the first date obtained in 1950, the same year the technique was made available to archaeologists (Emory and Sinoto 1961). That first date, of AD 1004 from the Kuli‘ou‘ou Rockshelter, had profound implications for Hawaiian archaeologists, as they were forced to rethink earlier notions that the Hawaiian Islands were settled relatively recently. This prompted the Bishop Museum to implement a research program of archaeological excavations throughout the state at the now renowned sites of H1 (Pu‘uali‘i), H2 (Makalai), and H8 (Waiahukini), at South Point on the Big Island and K3 (Nu‘alolo Kai), on the Nā Pali Coast of Kaua‘i. The new technology of radiocarbon dating was widely embraced in Hawai‘i, where dendrochronology and ceramic seriation are not viable options.

The 1970s saw a new reliance on volcanic glass dating, however, with benefits such as more refined chronological control, ease in collecting samples, and cost-effectiveness (e.g., Barrera and Kirch 1973). When the method was proven unreliable, archaeologists again turned to radiocarbon dating, and it continues to be the most widely used approach in Hawai‘i today. Despite its popularity, several methodological issues have been identified as problematic with regard to radiocarbon dating. These include problems of in-built age and sampling from insecure contexts (e.g., Spriggs and Anderson 1993; Dye 2000; Allen *et al.* 2002; Acabado 2009). Although these problems are easily controlled for by selecting short-lived taxa for dating and only dating materials associated with a human-related event, archaeologists continue to base interpretations on unsound dates.

This paper examines the methods used to date 19 wetland agricultural systems in Wailau Valley on the island of Molokaʻi, Hawaiʻi. Radiocarbon dates were obtained from short lived charcoal taxa collected from beneath wall foundation stones and several alternative dating approaches were utilized, such as wall superposition and abutment analyses, re-use of wetland terraces for non-agricultural purposes, and the presence of historical material and introduced plant taxa.

## 2. The Study Area

Wailau is the largest of four valleys on the remote windward coast of Molokaʻi, which stretches from Hālawa Valley on the east to Kalaupapa Peninsula on the west (Fig. 1). The island of Molokaʻi is approximately 67,340 ha in area and is made up of two shield volcanoes at either end (Hazlett and Hyndman 1996). The easternmost volcano is the younger of the two, and substrates on this eastern portion of Molokaʻi are roughly 1.5 million years old (Stearns 1985; Stearns and Macdonald 1947).

Heavy rainfall of 1,500 to 4,000 mm per year (Juvik and Juvik 1998) feeds two perennial watercourses, Wailau Stream and Kahawaiʻiki Stream, that cut through Wailau Valley and join at the coast. A series of intact irrigated terraces, or *loʻi*, forms an agricultural system that encompasses nearly the entire surface area of the 936-ha valley. Terraces such as these were used traditionally for pondfield agriculture of the staple crop, taro (*Colocasia esculenta*). Known as *kalo* in Hawaiʻi, taro produces edible roots and leaves that are prepared in a variety of ways, such as pounding the root into a paste called *poi*. Taro continued to be cultivated in Wailau until the 1930s when the valley was abandoned, due to a combination of factors, including flooding and unfavorable economic conditions.

Hawaiian *loʻi* systems, or complexes, are typically a set of adjoining terraces that are often reinforced with dry-laid stone walls and soil berms (Fig. 2), but occasionally are buttressed with soil berms alone. Wetland taro thrives on flooded conditions, and cool, circu-

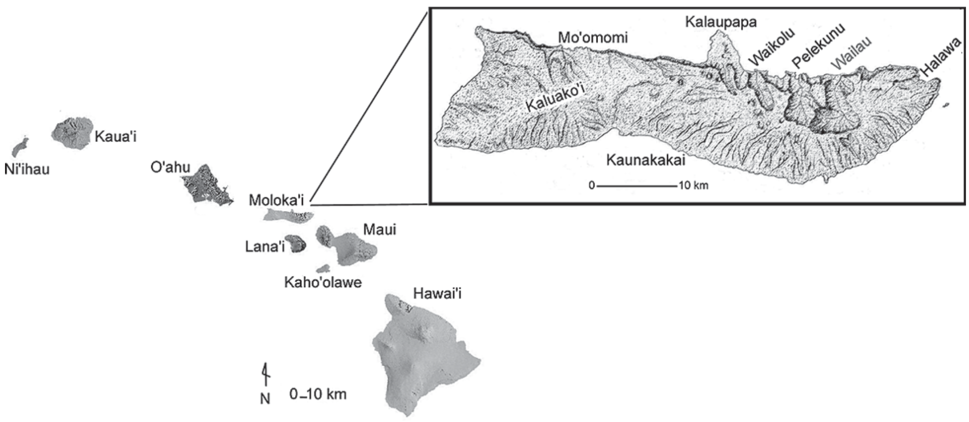


**Figure 1** Map of the Hawaiian Islands with inset of Molokaʻi Island

**Figure 2** Example of a Hawaiian irrigated agricultural complex, or *lo'i* system

lating water is optimal for taro growth (Hollyer 1997: 62; Wang 1983: 174), thus a system may include one or more irrigation ditches, or *'auwai*, to divert water into and out of the planting area. Terraces are generally cut into a slope to facilitate water movement from the upper to lower fields.

In addition to the *lo'i*, trails, habitation structures, and ceremonial sites are part of the cultural landscape of Wailau Valley. Wailau is remote, remains relatively pristine in terms of its archaeological resources, and has few year-round residents. Vehicular access ends outside the valley, at Hālawa, roughly 12 km to the east. Wailau is only accessible through a long and dangerous hiking trail or by boat during the calm summer months. High sea cliffs prevent access by foot along the coastline. These conditions make the valley a prime source of information about the past because archaeological remains have been left largely undisturbed by modern land use, with a wide variety of surface features available for study.

This study is based on data collected for 19 *lo'i* systems located from the coast of Wailau to approximately 2.5 km inland (McElroy 2007a, 2007b) (Fig. 3). Together, these 19 systems include 667 individual terraces and 19 irrigation ditches. Additional *lo'i* systems occur farther inland along Wailau Stream that were not examined.

## 3. Dating of Wetland Agricultural Features

The dynamic environment of wetland agricultural systems presents unique challenges for dating. As water and sediment move through the system, charred plant material is transported as well, thus scattered charcoal collected from pondfield deposits may have originated from

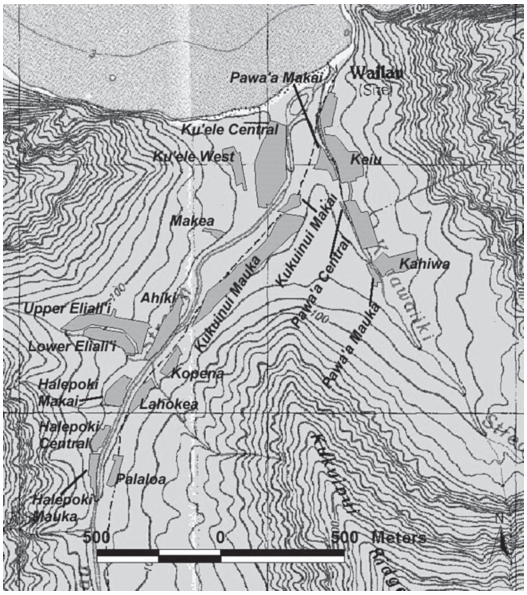


**Figure 3** Wailau Valley, showing the 19 *lo'i* complexes and their names

anywhere upslope. Wailau is a wet valley, where natural fires are highly unlikely, and the occurrence of any charcoal almost certainly dates human presence. Collecting charcoal samples from contexts that are stratigraphically inferior to terrace wall foundations secures a date that is unquestionably associated with wall construction, providing *termini post quem*, or dates before which the walls were not constructed. Before agricultural terraces were built, vegetation was likely cleared by burning (Allen 1992), thus the resulting charcoal found beneath terrace foundation stones does not pre-date terrace construction by a considerable amount of time.

In addition to radiocarbon dating, alternative dating approaches are considered here, such as devising construction sequences from wall abutment data and associating historical material and introduced plant taxa with wall construction. These methods enhance the value of each radiocarbon date by providing additional context in which to evaluate the age of the various parts of a *lo'i* system.

### 3.1 Radiocarbon Dating: *Termini Post Quem*, and Dating Re-Use of Terraces

A total of 20 AMS radiocarbon dates have been obtained for Wailau Valley, and 16 are from wetland agricultural contexts (Table 1 and Figs. 4 and 5) (McElroy 2004, 2007a, 2007b). The other dates are from a religious feature, an isolated hearth, and two terraces with undetermined functions. All samples were taxonomically identified prior to dating and only short-lived taxa were selected. Most charcoal was from native taxa, and this is consistent with burning to clear the native forest before cultivation.

For the *lo'i* system dates, careful attention was paid to collect charcoal from beneath wall foundation stones as *termini post quem*. Wall foundations were sometimes deeply buried,

**Table 1** Radiocarbon laboratory results, Arizona AMS laboratory and Beta Analytic

| Study Area | Lab No. | Material | Conventional $^{14}C$ Age (BP) | $^{13}C/^{12}C$ Ratio | 2 sigma Calibration (Cal AD) |
|---|---|---|---|---|---|
| Keiu | AA71544 | *Kōpiko* | 735±61 | –26.4 | 1160–1400 |
| | Beta-193986 | *ʻAkoko* | 330±30 | Not Published | 1476–1641 |
| Pawaʻa Makai | AA72161 | *Kōpiko* | 119±33 | –25.4 | 1670–1940 |
| Pawaʻa Central | AA71121 | Unidentified Parenchyma | 158±35 | –24.9 | 1660–1960 |
| Kuʻele West | AA71547 | *Kī* | 204±33 | –25.1 | 1640–1960 |
| Kuʻele West | AA71122 | *Kōpiko* | 566±37 | –28.7 | 1300–1430 |
| Kuʻele Central | AA71546 | *Hōʻawa* | 219±39 | –25.9 | 1520–1960 |
| Kuʻele Central | AA71549 | *Kōpiko* | 646±34 | –26.6 | 1280–1400 |
| Kuʻele Central | AA71543 | *ʻAlaʻa* | 695±42 | –24.7 | 1220–1400 |
| Makea | AA71548 | Unidentified Vine | Post-bomb | –31.5 | Modern |
| Kukuinui | AA71541 | *Kōpiko* | 649±45 | –26 | 1270–1400 |
| Lower Elialiʻi | AA70408 | *ʻŪlei* | 313±46 | –26.7 | 1460–1660 |
| Lower Elialiʻi | Beta-213276 | *Naupaka* | 790±40 | –26.3 | 1170–1290 |
| Upper Elialiʻi | Beta-213274 | *Aʻaliʻi* | 730±40 | –27.7 | 1210–1390 |
| Upper Elialiʻi | AA71545 | *Kōpiko* | 157±58 | –27.2 | 1650–1960 |
| Halepoki Makai | AA71542b | *Kōpiko* | 672±34 | –26.4 | 1270–1400 |
| Halepoki Central | AA71550 | Unidentified Bark | 450±34 | –28 | 1410–1610 |
| Halepoki Mauka | AA72162 | *Kukui* | 91±33 | –25.2 | 1680–1940 |
| Lahokea | Beta-215407 | *ʻŪlei* | 190±40 | –23.9 | 1660–1960 |
| Palaloa | AA71551 | *ʻIlima* | 283±33 | –27.3 | 1490–1800 |

extending an average of 50 cm below the surface (cmbs), but it was very obvious when the basal stones of the walls were encountered (Fig. 6). Stratigraphic changes were minimal in most excavation units, but vertical excavation was stopped once a characteristic sterile, saprolitic layer was contacted. From there, horizontal excavation proceeded directly beneath the wall foundation stones, where charcoal was removed by hand and bagged separately from that collected elsewhere in the unit. This strategy ensures that the dated charcoal has a direct stratigraphic relationship with the terrace wall.

*Examples:* There were several instances in which the approach described above was not so straightforward. The *loʻi* systems of Keiu, Makea, and Palaloa are examples in which complexities arose.

Keiu is a large *loʻi* system located on the northeast side of Wailau Valley. An excavation unit was placed roughly in the center of the system, against one of the terrace walls to collect material suitable for dating. During excavation, the terrace wall foundation was identified but the saprolitic layer was not, thus excavation continued deeper. A second, completely buried wall was found 14 cm below and 8 cm south of the base of the first wall. This lower wall is interpreted as a remnant of a *loʻi* system that was constructed earlier than the one visible on the surface today. Charcoal was collected from beneath the upper wall foundation, but none

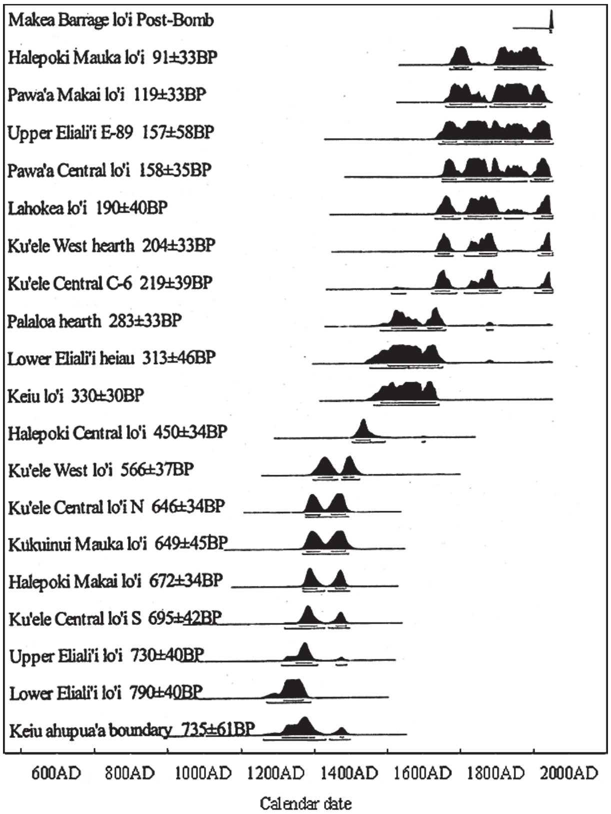


**Figure 4** Calibrated radiocarbon dates for Wailau Valley. These were calibrated using atomospheric data from Reimer *et al.* (2004); OxCal v3.10 Bronk Ramsey (2005); Cub r: 5 sd: 12 prob usp [chron]

could be found beneath the lower wall. Bayesian calibration of the dated charcoal indicated a construction date of AD 1635–1914 for the upper wall and some time before AD 1724 for the buried wall.

Makea is a small barrage terrace system located within a minor secondary drainage on the west side of the valley. Terrace walls extend directly across the drainage, so that water spills from one terrace to the next without the use of an irrigation ditch. Excavation was scheduled for a relatively dry time, when stream flow was reduced to a trickle. To expose an intact section of wall foundation, the excavation unit was placed within the drainage in an area of soft mud. Water began pooling in the unit at 15 cmbs, and excavation had to be halted at 18 cmbs when water filled the base of the unit. Because of the submerged conditions, it was not clear if the wall foundation stones had been reached or if they were buried deeper in mud. Only one stratigraphic layer was present; this was a cobble-rich runoff deposit. The excavators probed the lowest reaches of the west face of the unit and could feel no large stones, thus the basal stones are believed to be the ones extending to 16 cmbs. A sample of charred vine collected from beneath these stones returned a radiocarbon age of post-bomb, or modern.

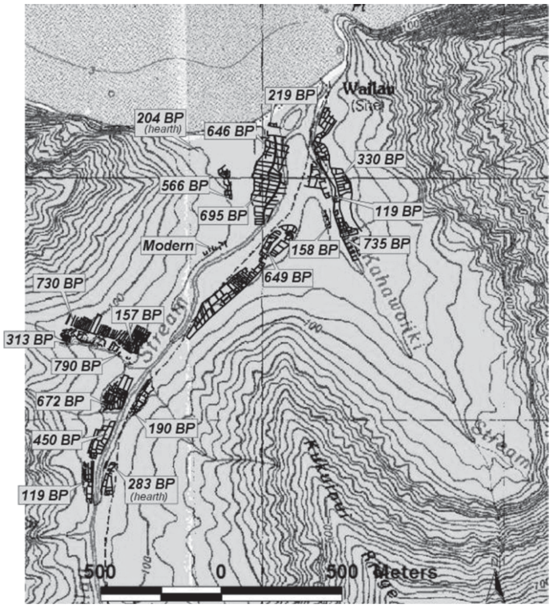


**Figure 5** Radiocarbon age determinations for Wailau agricultural systems (only the dated complexes are shown)

**Figure 6** Example of an excavated terrace wall with foundation stones exposed. The scale is marked in 10 cm increments

Because the date was obtained from an area that is still irrigated, it is possible that modern charcoal washed into the unit and was dated. Or the wall may have extended deeper than what was believed. Using a pump to drain the unit could have allowed for deeper excavation to rule this out, although this was not an option given our remote location. Alternatively, the system could have actually been constructed late in time. Barrage style terrace systems have been notoriously difficult to date. Because of their simple design, they are generally assumed to be an early development, but no early dates have been returned for barrage systems in Hawai‘i (Allen pers. com. 2007).

The Palaloa *lo‘i* system is one of the farthest inland complexes included in this study. A hearth was found in the middle of one of the terraces, indicating re-use of that terrace. The hearth feature clearly post-dates construction and use of the *lo‘i* complex, because the *lo‘i* had to have already been dried up for a hearth to have been built there and a fire burned. The hearth yielded a wide array of native charcoal taxa, and a sample of a short-lived shrub returned a radiocarbon age of AD 1490–1800, providing a *terminus ante quem*, or date after which the terrace was not built. The system was likely constructed a considerable time before the *terminus ante quem*, as it had to have been built, used, and abandoned before the hearth was burned. Charcoal was recovered from beneath one of the wall foundations, but unfortunately no short-lived taxa were identified. If suitable dating material was found from this context, it would provide a *terminus post quem*, and secure a sound age range for construction of the system.

### 3.2 Construction Sequences: Wall Superposition and Abutment

Recent work in Hawaiian dryland field complexes has developed and applied methods of relative dating utilizing wall abutment data (Ladefoged *et al.* 2003; McCoy 2001). This work has demonstrated that the temporal relationships of wall segments and trails can be discerned from surface examination alone, and relative chronologies have been tested through excavation. In a wetland field system such as Wailau, *‘auwai*, or irrigation ditches, can be used to infer chronology in place of trails, along with wall segments. In addition, the size, shape, and orientation of terraces can inform on the timing of construction, with similar styles of fields probably built at the same time. This kind of analysis has not been attempted previously for Hawaiian wetland complexes and establishes another approach to studying agricultural dynamics in Hawai‘i and other wetland systems. Construction sequences offer a more precise means of dating agricultural complexes than radiocarbon dates alone can provide. One radiocarbon date might pinpoint the age of a single wall or terrace within a complex, leaving the age of other parts of the complex unknown. Establishing phases of construction for the complexes provide additional context for the radiocarbon dates.

Three examples of construction sequences based on wall abutment analysis are presented here. For each *lo‘i* system, three construction phases are hypothesized. The construction sequences were devised by looking at the size, shape, and orientation of the terraces and the way that the terrace walls abut each other. Terraces that are relatively uniform in size and shape and that are similarly oriented were likely built at the same time and are grouped together in a cluster. Terraces that were added on later can be identified by walls that are offset to those of another terrace. *‘Auwai* are particularly useful in this analysis, for if a ditch

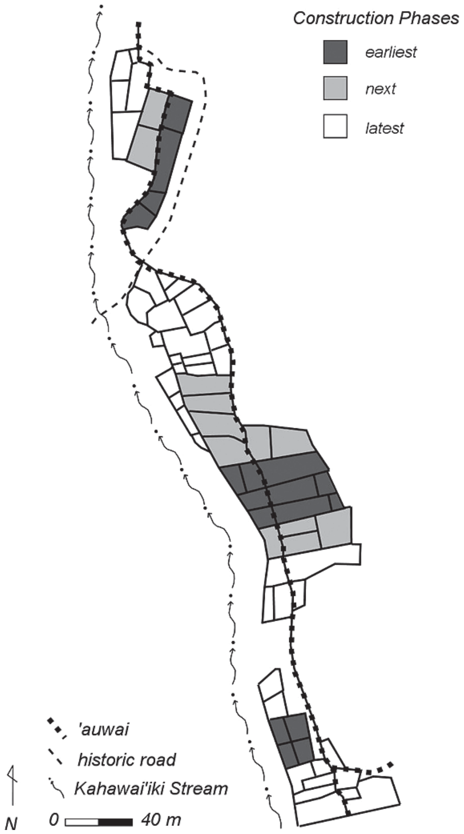


**Figure 7** Possible construction sequence for the Keiu *lo'i* complex

cuts through an existing set of terraces, walls on either side will line up, whereas walls that are offset on either side of an *'auwai* indicate that the ditch was built first, or before the walls on at least one side.

This approach is admittedly intuitive to some degree, but can be easily tested and refined by radiocarbon dating terraces from each of the proposed construction sequences in a given system. It is also important to note that construction sequences are not contemporaneous across the Wailau *lo'i* complexes. For example, the earliest construction phase at the Keiu complex did not occur at the same time as the earliest phase of the Ku'ele complex.

*Examples:* The Keiu complex consists of 79 terraces and two *'auwai*, and exhibits three distinct clusters of terraces. One of the *'auwai* connects the three terrace clusters and extends south into the neighboring land division. Two to three phases of construction are proposed for each cluster (Fig. 7), although the construction phases hypothesized for each cluster of the complex are not necessarily contemporaneous. For example, the earliest phase of the northern cluster may be earlier, later, or contemporaneous with the earliest phase for the central cluster. The earliest terraces are the easternmost block in the northern cluster and the central blocks of the central and southern clusters. These blocks appear to stand alone, and the other terraces abut them. The next terraces to be built were the ones abutting the early blocks, and in the northern and central clusters, the latest terraces abut these. In the central and southern clusters, the *'auwai* is probably later than the terraces, as it appears to cut through already established walls. In the northern cluster, the *'auwai* was probably built along with the earliest terraces, and the terraces to the west were built later, because walls are not continuous on either side of the *'auwai*, but offset where the *'auwai* passes through.

The Ku'ele *lo'i* system is made up of 63 terraces and three *'auwai*. Three possible construction sequences could be generated, with the earliest fields likely at either end of the complex (Fig. 8). The terraces at the far south end and those toward the north both stand alone as discrete blocks. The portion between these sets was probably next to be filled in. The two *'auwai* that feed the earliest terrace blocks were probably constructed along with those blocks and later extended as the system was expanded. The *'auwai* that skirts the western part of the complex was likely added during the second construction phase to provide additional water to the expanded system. The latest terraces were probably on the southeast side of the complex and at the far north side, although it has been proposed that the northernmost terraces are not *lo'i*, but habitation areas. The southeast set was assigned to the latest construction phase because walls are offset from those of the earliest phase on the opposite side of the *'auwai*. This suggests that the southeastern block was added on to an already established system.

The Kukuinui Mauka complex consists of 84 terraces and two *'auwai*. This system was likely constructed in three phases, with the southernmost block probably built first (Fig. 9). This is the farthest upstream, and terraces are of fairly similar size and can stand alone as a discrete unit. The central block of terraces was likely added next. Fields are generally smaller and more tightly packed than those to the north and south and are oriented at a slightly different angle than the surrounding terraces. The northern set may have been a late addition to the system, with its curved walls and layout around a natural gulch. The Wailau Trail cuts in and out of the complex, clearly post-dating the terraces.

Although only three examples are presented here, the larger sample of Wailau construction sequence data clearly indicate two trajectories of development (McElroy 2007a). The first is where a series of terraces sets are initially built within a circumscribed area and then the locations between them are filled in. The Keiu and Ku'ele complexes are examples of this first trajectory. The second is where construction begins at one end of a system and then spreads out from it. In the second case, the earliest construction occurs farthest up-slope or up-stream. The Kukuinui Mauka complex exemplifies this trajectory.

### 3.3 Other Temporal Indicators: Historic Material, Introduced Plant Taxa, and Historic Documents

Temporal indicators other than wall abutments and radiocarbon dates include the presence of historic artifacts and charcoal from recently-introduced taxa, and historic maps and photos. Associated materials on the surface or in cultivated zones indicate use of terraces, while artifacts beneath walls and abutment relations indicate when parts of each complex were constructed. Historic artifacts and historically-introduced charcoal taxa found in excavation

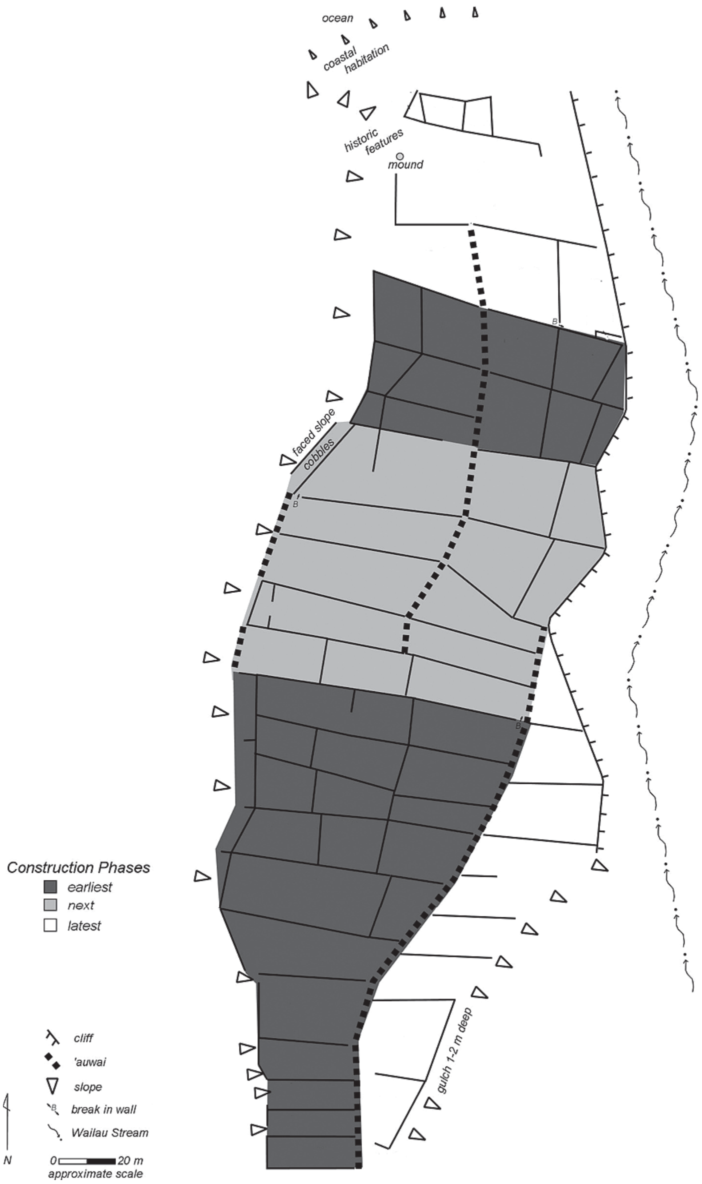


**Figure 8** Possible construction sequence for the Ku‘ele Central *lo‘i* complex

at a lower depth than a wall foundation provide *termini post quem*, while historic material found at a depth above a wall foundation or on the surface provide *termini ante quem*. Historic maps and photos that depict the *lo‘i* complexes also provide *termini ante quem*, because the *lo‘i* were already constructed at the time the map was drawn or the photo was taken.

Temporal indicators are shown in Table 2. Two examples are explained below.


**Figure 9** Possible construction sequence for the Kukuinui Mauka *lo'i* complex

*Examples:* For Keiu, an historic map depicts the *lo'i* walls of the entire land division. This map was drawn by G. Podmore in 1915, indicating that every wall shown was constructed before this time. In addition, the central and southern portions of the Keiu complex are labeled "taro" on a 1903 survey map (Monsarrat 1903), demonstrating that these parts of the *lo'i* system were already in production at this time.

At Lahokea, historic material was collected from two terraces at the head of the *lo'i* complex. A mid- to late-19$^{th}$ century bottle base was found wedged in the wall of terrace L-1. At the adjacent terrace L-2, glass shards and a porcelain button were recovered from excavation. They date from 1850 to the 20$^{th}$ century. Two of the glass shards were found at a depth lower than the wall foundation, clearly indicating that the wall was constructed in the historic era. Wall abutment analysis placed these terraces in the earliest construction phase of the complex, demonstrating that the entire complex was constructed late in time. In addition, historically-introduced pine charcoal was found beneath one of the walls. The Monsarrat

**Table 2** Other temporal indicators

| Study Area | Feature | Unit | Depth | Material | Relationship to Terrace | Count | Description | Date | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Keiu | N/A | N/A | surface | historic map | surface -*terminus ante quem* | N/A | map shows *lo'i* already constructed | 1915 | (Podmore 1915) |
| | N/A | N/A | surface | historic map | surface -*terminus ante quem* | N/A | map labeled "taro" | 1903 | (Monsarrat 1903) |
| Pawa'a Mauka | N/A | N/A | surface | historic map | surface -*terminus ante quem* | N/A | map labeled "taro" | 1903 | (Monsarrat 1903) |
| Ku'ele Central | M-10 | TU 11 | I/7 | mangrove | near base of possible soil berm - *terminus ante quem*; possibly during use of terrace | N/A | charcoal | after early $20^{th}$ C. | mangrove is a recent introduction |
| | N/A | N/A | surface | historic map | surface -*terminus ante quem* | N/A | map labeled "taro" | 1895 | (Monsarrat 1895) |
| | N/A | N/A | surface | aerial photo | surface -*terminus ante quem* | N/A | photo shows *lo'i* already constructed | 1924 | (U.S. Dept. of the Interior 1941) |
| Kukuinui Makai | KU-13 | N/A | surface | ceramics | surface -*terminus ante quem*; or unassociated with *lo'i* | 1 | E/A[1] large bowl sherd | $19^{th}$–$20^{th}$ C. | could have washed down stream |
| Kukuinui Mauka | N/A | TR 24 | I | metal | just below surface - *terminus ante quem* | N/A | rusted unidentified metal | $19^{th}$–$20^{th}$ C. | |
| Ahiki | N/A | N/A | surface | historic map | surface -*terminus ante quem* | N/A | map labeled "taro" | 1903 | (Monsarrat 1903) |

[1] English or American

**Table 2** Other temporal indicators (Continued)

| Study Area | Feature | Unit | Depth | Material | Relationship to Terrace | Count | Description | Date | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Upper Eliali'i | E-48 | TU 1 | I/2 | plastic | within possible builder's trench, not lower than wall foundation | 1 | | $20^{th}$ C. | $20^{th}$ C. |
| | E-48 | TU 1 | II/1 | plastic | base of pondfield deposit; not below wall foundation - *terminus ante quem* | 1 | | $20^{th}$ C. | $20^{th}$ C. |
| | E-93 | N/A | surface | ceramics | *surface -terminus ante quem* | 1 | E/A saucer sherd | 1880–1930 | |
| | E-93 | N/A | surface | ceramics | *surface -terminus ante quem* | 1 | E/A saucer sherd | 1883–1913 | |
| | E-93 | N/A | surface | ceramics | *surface -terminus ante quem* | 1 | Japanese medium bowl sherd | 1870–$20^{th}$ C. | |
| | E-93 | N/A | surface | ceramics | surface *-terminus ante quem* | 1 | E/A saucer sherd | 1880–1930 | |
| | E-93 | N/A | surface | ceramics | surface *-terminus ante quem* | 1 | E/A saucer sherd | 1883–1913 | |
| | E-93 | N/A | surface | ceramics | surface *-terminus ante quem* | 1 | Japanese medium bowl sherd | 1870–$20^{th}$ C. | |
| | E-93 | N/A | surface | ceramics | surface *-terminus ante quem* | 1 | Chinese tz'u rice bowl sherd | $19^{th}$–early $20^{th}$ C. | |
| | E-93 | N/A | surface | ceramics | surface *-terminus ante quem* | 2 | E/A large bowl sherds | $19^{th}$–$20^{th}$ C. | |
| | E-93 | N/A | surface | ceramics | surface *-terminus ante* | 3 | E/A soup plate sherds | 1873–1891 | |

**Table 2** Other temporal indicators (Continued)

| **Study** Area | **Feature** | **Unit** | **Depth** | **Material** | **Relation**ship to Terrace | **Count** | **Descrip**tion | **Date** | **Notes** |
|---|---|---|---|---|---|---|---|---|---|
| Upper Eliali‘i (Cont.) | E-93 | N/A | surface | slate | surface -*terminus ante quem* | 1 | probable chalkboard fragment | $19^{th}$–early $20^{th}$ C. | |
| Halepoki Makai | H-5 | N/A | surface | ceramics | surface -*terminus ante quem* | 3 | Modern plate | 1984 | |
| | H-50 | N/A | surface | ceramics | surface -*terminus ante quem* | 2 | Chinese sherds | $19^{th}$–early $20^{th}$ C. | |
| | H-50 | N/A | surface | ceramics | surface -*terminus ante quem* | 3 | E/A saucer sherds, undecorated | $19^{th}$–$20^{th}$ C. | |
| | H-50 | N/A | surface | ceramics | surface -*terminus ante quem* | 3 | E/A large bowl sherds, hand painted | $19^{th}$–$20^{th}$ C. | |
| | H-50 | N/A | surface | ceramics | surface -*terminus ante quem* | 17 | E/A large bowl sherds, undecorated | $19^{th}$–$20^{th}$ C. | |
| | H-50 | N/A | surface | glass | within wall -*terminus ante quem* | 1 | medium green fragment | $19^{th}$–$20^{th}$ C. | |
| | H-50 | N/A | surface | glass | within wall -*terminus ante quem* | 1 | light green fragment | $19^{th}$–$20^{th}$ C. | |
| | H-52 | N/A | surface | ceramics | surface -*terminus ante quem* | 1 | E/A saucer sherd | $19^{th}$–$20^{th}$ C. | |
| | N/A | N/A | surface | historic map | surface -*terminus ante quem* | N/A | map labeled “taro” | 1903 | (Monsarrat 1903) |

**Table 2** Other temporal indicators (Continued)

| Study Area | Feature | Unit | Depth | Material | Relationship to Terrace | Count | Description | Date | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Lahokea | L-1 | N/A | surface | glass | within wall -*terminus ante quem* | 1 | olive green black alcohol bottle fragment | mid-late $19^{th}$ C. | |
| | L-2 | TU 18 | I/1 | glass | just below surface - *terminus ante quem* | 1 | glass fragment | $19^{th}$–$20^{th}$ C. | |
| | L-2 | TU 18 | I/2 | button | near base of possible soil berm layer - *terminus ante quem*; possibly during use of terrace | 1 | porcelain button | 1850–$20^{th}$ C. | |
| | L-2 | TU 18 | I/3 | glass | below wall- *terminus post quem* | 2 | medium olive green glass fragment | $19^{th}$–$20^{th}$ C. | |
| | N/A | N/A | surface | historic map | surface -*terminus ante quem* | N/A | map labeled “taro” | 1903 | (Monsarrat 1903) |

map (1903) indicates that taro was being grown in Lahokea in 1903, thus the system was constructed sometime before the early 20th century.

### 3.4 Synthesis of Dating Results

Radiocarbon dates, construction sequences, and other temporal indicators are three discrete lines of evidence that were utilized to estimate the timing of *lo'i* construction in Wailau. The examples below show how the radiocarbon dates can be tied in to the other dating analyses.

*Examples:* The extensive Keiu *lo'i* system exhibits three distinct clusters of terraces, and two to three phases of construction were hypothesized for each cluster. The presence of a buried *lo'i* wall in the central portion of the complex indicates an even earlier episode of construction for this part of the system. An historic map (Podmore 1915) shows that the *lo'i* walls visible on the surface were built before 1915. Radiocarbon dates place the surface *lo'i* at AD 1476–1641 in the center of the complex and at AD 1160–1400 at the south end of the system. The buried *lo'i* could not be directly dated, but was built sometime before AD 1476–1641. The *lo'i* in the center cluster of terraces that was radiocarbon dated was thought to have been built in the earliest construction phase for that cluster. This means that the surrounding terrace blocks were built later, with construction of the latest blocks probably occurring in the early historic period. The radiocarbon dated *lo'i* in the south cluster was placed in the latest phase of construction, indicating that the surrounding terrace blocks were constructed before AD 1160–1400, very early in the history of agriculture in the valley. Clearly the construction phases for the central and southern clusters are not contemporaneous, with the southern cluster established much earlier. It is unclear where the northern cluster fits into the chronology.

The large Ku'ele system was already in place when a 1924 aerial photo was taken. In addition, a dividing wall in the central portion of the complex was constructed before the turn of the 20th century, as indicated by a fragment of introduced mangrove wood at a higher depth than the wall foundation. Radiocarbon dates suggest that the complex was built at an early time, AD 1280–1400 for the northern portion of the system and AD 1220–1400 for the southern portion. These very similar dates at opposite ends of the complex support the hypothesized construction sequence in which the north and south sides of the system were built first. The central part of the system was filled in later, and finally the southeast portion was expanded along Wailau Stream. The terraces on the far north side were probably habitation areas and these dated to AD 1520–1960, thus they were constructed after the *lo'i* system was established and probably after the system was at least partially expanded.

The Lahokea complex was the most straightforward with regard to dating. Three construction phases were proposed (McElroy 2007a), but all took place in the historic era, because historic material was found beneath a wall assigned to the earliest construction phase. In addition, a fragment of charred pine was recovered from beneath one of the wall foundations in Lahokea. Pine is an historic introduction and likely arrived in Wailau as lumber, but the possibility of a log washing ashore from far afield in pre-Contact times could not be ruled out. The pine was therefore submitted for AMS dating but did not provide enough carbon for analysis. A short-lived native shrub recovered from the same context was dated in its place and returned an age of AD 1660–1960, supporting an historic age for the complex.

## 4. Conclusion

This work outlines methods used to determine the dates of construction, use, and abandonment for irrigated agricultural systems in Wailau. A refined radiocarbon dating scheme was applied, utilizing wood taxa identification to select short-lived species and collecting samples from beneath wall foundations as *termini post quem*. Taking these simple steps in the radiocarbon dating process protects against the old wood problem, so that the event being dated (burning of the charcoal) is reasonably close in time to the target event (wall construction) and that the event being dated is truly associated with the target event.

Supplementary dating methods introduced here include generating construction sequences from wall abutment relationships and looking at other temporal indicators such as historic maps and photos and the occurrence of historic material and plant taxa. These methods complement and extend the utility of the radiocarbon chronology by providing additional context for the radiocarbon dates. Whereas one radiocarbon date might pinpoint the age of a single wall or terrace within a complex, applying supplementary dating methods might identify relationships between different parts of the system relative to that one date. No specialized training is needed to apply the supplementary dating techniques outlined above, making them particularly cost and time effective, compared to radiocarbon dating, where samples must be sent to a laboratory. And the examination of surface wall abutments and historic maps and photos requires no excavation, providing a completely non-destructive addition to the dating suite.

Radiocarbon dating is also a vital tool for testing the results of the other methods. For example, in Ku'ele, three construction sequences were hypothesized from wall abutment relations, with the north and south ends of the complex thought to be the earliest and the central portion filled in later. Radiocarbon dates from either end of the system turned out to be very similar to each other and very early in time, as would be expected from the proposed construction sequence. A third, later, date from the central portion of the complex would clearly confirm the sequence.

Wetland agricultural systems are often difficult to date because of their dynamic environment, large size, and complexity of features. Rigorous methods must be applied to date them accurately. This paper proposes ways in which this can be done in a cost-effective, minimally-destructive manner.

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